Hay Mountain Exploration Report
Tombstone District, Arizona

Report Prepared for

Liberty Start Uranium & Metals Corp.

Report Prepared by

SRK Consulting (U.S.), Inc.
173300.030
August 31, 2011

Hay Mountain Exploration Report Tombstone District, Arizona

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1 Summary (Item 3)

Liberty Star Uranium & Metals Corporation (Liberty Star) of Tucson, Arizona, retained SRK Consulting (U.S.), Inc. (SRK) to prepare a Technical Report on Exploration at the Hay Mountain project in the Tombstone mining district of southeastern Arizona. The report follows the format of a Canadian National Instrument 43-101 Technical Report for the convenience of those who regularly use these reports.

The Hay Mountain project is an early stage, conceptual exploration target based on geological, geophysical, and geochemical data compiled by James A. Briscoe, Chief Executive Officer, Liberty Star (formerly JABA (US) Inc. (JABA) (Briscoe, 1993a, 1993b, 1994).

Section 1 summarizes this Technical Report.

1.1 Property Description and Location

The Hay Mountain project is located southeast of the town of Tombstone, Cochise County, Arizona, with a center at approximately latitude 31º39'15" N and longitude 110º00'10" W. Tombstone is approximately 72 miles (mi) southeast of Tucson (Figure 1-1). The Hay Mountain project area (Figure 1-2) is on two U. S. Geological Survey (USGS) 7 ½ minute topographic maps, Tombstone and Hay Mountain quadrangles. It is located in parts of Sections (Secs.) 23, 22, 21, 20, 29, 28, 27, 26, 35, 34, 33, and 32 in Township 20 South (T20S), Range 23 East (R22E), and in parts of Secs. 2, 3, 4, and 5, T21S, R23E, Gila and Salt River Meridian. The Tombstone Southeast and Potter Mountain quadrangles are immediately south of the Hay Mountain project area. The Hay Mountain project area is shown on Figure 1-2.

1.2 Ownership

Mineral exploration rights are under investigation by a contractor for Liberty Star. The Hay Mountain area of interest covers about 7,500 acres (a little over 12 square miles) southeast of the historic Tombstone mining district.

1.3 Mineralization and Geology

The target is a porphyry copper deposit related to a fracture system in an eroded caldera margin. Exploration to date has been regional-scale airborne geophysical surveys, geochemical, and biogeochemical surveys. Previous exploration for gold (Au) included geochemical, geophysical, and geological surveys and drilling on the Zebra and Redrock Canyon projects that are within the Hay Mountain project area.

The principal past production from the Tombstone mining district has been silver (Ag) from high grade veins associated with the intersection of north-northeast-striking fissures and andesite dikes with the fractured crests of northwest-trending anticlines (Butler and others, 1938). This mineralization has been dated at 74.5 million years ago (Ma) and alteration at 72 Ma (Newell, 1974). It is probably related to the intrusion of the Schieffelin Granodiorite and associated tuff, the Uncle Sam Tuff, which have been dated at 76 Ma and 73.5 Ma (Creasey and Kistler, 1962; Marvin and others, 1973).

A later period of mineralization was likely associated with the Tombstone rhyolite, dated at 66.6 Ma (Marvin and Cole, 1978) or 63 Ma (Newell, 1974) and the associated Extension/Comstock quartz monzonite porphyry in the eastern part of the district, dated at 62.8 ± 2.6 Ma (Drewes and others, 1985). This younger date is typical of the age of mineralization of porphyry copper deposits throughout southeastern Arizona. Liberty Star's exploration model focuses on porphyry copper mineralization that is centered on structural intersections created by fracture systems associated with emplacement of 74 Ma calderas in the Tombstone district.

Numerous publications describe the general geology and mining of the Tombstone mining district. The early reports focused on the central mining district where the more productive Ag mines were located (Blake, 1882a; Church, 1903; Ransome, 1920; Butler and others, 1938; and Gilluly, 1956). Additional research has been conducted by graduate students (economic geology by Newell, 1974, and hydrology by Hollyday, 1963), U.S. Geological Survey (USGS) geologists (Force, 1996), and Arizona Bureau of Mines researchers (manganese [Mn] deposits by Wilson and Butler, 1930).

The oldest rocks in the Tombstone Hills are the phyllites and metarhyolites of the Pinal Schist, which was dated at 1,695 Ma in the nearby Little Dragoon Mountains (Silver, 1967). It is intruded by granite, which may be similar to the granite dated at 1,420 Ma in the nearby Little Dragoon Mountains (Silver, 1978). The Precambrian rocks are unconformably overlain in the Tombstone Hills by a thick sequence of Paleozoic quartzite, limestone, and siltstone ranging in age from Cambrian (about 500 Ma) through Permian (about 250 Ma). These sedimentary rocks generally are excellent hosts to mineralization, as the limestone beds are reactive and the more resistant quartzite beds fracture easily under tectonic stress and provide pathways for veins and mineralization.

In southern Arizona, five mountain building episodes occurred during the Mesozoic and Cenozoic, bringing various types of structures, igneous rocks, and mineralization with each orogenic episode (Keith and Wilt, 1986). The Nevadan orogeny (approximately 190 to 145 Ma) in the Triassic and Jurassic was responsible for the copper-gold (Cu-Au) porphyry mineralization at nearby Bisbee and Courtland-Gleeson, but no rocks have been dated of this age in the Tombstone Hills. The Sevier orogeny (approximately 145 to 85 Ma) was mostly active in Nevada and Utah (Armstrong, 1972) and no rocks of this age have been dated in the Tombstone Hills.

The Laramide orogeny (85-43 Ma) is represented in the Tombstone Hills by two structural and mineralization types. The east-west faulting that uplifted Government Butte was emplaced early in the Laramide and may be related to early movement on the Prompter fault. The Ag mineralization in the main district was emplaced in association with northeast structures and caldera volcanism and intrusive rocks (74 Ma). A later intrusion of quartz monzonite porphyry and rhyolite (63 Ma) in the northern and eastern Tombstone Hills is of the same age and style as the porphyry copper mineralization that was emplaced throughout southern Arizona at that time period.

Cenozoic orogenies in southern Arizona include the Galiuro (mid-Tertiary) orogeny (37-13 Ma) and Basin and Range Disturbance (13-5 Ma) (Keith and Wilt, 1985). The Galiuro orogeny is responsible for the epithermal precious metal mineralization in the Swisshelm Mountains of southeastern Arizona. However, no mineralization or igneous rocks of this age have been identified in the Tombstone Hills. The Basin and Range Disturbance is characterized by basalts and the development of thick basin-fill formation. There is usually no mineralization associated with the Late Tertiary, other than industrial minerals and aggregate associated with sedimentary basin-fill deposits.

1.4 Exploration Concept and Status

The exploration concept pursued by Liberty Star in the Hay Mountain project area focuses on the potential for a porphyry copper deposit under the basin-fill deposits. Evidence for this Cu mineralization is the high Cu and molybdenum (Mo) values in mesquite twigs as reported by Newell (1974). Potential in the district is for carbonate-hosted replacement-type porphyry copper mineralization at intermediate to moderate depth, as well as for shallow chalcocite blanket porphyry type mineralization (Guilbert, 1993).

Geochemical and geophysical surveys in the Tombstone district have been interpreted by Liberty Star to indicate a potential center of porphyry copper mineralization in the Hay Mountain project area. Liberty Star believes that porphyry copper mineralization has been emplaced into structures prepared by the eruption and collapse of the Tombstone caldera. This concept was based on research conducted by James A. Briscoe, Chief Executive Officer of Liberty Star, into caldera volcanism that is physically associated with porphyry copper deposits in southern Arizona and other areas of the world along the Pacific "Ring of Fire". Exploration at the Hay Mountain project focuses on geophysical surveys and metal zoning revealed by the geochemical sampling programs. The surveys suggest the presence of centers of potential porphyry copper mineralization at several centers in the Tombstone area (Guilbert, 1993).

The status of the Hay Mountain project is a grass-roots exploration target, with geochemical, alteration, and metal zoning patterns indicative of potential porphyry copper mineralization.

1.5 Mineral Resources

The Hay Mountain project is in the exploration phase. The best targets, as identified by the geochemical sampling, have yet to be drilled. Therefore, no indicated or inferred mineral resources have been delineated.

1.6 Development and Operations

No development has been started on the surface. No facilities or operations are currently in place on the Liberty Star claims.

1.7 Exploration Potential

There is potential to drill the favorable geochemical targets and discover porphyry copper mineralization. It is possible that a deposit could be discovered that would be amenable to underground mining. Numerous mining companies have pursued Ag, Au, and Cu mineralization targets in the Tombstone district, but none have yet drilled for Cu in the Hay Mountain area.

1.8 Conclusions and Recommendations

The Liberty Star exploration plan includes scout drilling on the most promising of the geochemical anomalies. Liberty Star's goal is drillhole discovery of a potentially productive porphyry copper deposit that would warrant additional exploration drilling, deposit delineation, and scoping level studies. Ultimately, the goal is to define Cu resources of sufficient size and grade to allow for conducting a feasibility study, obtaining permits, and designing and constructing a mine.

SRK has reviewed the existing data and recommends the proposed exploration drilling program. SRK concludes the project information generated to date has defined exploration concepts that are worthy of follow-up work by exploration drilling.

The Hay Mountain project represents a beginning exploration project with a limited amount of historical and current data. The data are insufficient to take the property to resource classification by current industry standards.

SRK makes the following recommendations. Details are in relevant sections of the report.

- Conduct helicopter-borne ZTEM (helicopter-borne Audio Frequency Magnetics (AFMAG) Z-axis Tipper Electromagnetic) geophysical surveying;
- Conduct biogeochemical and soil surveys to be analyzed for 64 elements;
- Data reduction and analysis by appropriate computer techniques;
- Use industry-standard software mapping and record-keeping;
- Conduct vertical diamond core drilling into bedrock;
- Conduct appropriate downhole surveys;

- Conduct drill logging in digital format logs;
- Develop Standard Operating Procedures for sampling and QA/QC programs;
- Analyze the half-core samples from bedrock portions of the drill hole, for at least ten drill holes; and
- Compare assay results of duplicate samples from two laboratories to determine analytical precision.

REFERENCES

1. SRK (2008)

GENERAL NOTES

1. THIS DRAWING IS FOR ILLUSTRATIVE PURPOSES ONLY. ALL DIMENSIONS AND LOCATIONS ARE APPROXIMATE BASED ON AVAILABLE INFORMATION.

srk consulting

LIBERTY STAR URANIUM & METALS CORP.

Tombstone, Arizona

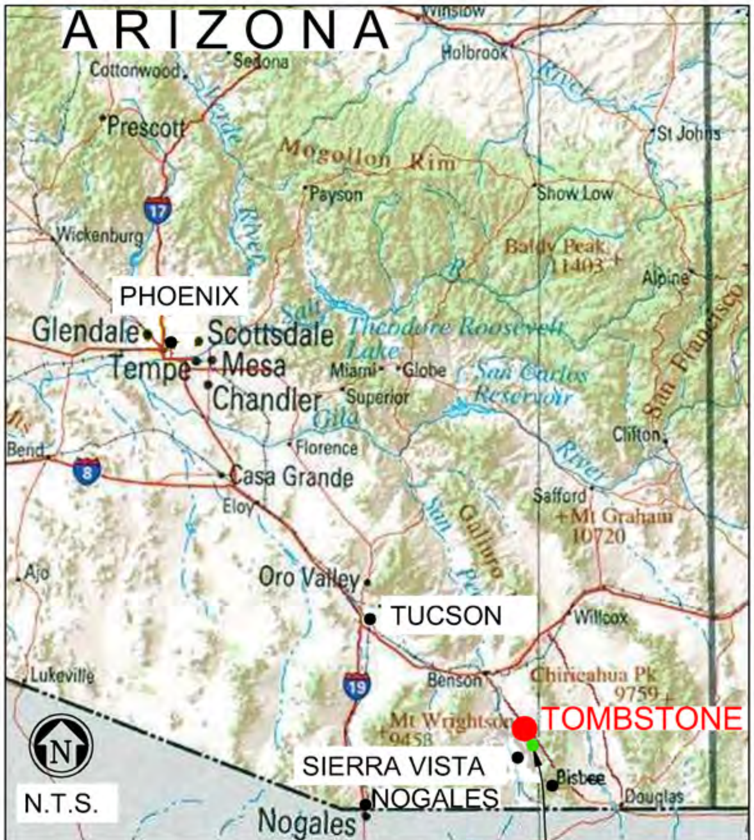
Location map of the Tombstone district, Arizona

SRK JOB NO.: 173300.03 Task 600 | Internal Control Number 3

FILE NAME: 1-1 LOCATION MAP OF THE TOMBTONE DISTRICT, ARIZONA

Hay Mountain Exploration Report

DATE:	APPROVED:	FIGURE:	REVISION NO.
June 2011	JR	1-1	1



REFERENCES

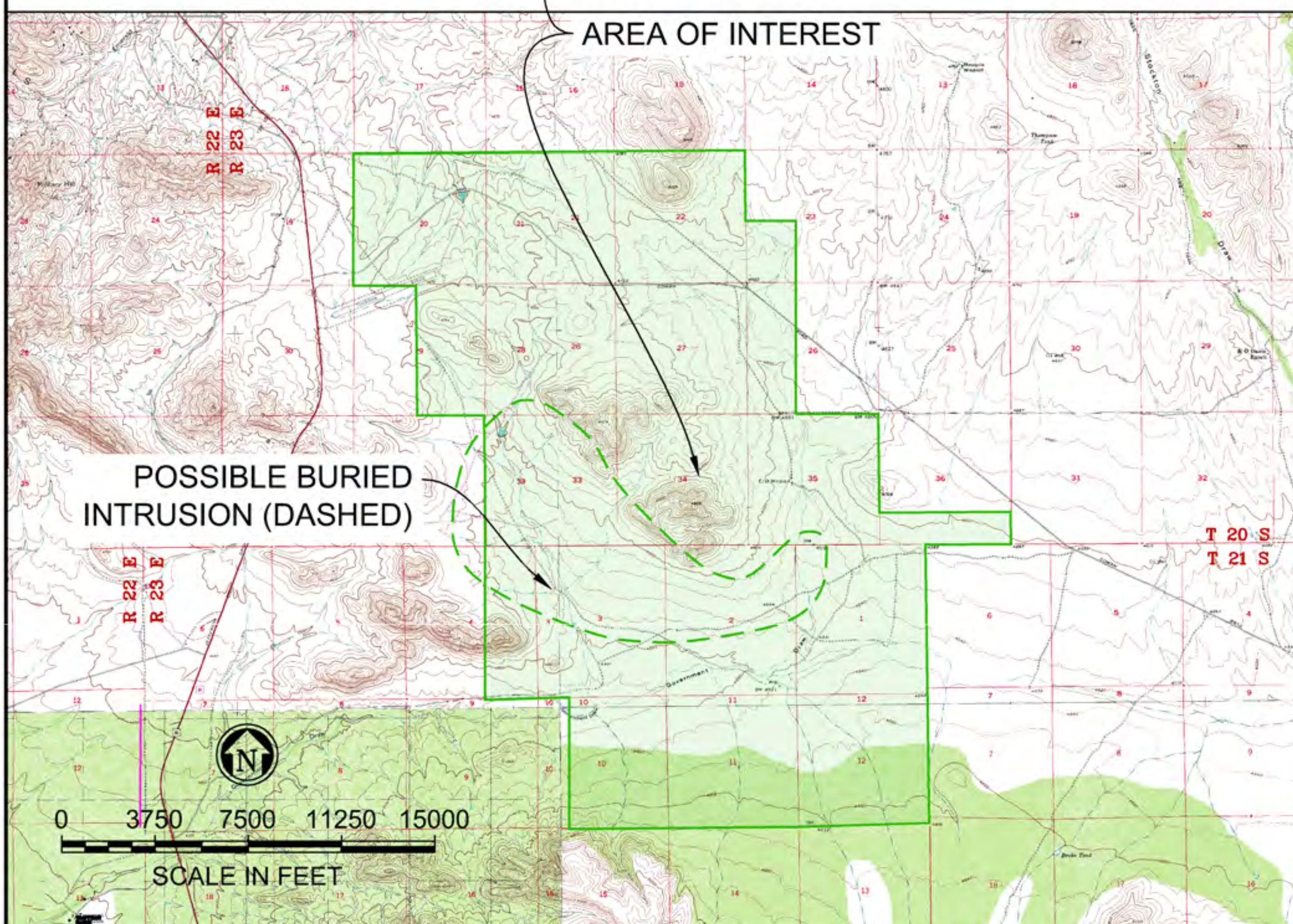
1. SRK (2008)
2. LIBERTY STAR DATA FILES
3. USGS 7½ MINUTE QUADRANGLES (SRK LIBRARY)

GENERAL NOTES

1. THIS DRAWING IS FOR ILLUSTRATIVE PURPOSES ONLY. ALL DIMENSIONS AND LOCATIONS ARE APPROXIMATE BASED ON AVAILABLE INFORMATION.
2. THE DRAWING IS IN UTM NAD 27 COORDINATES, ARIZONA ZONE 12N, FEET.

EXPLANATION

HAY MOUNTAIN AREA OF INTEREST



srk consulting	LIBERTY STAR URANIUM & METALS CORP.	Tombstone, Arizona
		Location of Hay Mountain area of interest Tombstone Arizona
SRK JOB NO.: 173300.03 Task 600 — Internal Control Number 3	Hay Mountain Exploration Report	DATE: June 2011 — APPROVED: JR — FIGURE: 1-2 — REVISION NO. 1
FILE NAME: 1-2 Location of Hay Mountain area of interest, Tombstone, Arizona		

2 Introduction (Item 4)

This section describes for whom the technical report was prepared and the purpose of the report (Section 2.1), the qualifications and responsibilities of SRK personnel (Section 2.2), the personal inspection of the property and data files (Section 2.3), and the sources of information and data contained in the report (Section 2.4).

2.1 Terms of Reference and Purpose of the Report

Liberty Star has engaged SRK to prepare this technical report in anticipation of raising funds for the exploration program and future work. Liberty Star requested that an independent corporation prepare a technical report that complies with the standards of a Canadian National Instrument 43-101 technical report.

SRK prepared this Technical Report in accordance with industry accepted CIM "*Best Practices and Reporting Guidelines*," the revised regulations in NI 43-101 (*Standards of Disclosure For Mineral Projects*) and Companion Policy 43-101CP of the Canadian Securities Administrators, and *CIM Definition Standards for Mineral Resources and Mineral Reserves* (April 2011). The report is also designed to follow guidance established by the United States Securities and Exchange Commission (SEC), which regulates the reporting of exploration results, resources and reserves by organizations, individuals or companies ("entities") subject to the filing and reporting requirements of the SEC. "Decisions as to when and what information should be publicly reported are the sole responsibility of the entity owning the information, and are subject to SEC rules and regulations (SME, 2007)." Guidance on reporting exploration results, resources, and reserves per requirements of the SEC are summarized in the 2007 SME Guide (SME, 2007).

This Technical Report provides a: (1) review of the historical data and the previous exploration activities conducted in the Tombstone district and specifically on the Hay Mountain project, (2) discussion of the geology of the potential porphyry copper deposit and the deposit model, and (3) presentation of the recommendations by SRK to explore for mineral resources that are compliant with Canadian NI-43-101 and SEC guidelines.

2.2 Qualifications of Consultants

The examination of the Hay Mountain and Tombstone data files and writing the report on the Hay Mountain project property was performed by the following SRK personnel. Each of the authors is a Qualified Persons that is independent of Liberty Star, per requirements of Section 1.4 of NI 43-101.

Jan C. Rasmussen, R.G., Ph.D.

Jan Rasmussen is a Senior Associate Geologist with SRK, with 37 years of experience in mineral and energy resource exploration, environmental management, and project recommendations and reports, including more than 5 years of experience with the geology of precious and base metals, industrial minerals, energy resources, and uranium exploration. She has a Ph.D. in Economic Geology, is a Registered Geologist in Arizona and an SME Registered Professional Member. She is a Qualified Person for this Technical Report, and is responsible for writing the report.

Corolla K Hoag, R.G., C.P.G.

Corolla Hoag is a Principal Geologist with SRK with 24 years of experience in exploration, mine development, environmental permitting, and mine reclamation including 6 years of direct experience with evaluations and operations of Cu projects and operations in Arizona. She is a Registered Geologist in Arizona, an SME Registered Professional Member, and a Certified

Professional Geologist. She is a Qualified Person for this Technical Report, and is responsible for review of all sections of this report.

2.3 Site Visits

Jan Rasmussen and Corolla Hoag, the Qualified Persons signatory to this Technical Report, visited the property on July 1, 2011. A tour was made of the Tombstone district and the Hay Mountain project area. Historically, Ag mineralization cropped out at the surface at numerous localities in the Tombstone district, and historic shafts, adits, and pits are abundant in the district. The more important of these historic structures and one underground working were examined, as were historic mine dumps, recent trenches, and the client's Hay Mountain project area. The site visit permitted examination of accessible and representative outcrops, pits, adits, and mine dumps with exposures of mineralized rock.

2.4 Sources of Information

This report is based on the following information:

- Personal inspection of Liberty Star data on the project and surrounding areas;
- Updated land ownership and other information provided by Liberty Star;
- Digital databases, images, AutoCAD maps, and unpublished reports provided by Liberty Star; and
- Additional publicly available information obtained from public domain sources.

The authors and SRK are not insiders, associates, or affiliates of Liberty Star. The results of this Technical Report are not dependent upon any prior agreements concerning the conclusions to be reached, nor are there any undisclosed understandings concerning any future business dealings between Liberty Star and the authors or SRK. SRK will be paid a fee for its work in accordance with normal professional consulting practice.

The authors' statements and conclusions in this report are based on the information available at the time of the report. It is to be expected that new data and test results may change some interpretations, conclusions, and recommendations going forward.

Numerous sources of information were used in the preparation of this Technical Report. These include more than 40 historical documents in digital, scanned, or hard-copy format, the majority of which were obtained from Liberty Star, the Arizona Geological Survey, or downloaded from the Internet. Other sources of information were from the authors' personal libraries, the Science Library at the University of Arizona, files at the Arizona Department of Mines and Mineral Resources (now the Arizona Geological Survey) in Phoenix, and more than 100 notebooks of data from Liberty Star. The documents are enumerated in Section 22 (References) and in the various chapters where they are cited.

The historical reports from the approximate period 1878 through 1936 generally were prepared by prominent mining engineers of the day. These authors typically reported production in historical dollars, or published "notes" in the Engineering & Mining Journal (E&MJ). More recent reports, between 1963 and 2007, generally were prepared by mining companies whose work is not available, the USGS, or students as masters or doctoral-level theses. Several reports prepared by independent geologists were also available.

3 Reliance on Other Experts (Item 5)

The authors, as Qualified Persons, have examined the Liberty Star exploration data for the Hay Mountain project, NI 43-101 documents on the Zebra and Tombstone Exploration Inc. projects, and publications by State and Federal geological surveys. The authors have relied on that basic data to support the statements and opinions presented in this Technical Report.

In the opinion of the authors, the available data are present in sufficient detail to prepare this exploration technical report and are generally correlative, credible, and verifiable. The project data are a reasonable representation of the Hay Mountain project. Any statements in this report related to deficiency of information are directed at information that, in the opinion of the authors, has been lost during transfer of property files, or is information that is recommended by SRK to be acquired.

The authors have relied upon the work of others to describe the land tenure and land title in Arizona with reference to the ownership and current land status (Section 4), and the permit status of the Hay Mountain project. SRK has relied upon Liberty Star for this information.

4 Property Description and Location (Item 6)

This section describes the area of interest and the Hay Mountain project location.

4.1 Property Location

The Hay Mountain project is located southeast of the Tombstone mining district in western Cochise County in southeastern Arizona (Figure 1-1). Tombstone is approximately 72 miles (mi) southeast of Tucson and 24 mi northwest of Bisbee, Arizona.

The main Tombstone mining district is on the Tombstone USGS 15-minute quadrangle. This map is bounded by longitude 110º 15’ and 110° W, and latitude 31º 30’ and 31º 45’.

The Hay Mountain project area consists of several sections of Arizona State Trust Land, public lands administered by the Bureau of Land Management (BLM), and some private property. The area of interest is located southeast of the town of Tombstone in portions of Secs. 19, 20, 21, 22, 23, 26, 27, 28, 29, 30, 31, 32, 33, 34, and 35, T20S, R23E, and portions of Secs. 2, 3, 4, and 5, T21 S, R23E, Gila and Salt River Meridian (Figure 1-2).

4.2 Mineral Titles

Liberty Star has contracted with Arizona registered land surveyor (RLS) Robert Breen, Environmental Field Services of Oracle, Arizona, to investigate the current status of mineral titles in the Hay Mountain project. The current status map (Figure 4-1) indicates that approximately three-fourths of the area of interest is administered by the State of Arizona and one-fourth is private land ownership. No federally administered lands, either Bureau of Land Management (BLM) or U.S. Forest Service, are present in the Hay Mountain area. Much of the ground will be acquired by Arizona state Mineral Exploration Permits (MEPs) and leases.

4.3 Description

The town of Tombstone is at an elevation of 4,530 ft, on the northeast flank of the Tombstone Hills within the upper San Pedro River drainage basin. The Tombstone Hills are low scattered hills that have a maximum elevation of 5,320 ft and are composed of igneous and sedimentary rocks. The alluvial plain between the Dragoon Mountains to the northeast and the Tombstone Hills slopes at about 75 ft to the mile west toward the San Pedro River. With few exceptions, the tributary washes in the region flow for less than one percent of the year, which is during flash runoff following summer thunderstorms.

The Hay Mountain project is situated in the semi-arid borderland of the Sonoran/Chihuahuan deserts, with elevations across the area that range from a low of 4,521 ft in Government Draw on the south to a high of 4,980 ft in the hills in the central part of the area of interest. The maximum relief between peak and basin is approximately 450 ft.

4.4 Mineral Claims and Leases

Liberty Star has contracted with Robert Breen, RLS, of Environmental Field Services of Oracle, Arizona, to investigate the land status and existing mineral claims and leases in the Hay Mountain project. A map of the land ownership is shown in Figure 4-1. Currently Liberty Star has no federal mining claims (as there is no federal land), State MEPs, or leases in the Hay Mountain project area of interest.

4.4.1 Mineral Rights on Arizona State Land

Mineral exploration rights on Arizona State Land are obtained from the Arizona State Land Department (ASLD) by application for and award of a "State Mineral Exploration Permit" (MEP). If mineral sufficient to mine is defined during the life of the MEP, then a Mining Lease must be obtained (ADMMR, 2011). An application fee of $500 is required to obtain an exploration permit. An MEP covers all or part of an individual section and has a minimum size of 20 acres, is defined by legal subdivision, and has no maximum size (though limited to one section per MEP). Prior to conducting any exploration activities on the MEP, the permittee must receive authorization from the ASLD in the form of an approved exploration plan of operation. Depending on the activities proposed, archaeological and native plant clearances may be required.

4.4.2 Requirement to Maintain the Claims in Good Standing

Arizona State Land MEPs are issued for a period of one year, subject to renewal on an annual basis and for an aggregate period not to exceed five years. During the period the permit is in effect, the permittee has the exclusive right to conduct exploration type activities on the state land covered by the permit. A rent in the amount of $2 per acre is required for the first year of the permit, no rent is required for the second year, and a rent of $1 per acre for years three, four, and five of the permit. There is a required minimum work expenditure for each exploration permit of $10/acre per year for years 1 and 2 and $20 per acre per year for years 3 through 5. A work expenditure report must be filed and if it is technical work, a complete report detailing the results must be filed. The reports are held in confidence for 3 years, after which time the report becomes part of the public record. A restoration cash bond of $25,000 or suitable insurance bond is required for each MEP.

4.4.3 Titles and Obligations, Agreements, and Exceptions

The authors have not independently verified the validity of the mining claims, their ownership, or the history of the land tenure in years past. Liberty Star currently has no title or obligation agreements in the project area. There are no exceptions to the titles.

4.5 Required Permits and Status

Permits to conduct drilling in Arizona are administered by the Arizona Department of Water Resources (ADWR). The filing fee for a Notice of Intent to Drill is $150 and the average processing time is 15 days. The drilling company must be licensed with the Arizona Registrar of Contractors and the ADWR. Drilling on Arizona State land also requires a Notice of Intent to Drill, unless the drilled bore hole will be less than 100 ft deep.

Permits to conduct exploration drilling on BLM lands require either a Notice of Intent or a Plan of Operations, depending upon the amount of new surface disturbance that is planned. A Notice of Intent is for planned surface activities that anticipate less than 5.0 acres of surface disturbance, and usually can be obtained within a 30 to 60 day time period. A Plan of Operations will be required if there is greater than 5.0 acres of new surface disturbance involved with the planned exploration work. A Plan of Operations can take several months to a year to be approved, depending on the nature of the intended work, the level of reclamation bonding required, the need for archeologicaland biological surveys, and other factors as may be determined by the BLM. No other permits are required for exploration drilling.

4.6 Location of Mineralization

The exploration target areas on the Hay Mountain project are primarily within the cadastral location of Secs. 19, 20, 21, 22, 23, 26, 27, 28, 29, 30, 31, 32, 33, 34, and 35, T20S, R23E, and portions of Secs. 2, 3, 4, and 5, T21S, R23E, Gila and Salt River Meridians.

According to the 10-Q form filed by Liberty Star with the SEC in 2010, "There is no assurance that a commercially viable mineral deposit exists on any of our properties, and further exploration is required before we can evaluate whether any exist and, if so, whether it would be economically feasible to develop or exploit those resources."

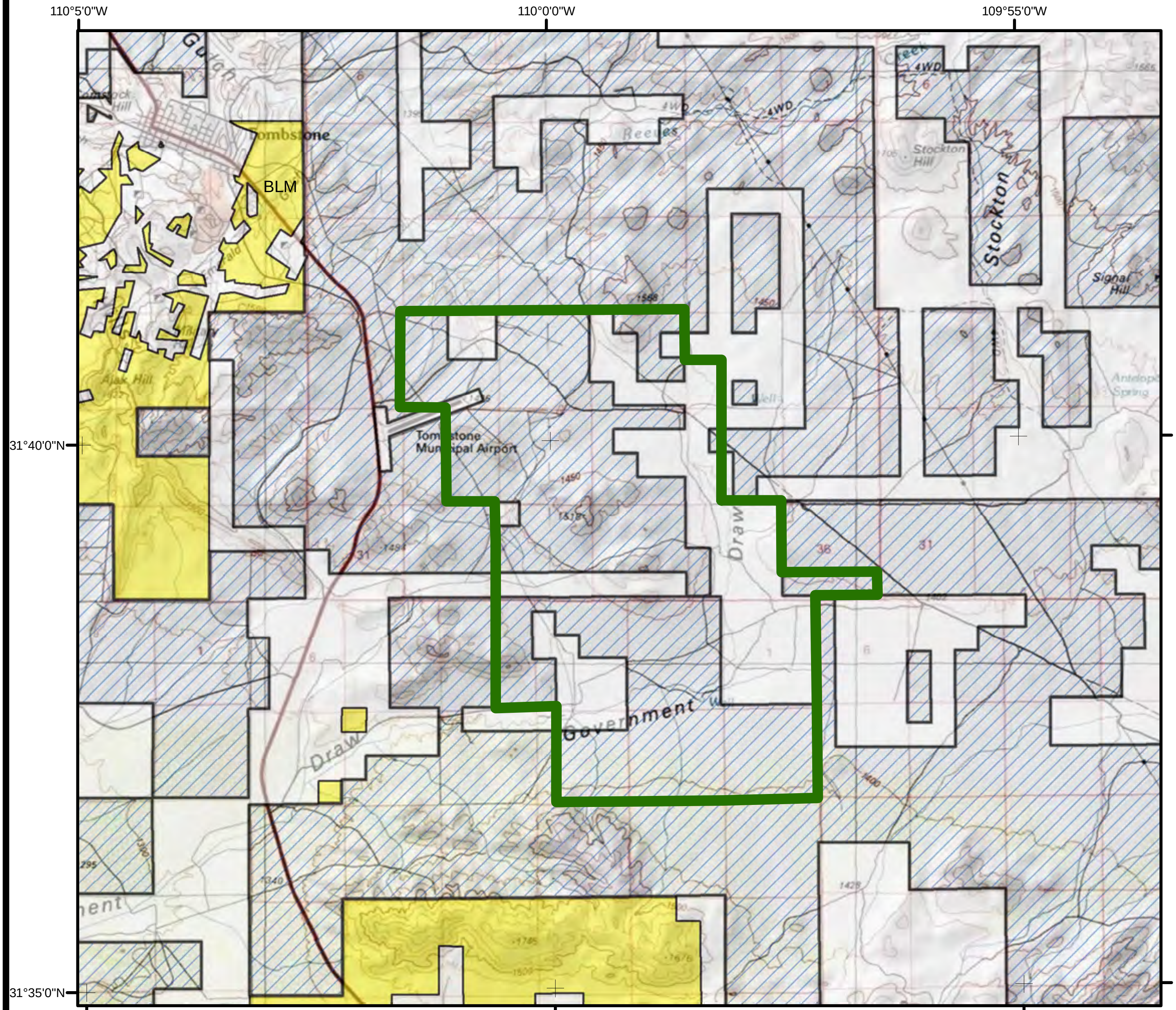
4.7 Royalties, Agreements and Encumbrances

There are no royalty agreements or encumbrances on Federal mining claims. Mineral leases are required on State land before mining can proceed.

4.8 Environmental Liabilities and Permitting

Existing environmental liabilities are not described in the project files. The brief site visit indicated no mine shafts or waste disposal issues on the site. A more detailed site survey may identify presence of open shafts, prospect pits, or adits. Access roads and open mine shafts and adits were largely left un-reclaimed in the Tombstone district, which was the standard industry practice at the time.

It is outside the scope of this report to review the status of all applicable agreements and permits. These permits are not required to complete the SRK-recommended next step, which is an exploration assessment and preparation of a related budget.



Legend

- Hay Mountain area of interest
- Private
- State
- BLM

References

1. Liberty Star data files
2. USGS Topo maps
3. Bureau of Land Management

0 750 1,500 3,000 4,500 6,000 Meters

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter

srk consulting

LIBERTY STAR URANIUM & METALS CORP.

Tombstone, Arizona

Land ownership at Hay Mountain

SRK JOB NO: 173300.03

FILE NAME: 4-1 Land ownership at Hay Mountain

Hay Mountain Exploration Report

DATE: 6/21/2011 | APPROVED: JA | FIGURE: 4-1 | REVISION NO.: 0

P:\Liberty_Star_Uranium+Metals\173300.030_Walnut_Creek_Exp_Rpt\040_AutoCAD\HAY_MOUNTAIN\4-1 Land ownership at Hay Mountain.mxdTombstone Caldera South land ownership map21 Jun 2011

5 Accessibility, Climate, Local Resources, Infrastructure and Physiography (Item 7)

This section discusses the physical conditions of the project site, specifically the accessibility, climate, local resources, infrastructure, and physiography of the Tombstone area. None of these characteristics are likely to negatively impact the Hay Mountain project as proposed. The project location in southern Arizona has good infrastructure and accessibility, with access to exploration and development service companies in the state that currently support active mining operations.

5.1 Topography and Elevation

The Hay Mountain project area is in an area of gently rolling hills (Figure 5-1). The project area is in the Tombstone Hills, which are a group of low, scattered hills at an elevation of 4,530 feet (ft) above sea level (asl) to approximately 5,340 ft asl (Figure 5-2). The hills are about 600 feet above the surrounding bedrock pediment or alluvial plain and about 670 feet above the San Pedro River to the west at Fairbank. The topography consists of rounded hills in the northern part of the district and of steep-sided, linear ridges in the southern part of the district.

No perennial streams are present in the district, though steep-sided gulches or arroyos run in short-lived, torrential floods during the summer monsoon season. These streams generally drain westward to the San Pedro River, which drains north toward the Gila River in central Arizona, but which is perennial only in certain stretches of the river. Although water is intersected at an elevation of approximately 4,120 ft asl in mines in the eastern part of the district, this water is too fluoride-rich to be used for drinking water.

5.2 Climate and Length of Operating Season

The climate of the Tombstone area is intermediate altitude desert and is semiarid with the mild climate typical of the lower elevations of the southwestern U.S. Temperatures are commonly high through the summer months (94.5°F, average maximum temperature for the period July 1893 to April 2007) and generally cool through the winter months (34.7°F, average minimum temperature 1893-2007). The total average annual precipitation in Tombstone is 13.8 inches, with recorded extremes of 7 inches and 28 inches (U.S. Historical Climatology Network, 2008).

Flood conditions occur infrequently, although heavy thunderstorms during July and August at times cause floods that do considerable local damage. High winds accompanying heavy thunderstorms during July and August sometimes reach peak gusts of about 100 mi per hour in local areas, while tornadoes are reported on the average of about once a year. Snow may fall from November through March, but generally it averages less than 1 inch in a month and accumulations rarely last more than a few days.

5.3 Vegetation

The vegetation in the Tombstone mining district is characteristic of the intermediate elevations of southern Arizona. The elevation is above that favorable to cacti and below that favorable to forest trees, so that desert shrubs predominate. The foothill slopes and pediments contain cat claw and creosote, together with some mesquite and ocotillo in dense thickets. As rock type and slope-facing direction are also as important as elevation in determining vegetation zones, the rocky slopes generally contain ocotillo, prickly pear cactus, mescal, grasses, and occasional agave and yucca. Trees are not common in the area, although mesquite, palo verde, and walnut grow along gulches and arroyos. No trees in the district are suitable for mine use. Drill sites and roads exhibit slow re-growth of vegetation.

5.4 Physiography

The Hay Mountain project in southeastern Arizona is located in the Basin and Range physiographic province in southeastern Arizona (Hayes, 1969) (Figure 5-3). The regional setting and names of surrounding mountain ranges are shown in Figure 5-4. The Basin and Range is characterized by generally long, narrow, mountain ranges separated by desert plains underlain by deep basins. The mountain ranges trend generally north to northwest and are composed of igneous, sedimentary, and volcanic units ranging in age from Precambrian to Tertiary. Mountain peaks have elevations greater than 9,000 ft and often rise more than 5,000 above the adjacent valleys. The basins are composed of thick sequences (more than 1,000 to 10,000 ft) of generally unconsolidated sand, gravel, clay, and evaporites. Major drainages, which are mostly ephemeral, are cut into the valleys and flow northward to the Gila River.

The Tombstone Hills, located south of the town of Tombstone, are a series of low hills with a general trend of North 35º West (N35ºW) to N50ºW. The average elevation of the hills are 5,750 to 5,300 ft asl, while the surrounding plains are 4,100 to 4,600 ft asl, sloping gently westward toward the San Pedro River.

5.5 Access to Property

The Tombstone mining district is readily accessible via good quality paved roads, one of which is adjacent to the Hay Mountain project. The Tombstone mining district may be reached from Tucson via Interstate Highway 10 (I-10) to Benson and then State Route 80 (SR 80) from Benson through St. David to Tombstone. Access to the district from nearby towns is via paved two-lane highways. The Tucson International Airport is less than 70 miles from Tombstone (Figure 5-5). The Tombstone Municipal Airport is 3 mi southeast of the town and within the Hay Mountain area of interest. It has a 5,000-foot, oiled air strip that is adequate for light planes, but has no fuel or other facilities available.

Access to the Hay Mountain project area is by two-wheel drive vehicles along graded and maintained dirt roads (Figure 5-6). More remote locations in the Tombstone mining district require four-wheel drive or all-terrain vehicles. Travel along old and partially overgrown ranching and mine roads is feasible and provides good access throughout the district.

Other nearby towns are Sierra Vista and Bisbee. Sierra Vista, which is the location of Ft. Huachuca, is 18 mi (25 km) west of Tombstone via the Charleston Road. Many mining supplies are available in Tombstone, and most types of supplies are available in Sierra Vista, which has nearly 40,000 inhabitants. Semi-skilled to skilled labor is available in Tombstone and Sierra Vista.

5.6 Surface Rights

Parts of the Hay Mountain project area are State land and state prospecting permits have been held by companies associated with Mr. Briscoe in the past.

5.7 Local Resources and Infrastructure

Tombstone is the nearest town to the Hay Mountain project. The U.S. Census Bureau (2008) reports a year-2000 population of 1,500 people. Services at Tombstone are marginally adequate to support the requirements of a mining exploration and development project, but other nearby towns have services such as drilling contractors, equipment rental and services, engineering services, and a labor force that are more able to support the project. U.S. Census Bureau populations in 2000 were: Willcox, 3,733; Benson, 4,700; Bisbee, 6,100; and Sierra Vista, 37,775). Sierra Vista is about 18 mi from the project area. The nearest large city is Tucson, which is located 70 mi northwest of Tombstone along I-10. Tucson has a population of more than 485,000 (2000 Census) and has company, service, and contractor resources that may not be available in Tombstone.

Surface water is scarce and groundwater supplies are regulated and may be somewhat limited. Walnut Gulch to the northeast is an ephemeral stream, as is the San Pedro River to the west. In 1882, a pipeline was constructed that is still in use to bring industrial water to Tombstone from the Huachuca Mountains, which are 27 mi to the west. Today the town has municipal wells that supply the needs of the town population. Ranchers in outlying areas obtain domestic and stock water from private wells.

A definitive groundwater resources investigation of the region by earlier mining companies is not known to exist, nor are published studies by the USGS or the Arizona Department of Water Resources (ADWR). Hollyday (1963) reported that in the Walnut Creek drainage northeast of Tombstone, during an 8-year period of pumping for mine dewatering between 1901 and 1911, 36,900 acre-feet of water was withdrawn from storage, with a maximum drawdown of 440 ft. Similar conditions are likely to occur in the Hay Mountain area.

Water supplies for development and mining would come from groundwater sources in the area. ADWR well records for the area indicate the water table is generally shallow, 200 to 400 feet below ground surface. However, there are ADWR reports of dry wells in the area, one of which was drilled to a depth of more than 1,000 ft. The Hollyday (1963) investigation at Walnut Creek suggests that moderate supplies of water could be sustained for a long period of time, while large yields would decline very rapidly.

5.8 Infrastructure

Telephone and electric power are available to the Hay Mountain area, providing service to local ranchers and small service companies located outside of the town. Internet and television services also are available locally. Electric power is supplied through Sulphur Springs Valley Electric Cooperative, with 440V, three-phase lines nearby. Postal services are available by post offices boxes and ground delivery. UPS, DHL, and Federal Express also are available locally.

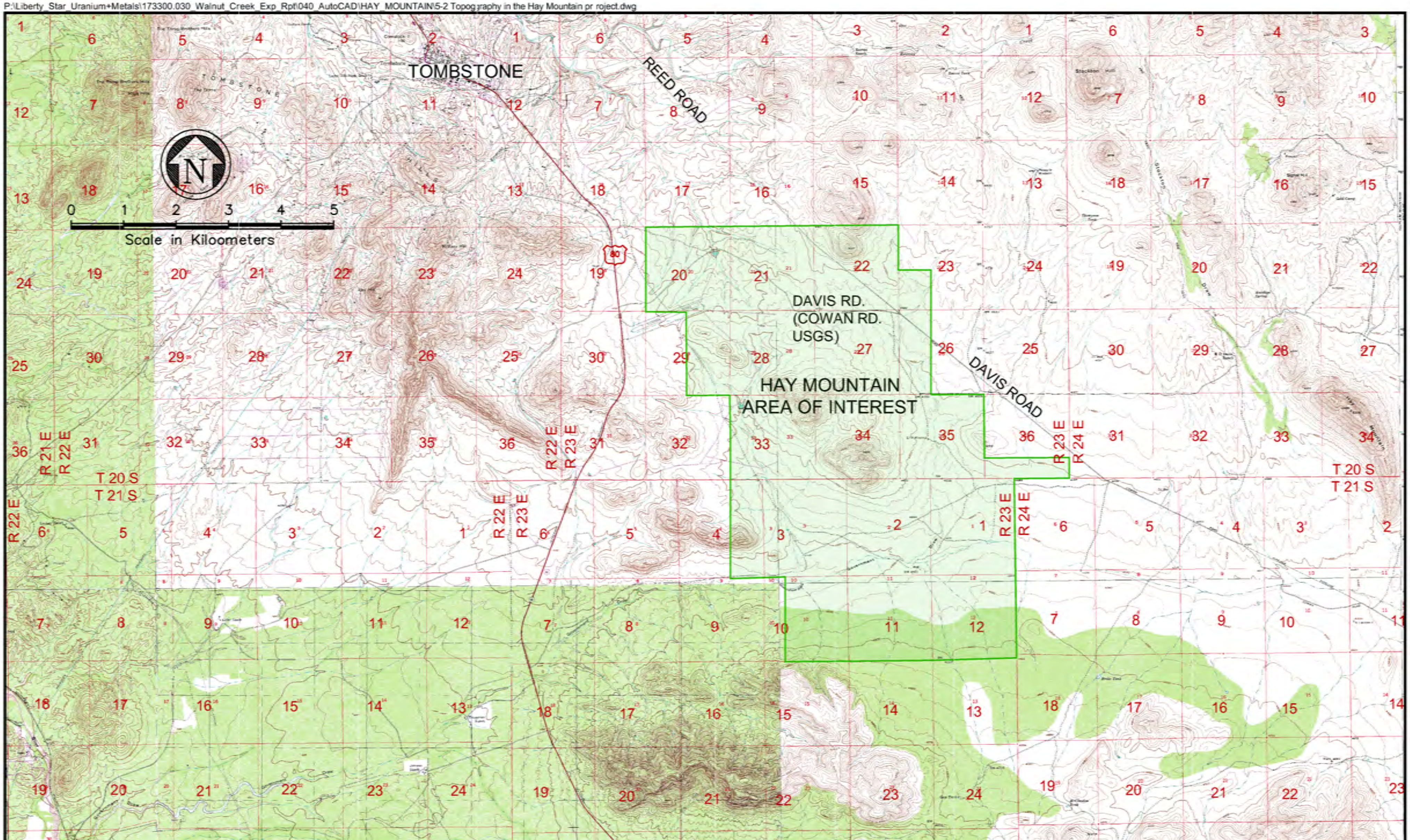
Gas and diesel stations are near the property, and major fuel supply stations are 15 mi away in Sierra Vista. El Paso Gas has a gas line that crosses the northeast corner of Sec. 7, T20S, R22E. The Arizona Southern Railroad line right of way parallels the San Pedro River, but the rails were removed before 2005. A spur built in 1903, between Fairbank and Tombstone, no longer exists, but traces of the old railroad grade can be seen on Google Earth.

All levels of education are available in the area, including three community colleges in Sierra Vista, Douglas, and Benson. The University of Phoenix also maintains a campus in Sierra Vista. Skilled labor and computer-literate personnel are available locally.

The old mining camp of Bisbee is about 36 mi southwest of Tombstone. Bisbee is the site of underground and open-pit Cu mines that were operated for about 100 years by Phelps Dodge and others, but were shut down in 1982.

Figure 5-1 Typical Hay Mountain project topography

P:\Liberty_Star_Uranium+Metals\173300.030_Walnut_Creek_Exp_Rpt\040_AutoCAD\HAY_MOUNTAIN\5-2 Topography in the Hay Mountain pr roject.dwg



GENERAL NOTES

1. MAP DRAWN IN UTM NAD27, ARIZONA ZONE 12 COORDINATES, METERS.
2. FOR ILLUSTRATIVE PURPOSES ONLY. DIMENSIONS AND LOCATIONS ARE APPROXIMATE.

REFERENCES

1. LIBERTY STAR.
2. USGS 7½ MINUTE QUADS (SRK LIBRARY)

srk consulting

SRK JOB NO.: 173300.03 Task 600 | Internal Control Number 3

FILE NAME: 5-2 Topography in the Hay Mountain project

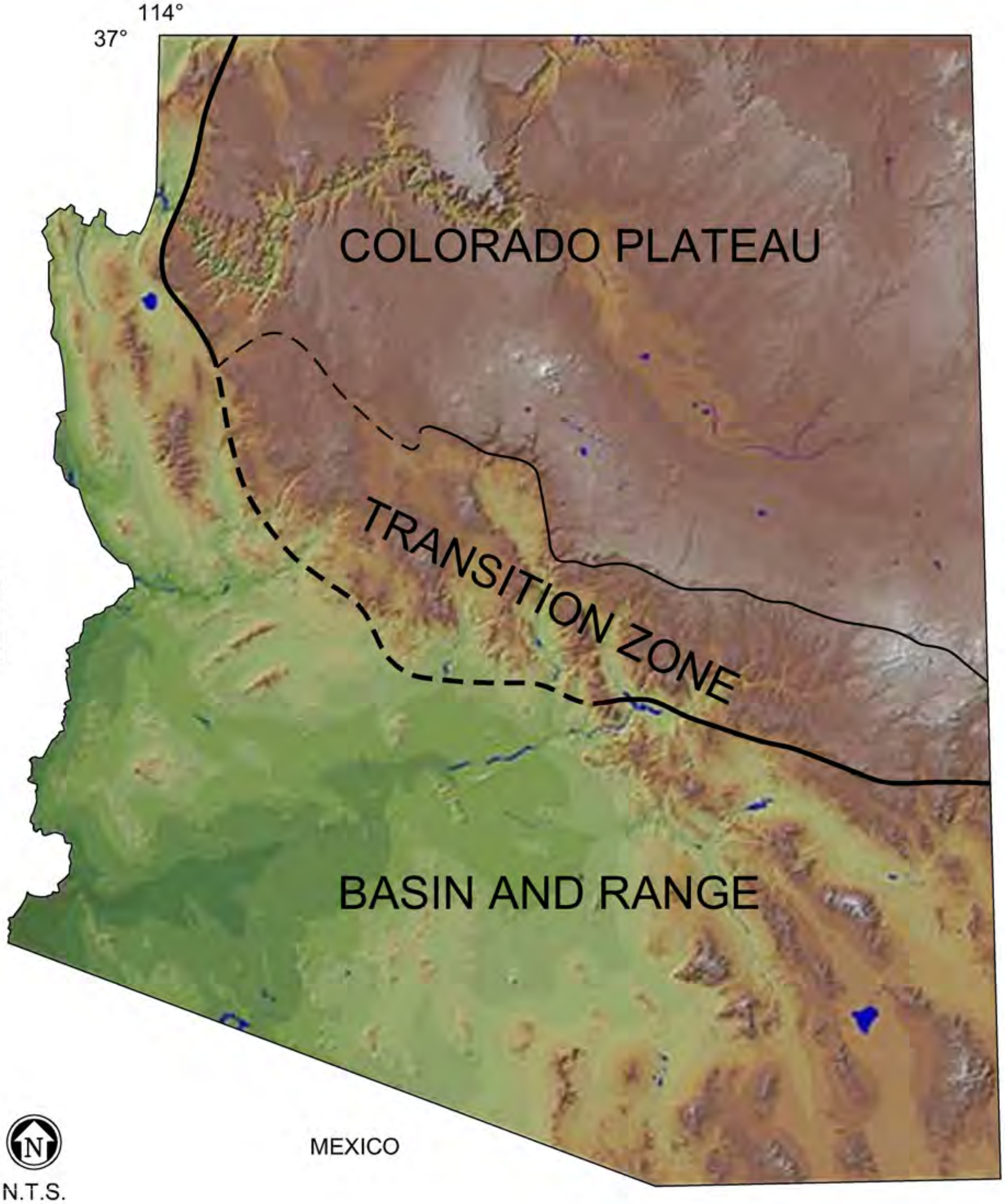
LIBERTY STAR URANIUM & METALS CORP.

Hay Mountain Exploration Report

Tombstone, Arizona

Topography in the Hay Mountain project

DATE:	APPROVED:	FIGURE:	REVISION NO.
June 2011	JR	5-2	1



REFERENCES

1. USGS, NATIONAL ELEVATION DATA SET SHADED RELIEF OF ARIZONA
2. HAYES, 1968

GENERAL NOTES

1. THIS DRAWING IS FOR ILLUSTRATIVE PURPOSES ONLY. ALL DIMENSIONS AND LOCATIONS ARE APPROXIMATE BASED ON AVAILABLE INFORMATION.

srk consulting

LIBERTY STAR URANIUM & METALS CORP.

Tombstone, Arizona

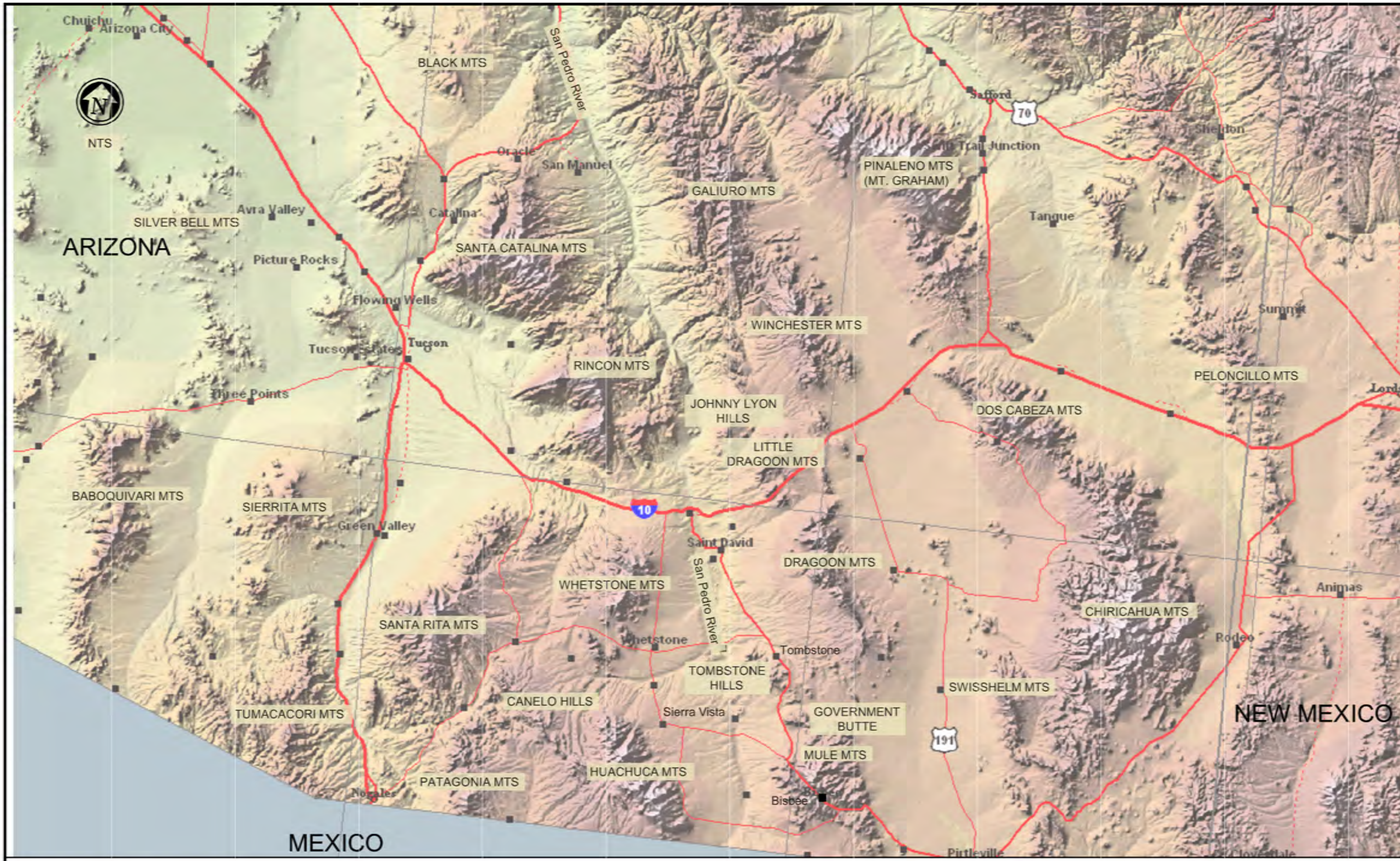
Physiographic provinces of Arizona

SRK JOB NO.: 173300.03 Task 600 — Internal Control Number 3

FILE NAME: 5-3 Physiographic provinces of Arizona

Hay Mountain Exploration Report

DATE:	APPROVED:	FIGURE:	REVISION NO.
June 2011	JR	5-3	1



GENERAL NOTES

1. FOR ILLUSTRATIVE PURPOSES ONLY. DIMENSIONS AND LOCATIONS ARE APPROXIMATE.

REFERENCES

1. USGS: NATIONAL ATLAS OF THE UNITED STATES.

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LIBERTY STAR URANIUM & METALS CORP.

SRK JOB NO.: 173300.03 Task 600 Internal Control Number 4

FILE NAME: 5-4 MOUNTAIN RANGES IN THE VICINITY OF TOMBSTONE

Hay Mountain Exploration Report

Tombstone, Arizona

Mountain ranges in the vicinity of Tombstone

DATE:	APPROVED:	FIGURE:	REVISION NO.
June 2011	JR	5-4	1

Legend

Hay Mountain area of interest

References

1. Liberty Star data files
2. Bing Roads (ArcGIS Base map)

0 10000 20000 30000 40000 Meters

Coordinate System: NAD 1983 UTM Zone 12N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter

P:\Liberty_Star_Uranium+Metals\173300.030_Walnut_Creek_Exp_Rpt\040_AutoCAD\HAY_MOUNTAIN\5-5 General access to the Hay Mountain project.mxdTombstone Caldera South land ownership map22 Jun 2011

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LIBERTY STAR URANIUM & METALS CORP.

Tombstone, Arizona

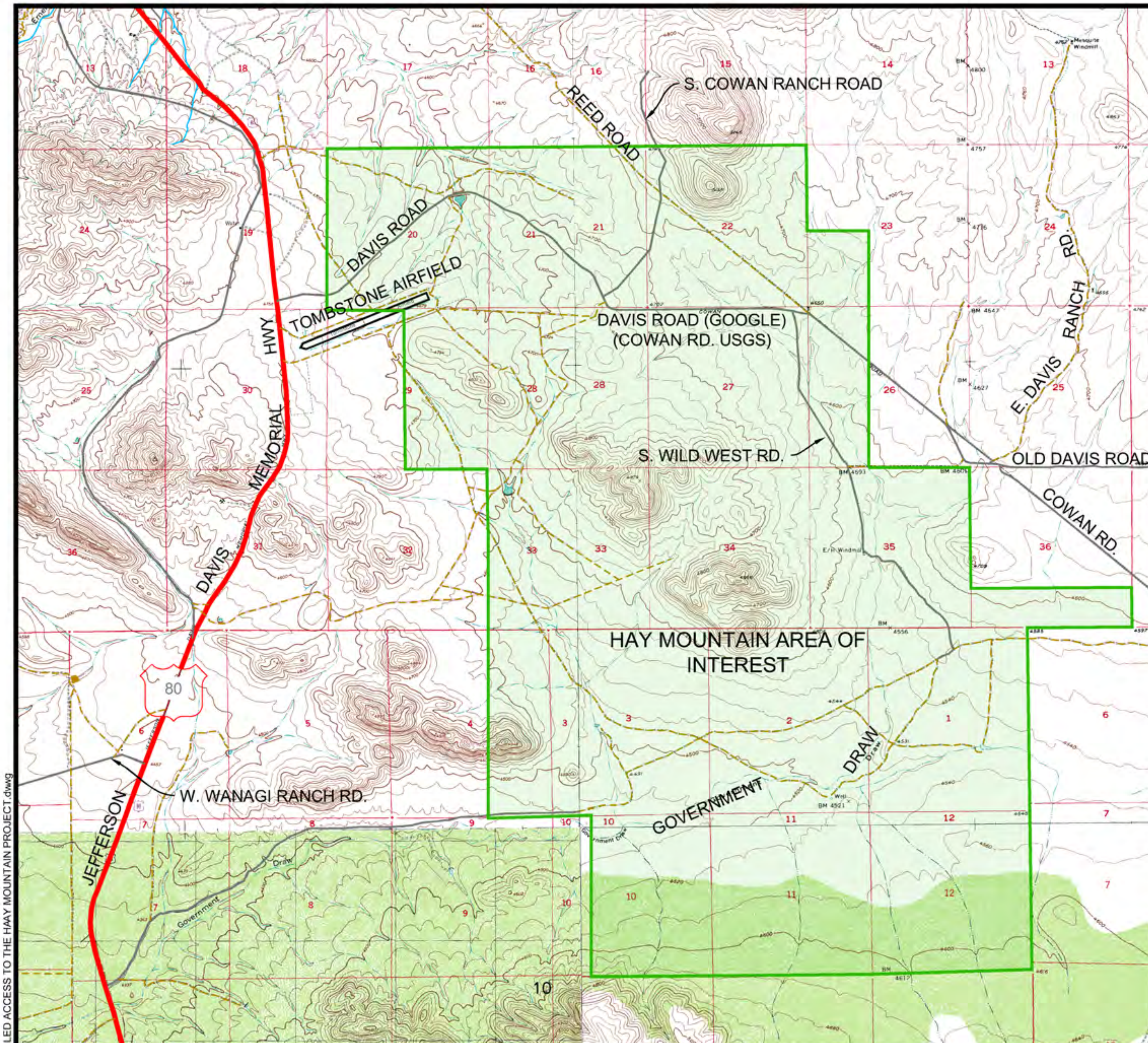
General access to the Hay Mountain project

SRK JOB NO: 173300.03

FILE NAME: 5-5 General access to the Hay Mountain project

Hay Mountain Exploration Report

DATE:	APPROVED:	FIGURE:	REVISION NO.:
6/22/2011	JA	5-5	0



LEGEND

- HAY MOUNTAIN AREA OF INTEREST
- PAVED ROADS
- UNPAVED ROADS
- NATURAL DRAINAGE AND AQUEDUCT
- US HWY

REFERENCES

1. LIBERTY STAR.
2. USGS 7½ MINUTE QUADRANGLES (SRK LIBRARY)
3. GOOGLE MAPS (STREET NAMES)

GENERAL NOTES

1. MAP DRAWN IN UTM NAD27, ARIZONA ZONE 12 COORDINATES, METERS.
2. FOR ILLUSTRATIVE PURPOSES ONLY. DIMENSIONS AND LOCATIONS ARE APPROXIMATE BASED ON AVAILABLE INFORMATION.

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Scale in Kilometers

srk consulting

LIBERTY STAR URANIUM & METALS CORP.

Tombstone, Arizona

Detailed access to the Hay Mountain project

SRK JOB NO.: 173300.03 Task 600 — Internal Control Number 3

FILE NAME: 5-6 DETAILED ACCESS TO THE HAY MOUNTAIN PROJECT

Hay Mountain Exploration Report

DATE:	APPROVED:	FIGURE:	REVISION NO.
June 2011	JR	5-6	1

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6 History (Item 8)

The Tombstone mining district has a long history (1877-present) of Ag production, along with associated base metals. Exploration by major mining companies in the southern and eastern parts of the district has targeted Au mineralization, which is common in the outer zoning of porphyry copper deposits.

History of the exploration and development of the Tombstone district has been extracted from previous reports, primarily Guilbert (1993), Devere (1978), and SRK (2008). The Tombstone mining district is one of 12 mining districts in Cochise County, Arizona. Cu, Ag, zinc (Zn), lead (Pb), and Au were the principal metals produced from the different mines in Cochise county, most of which were from Bisbee and from polymetallic vein and replacement deposits (Table 6-1).

6.1 Tombstone District History

Mines in the Tombstone district were described by Keith (1973) and are shown on Figure 6-1.

6.1.1 1877-1913

The first mining claim in the Tombstone district was located in 1857 (Butler and others, 1938), but mining did not commence until prospector Ed Schieffelin located rich Ag deposits at Tombstone in 1877. Immediately thereafter, development and mining in the Tombstone district boomed. The web site, www.mindat.org, lists approximately 120 mines in the district.

Oxide ores were mined from above the water table in the early years, but water plagued the district from the beginning. A lack of sufficient water in the early years meant the first mills at Tombstone were built along the San Pedro River, 9 miles to the west, which incurred high transportation costs. The situation reversed in March 1881 when water was encountered in the Sulphuret mine at a depth of 520 ft. The Engineering and Mining Journal (E&MJ) of 1881 reported the mine was estimated to flow at about 1,000 gallons per minute (gpm) (Newell, 1974). As other operations reached the water table, pumping was initiated in 1884 to dewater the mines. Pumping was successful for 3 years until fire destroyed the pumps. Coupled with low Ag prices at that time, many mines were forced to close.

Even though the mills were relocated to Tombstone after 1881, haulage costs remained a burden to the mines and mills because the nearest Southern Pacific – El Paso & Southern branch railroad spur line was 9 mi to the west at Fairbanks. The spur between Fairbank and Tombstone was not constructed until 1903.

Between the years 1878 and 1906, E&MJ (1878-1883, 1902, 1904, and 1906) published numerous notes concerning the nature, extent, and progress of underground development work in the district. E&MJ (1881b) stated the Tombstone Ag ores were mostly of a carbonate or chloride nature, and that production was about 300 tons/day. Recoveries were about 80%, and the average yield was about $75/ton. E&MJ (1883a) reported that on the third level of the Westside mine the ore was assaying about 40 oz/ton Ag and about 0.5 oz/ton Au. Mn ore from the Lucky Cuss mine at a depth of 100 ft, carried about 25 oz/ton of Ag. E&MJ (1883b) announced the discovery, between the third and fourth levels, in the Westside mine, of several tons of telluride ore that averaged $1,200/ton (assumed to be Au telluride - at $20/oz, about 60 oz per ton).

Blake (1882a, b, c, d) provided the earliest geologic descriptions of the district, and he recognized that the mineralization was closely associated with north-south striking dikes and cross-cutting northeast-striking fissures. He also stated that, where either dikes or fissures crossed anticlinal structures, mineralization often developed along crests of the folds as bedded replacement deposits. Comstock (1900) confirmed that folds were important to ore deposition at Tombstone.

Church (1903) believed that dikes in the district exercised a relatively minor control on the mineralization, and that the major controls were anticlinal folds and cross-cutting fissures. Lakes (1904) compared anticlinal structures at Tombstone with those at Bendigo, Australia. Between 1904 and 1920, little was published that dealt with the geology in Tombstone.

The mineralogy of the Tombstone ores has been studied from the earliest investigations. E&MJ (1881b) reported that the Tombstone Ag ores were mainly of chloride varieties, and that the ore contained a little Pb. In 1883, E&MJ (1883b) reported the discovery of several tons of telluride ore between the third and fourth levels of the Westside mine.

Penrose (1890) noted the presence of manganiferous Ag ore at Tombstone, and Moses and Laquer (1892) reported the existence of alabandite at the Lucky Cuss mine. Ag-bearing Mn minerals in Arizona and New Mexico were studied by Hewett and Pardee (1933), and they found that Ag was present as argentiferous manganite. These authors observed that black calcite was commonly associated with the Mn deposits, and that the calcite had black Mn oxide intergrowths that could be manganite, but not hausmannite.

The earliest mention of milling procedures at Tombstone (E&MJ, 1879b) indicated the successful operation of a 10-stamp mill, which yielded a recovery of about 77%. In 1881, about 120 stamps were in operation at Tombstone, treating about 300 tons/day (E&MJ, 1881b).

After water was first encountered in the Sulphuret mine in 1881, pumps with a capacity of 700 gallons per minute (gpm) were installed at the Contention and Grand Central mines in December 1883 (E&MJ, 1883c, d). The pumps worked successfully until 1886, when the Grand Central pump house burned (Dunning, 1959). Blake (1904a, b) mentioned that new pumps had lowered the water level to near the 700 ft level of the Contention mine. The water temperature was reported to be about 80º F.

Walker (1909) stated that water volumes of up to 4,500 gpm were not uncommon. High pumping costs coupled with a low Ag price (about $0.50/oz) forced abandoning operations on January 19, 1911. Water pumps remain on the 1000-, 800-, 700-, and 600-ft levels (Butler and others, 1938).

In 1900, the larger mines in the eastern part of the district were consolidated into the Tombstone Consolidated Mining Company. With new, larger pumps, mining operations below the water table resumed. In 1911, the pumps failed once more, the lower levels were allowed to flood, and mining by the Tombstone Consolidated Mining Company ceased. The smaller mines continued mining above the water table for several years, but by 1918 most of the mines were operated by lessees. By 1911, the rich Ag deposits above the water table were depleted and Ag prices had declined to $0.50 per oz.

The price of Ag had the greatest effect on the success and failure of the Tombstone mines. Most of the ore was produced during the 38-year period from 1877 to 1915, during which Ag prices declined, financial panics ensued, and the United States currency was removed from the Ag standard. In 1911, Ag prices of $0.55 per ounce (which was less than half that in effect when Schieffelin discovered Tombstone) ended efforts to de-water the mines and contributed to the bankruptcy of the Development Corporation of America and its Tombstone Consolidated Mining Company subsidiary.

6.1.2 1914-1932

In 1914, a creditor, the Phelps Dodge Corp., acquired the holdings of the Tombstone Consolidated Mining Company and began mining under the name of Bunker Hill Mines Company, concentrating on the lower grade Mn-Ag ores at shallower depth. Phelps Dodge mined above the water table until 1918 and operated the mines in a desultory fashion from 1914 through 1933. The Pittman Act, supporting the price of Ag at $1 per ounce between 1920 and 1923, stimulated some production in the main part of the district, primarily in the Bunker Hill mine, and small production in the western part. With the repeal of the Pittman Act in 1923, the price of Ag plummeted and the mines closed.

Ransome (1920) described the Mn mineralization at Tombstone. High concentrations of Mn were associated with the Prompter fault, and the principal Mn production was derived from the Oregon, Prompter, Lucky Cuss, Luck Sure, Bunker Hill, and Comet mines. Psilomelane, the major Mn mineral, typically occurred in pipes and chimneys in limestone horizons. Supergene processes were considered to have been responsible for forming the Mn deposits. High grade mineralization contained between 70% and 80% MnO after sorting, and low grade mineralization contained about 40% MnO. Ransome mentioned that in 1917 the Mn ore contained between 7 and 8 oz/ton Ag. Chapman (1924) reported that the historic State of Maine mine produced 200,000 to 300,000 ounces of Ag from 1900 to 1921.

6.1.3 1933-1950

The Phelps Dodge holdings were taken over by the Tombstone Development Co. in 1933. This company and its lessees mined ore in the district until the late 1930s or early 1940s (Needham and Storms, 1956; Farnham and others, 1961).

The higher Au price instituted by Franklin Roosevelt in 1932 stimulated some development, particularly in exploration in the main part of the district. During World War II, there was some study of the Mn deposits in the district in relation to the war effort. Also during World War II in late 1940, a controlling interest in the surviving Tombstone Development Company was acquired by the Newmont Mining Company. After holding the property until late 1950, Newmont's controlling interest was sold to a group of investors from Grand Island, Nebraska, under the name Tombstone Development Company. Exploration work in late 1950 by the Eagle Picher Company in the northeastern part of the main district showed values in Pb and Zn (Burton DeVere, Billiton Exploration, 1983, personal communication to Briscoe).

The geology at Tombstone was investigated in more detail during the late 1930s. Butler and Wilson (1937) noted that the mineralization was associated with north-south fissures, faults, anticlines, and northeast-striking fissures. Rasor (1937) investigated the mineralogy and petrography of the district and found hypogene Ag-bearing minerals to include hessite, tetrahedrite, and galena. Alabandite was found to be the only definitely hypogene Mn mineral. Bromargyrite, embolite, cerargyrite, argentite (acanthite), stromeyerite, native Ag, native Au (Butler and others, 1938), and argentojarosite were identified as supergene ore minerals. The zone of oxidation was thought to be at least 600 ft deep (Rasor, 1937), and bromargyrite was believed to be the most abundant supergene Ag mineral. Butler and others (1938) and Butler and Wilson (1938) published insight into a complex sequence of structural events in the district, and the authors also suggested a broad pattern of mineral zoning. Butler and Wilson (1942) summarized their work at Tombstone in Newhouse (1942).

Ingerson (1939) measured joint and platy inclusion orientation within the Uncle Sam Tuff west of Tombstone. The emplacement of the Uncle Sam Tuff was discussed at length by Gilluly (1945), and he considered the body to be an epithermal laccolithic or sill-like intrusion.

Rasor (1937) conducted the first detailed study of the mineralogy at Tombstone and discussed the Mn mineralization at Tombstone (Rasor, 1939). He identified four main stages of hypogene mineralization. Rasor (1938) reported the first United States occurrence of bromargyrite (formerly called bromeyerite) at Tombstone.

Romslo and Ravitz (1947) reported the successful treatment of Mn-Ag ore from Tombstone. Very poor results were obtained by direct cyanide and flotation methods, but a calcium dithionate process recovered 80% to 90% of the Ag and 90% of the Mn.

6.1.4 1951-1977

In 1965, the Duval Corporation drilled several rotary holes in the main part of the district probing for porphyry copper type mineralization. Not much is known of the results of this exploration, though data is thought to be in the files of the Tombstone Development Company.

In the period of 1972 to 1973, the American Smelting & Refining Company (ASARCO) obtained a lease on the Horne claims around the Robbers’ Roost breccia pipe. They drilled three holes to a maximum depth of approximately 5,000 ft on a porphyry copper alteration zone in the vicinity of the breccia pipes. These holes intersected extensive, but low-grade mineralization, grading vertically downward from a Pb-Zn phase of mineralization into Cu type mineralization, including disseminated pyrite, chalcopyrite, and molybdenite, as well as secondary K-feldspar and purple anhydrite. The drillhole penetrated Uncle Sam Tuff, intersected the Bisbee Group, and at about 5,000 ft, the drill entered the Naco Group limestone. Poor Cu prices at the time discouraged further exploration for Cu at this depth.

In 1973, a limited partnership headed by Hewlett, Stevenson, and Bishop optioned holdings in the western part of the district, and later the lands belonging to the Tombstone Development Company, Inc. In the spring of 1973, geologist James A. Briscoe was hired by Richard Hewlett to prepare a report on the State of Maine area (Briscoe, 1973). A topographic and geologic map of the State of Maine area was prepared at a scale of 1 inch to 200 ft (1" = 200'). Previously unrecognized windows exposing sediments beneath the Uncle Sam Tuff, as well as isoclinal folding in the sediments, were mapped. A comprehensive exploration program was planned and recommended. Also, in October of 1973, just before completion of the detailed report on the State of Maine area, the entire Tombstone district was flown for color aerial photography at a scale of 1" = 2,000' along north-south flight lines. The partnership also consolidated all of the old mine dumps in the main district on Tombstone Development Company land into one large heap leach pad, which was operated until 1977, when the Tombstone Development Company lease was relinquished. None of the exploration program recommended to the partnership by Briscoe was carried out.

At about the same time, Roger Newell completed a Stanford Ph.D. dissertation, in which he sampled mesquite twigs over 125 square miles of the Tombstone Hills and nearby areas. Newell's maps cover the district as far west as the San Pedro River and as far south as the Bronco Hills at a scale of 1:31,250 and 1:12,000 (Newell, 1974, Plates 1 and 2). Newell also presented geochemical data from regional sampling of mine dumps.

Gilluly and others (1954) described the Late Paleozoic stratigraphy of central Cochise County. Gilluly incorporated his earlier work on the Uncle Sam Tuff (Gilluly, 1945) with the stratigraphy to provide an exhaustive description of the geology of central Cochise County. Creasey and Kistler (1962) determined radiometric ages for an intrusive rhyolite and the Schieffelin Granodiorite by K-Ar methods as 63 and 72 Ma respectively. Andreason and others (1965) published an aeromagnetic map for the area around and including Tombstone.

Hewett (1972) observed that the minerals hollandite, psilomelane, and cryptomelane formed most of the Mn oxide deposits. He assigned a hypogene origin to all of the minerals.

6.1.5 1980-1985

In 1980, Tombstone Exploration, Inc. (TEI) obtained a lease on patented Tombstone Development Company lands in the main part of the district. Between 1980 and 1985, TEI operated an open pit mine on the Contention vein, and produced up to 3,000 tons per day of ore averaging in the range of 1.25 ounces Ag and 0.02 ounces Au. Approximately 40% of the Ag and 60% of the Au was recovered by cyanide leaching. Graves (1985) reported that 2 million ounces of Ag and 10,000 ounces of Au were produced in the period from 1970 to 1985, mostly from the TEI open pit operation, and in a small part by the partnership mine dump consolidation. The strongest zone of metallization exploited in the Tombstone district was the Contention-Head Center-Grand Central area (Greeley, 1984). No exploration drilling was done, and no ore reserves of significance were measured ahead of mining. Lowered Ag and Au prices, poor management, and a lack of reserves forced TEI into bankruptcy in 1985, and its assets were liquidated.

A regional map covering southeastern Arizona, compiled by Harald Drewes of the USGS, was published in 1980 (Drewes, 1980). In 1982, J. A. Briscoe and T. E. Waldrip, Jr. compiled data and maps from the work of Newell, Drewes, and others. Briscoe and Waldrip (1982) concluded from these various data that the volcanic geology and structure in the Tombstone area is related to a district-scale Laramide caldera. Ag mineralization in the district is also related to the caldera and attendant hydrothermal fluid migration, a concept that was later verified by Peter Lipman of the USGS.

6.2 Tombstone District Production

A number of reports have tabulated the historic production in dollars and tons in the Tombstone mining district, but there is no consolidated estimation of the historical resource or reserve figures. What production figures exist, as reported in the literature, are reported here for historical context. Values are reported in historical dollars, as found in the literature. The historical production figures are not treated as representative of current or future mineral production. Historical cut-off grades for the Tombstone district are not available. Tombstone was a Ag bonanza historical district, and most exploration data since the time of the boom (1878 to approximately 1911) generally are not available.

Varied historical production has been reported for the Tombstone mining district over the years. Detailed reports from the early period of the district generally were prepared by prominent mining engineers of the day and published in the Transactions of the American Institute of Mining Engineers. Production was typically reported in dollars. Blake (1902) reported that the historical values of Au and Ag produced by the mines of the principal Tombstone district, to the end of 1881, was $7.4 million. Hamilton (1884) reported that between 1879 and 1884 the Tombstone mining district produced $25 million in precious metals. Church (1902) estimated the yield up to the end of 1901 amounted to about $25 million.

Sarle (1928) prepared an independent report that stated the Tombstone mining district had known ore production totaling $85 million, gross value. Of this sum he reported that approximately $79 million came from 20-plus mines in the eastern area and approximately $6 million came from a dozen or more mines in the western district. He reported production in dollars from many mines and in tons from five of 23 known veins on the Mellgren property in the western part of the district.

Butler and others (1938) evaluated early production records and concluded that production to that time averaged more than a third of a million dollars per year. They estimated the value of the metals produced to the close of 1936 at $37 million: $19 million from 1879 to 1886, and $18 million from 1886 to 1936. Their inventory included remarks on historical developments during the reported period and the price of Ag for the period.

Stanton Keith (1973) stated that through 1970, the Tombstone mining district produced not less than 1.5 million tons of Ag-bearing ore, either with Pb or Mn (Table 6-2). He calculated that the yield between 1879 and 1970 was approximately 1.5 thousand tons of Cu, 22.5 thousand tons of Pb, 9,000 tons of Mn ore shipped during war years, 590 tons of Zn, 240 thousand ounces of Au, and 30 million ounces of Ag. He estimated that by 1890 over one-half the total Tombstone district Ag production had been extracted.

Keith (1973) reported the dollar production from the Tombstone district from several sources. J.B. Tenney (1929) compiled unpublished figures and estimates from old company reports and from these, and estimated that the total production to the end of 1907 was approximately $28.4 million. Unfortunately, this compilation is based only on value; it is assumed this production was primarily Au and Ag. *Mineral Resources of the United States* (USGS, 1999) reported production of Au, Ag, Cu, Pb, and Zn from 1908 to 1934, inclusive, was 608,345 tons and had a total value of approximately $8.1 million. Production by Tombstone Development Company and the Tombstone Mining Company for 1935 and 1936 had a total value of $564,437. From these records, Keith (1973) concluded that through 1970, "The total value of the production would exceed $38.8 million dollars." The historic Ag price in 1879 was $1.144 per oz and in 1970 it was $1.635 per ounce. In the intervening years the price of Ag ranged from $0.254 to $2.060 per oz (Kitco, 2008). Production for the Tombstone district between 1879 and 1970 is summarized in Table 6-3. Using the historical production values, Keith also provided information on owners, estimated production, and mineral products for individual mines (Table 6-2).

Moore and Roseveare (1969) estimated that between 1887 and 1940, 100,000 to 200,000 ounces per year of Arizona Ag production came from the Ag deposits of the Tombstone mining district. The historic Ag price in 1879 was $1.14 per oz and in 1970 it was $1.63. In the intervening years the price of Ag ranged from $0.25 to $2.06 per oz (Kitco, 2008).

Tombstone has primarily been a Ag camp, although substantial Au and Pb, and subordinate Cu, Zn, and Mn have also been produced. The Ag to Au ratio for documented production between 1877 and 1937 is 126 to 1. Production has come mainly from mineralized veins and fractures cutting folded Lower Cretaceous limestones and basal conglomerate of the Bisbee Group within the Tombstone Basin (main part of the district). Ninety-five percent or more of the production is from the surface to 656 ft, and is primarily from oxide ore minerals.

From 1908 through 1936, Briscoe has estimated that 1.25 million tons of ore was produced from the Tombstone district. Using this estimated tonnage and the recorded metal production, average grade for ore produced was 26 oz/ton Ag, 0.21 oz/ton Au, 2.6% Pb, and 0.10% Cu, with smaller amounts of Zn and Mn. Not included in these figures are the substantial amounts produced between 1980 and 1985 by TEI from its open pit mining operation along the Contention vein, nor from the dump leaching done by the Partnership between 1974 and 1977.

Total production at Tombstone, not including that of the Partnership or TEI, in terms of $400 Au and $10 Ag, $0[.50 Pb, $1.00 Cu, and $0.40 Zn, is approximately $463 million (Guilbert, 1993). Over a quarter million ounces of Au (262,500 oz.) are included in that figure.

The U.S. Bureau of Mines conducted investigations in 1947, 1956, and 1961 and reported on Mn production in the Tombstone district. The first Mn ore was produced during World War I by Bunker Hill Mines Co. from the Oregon-Prompter mine. Interest in Mn was revived during World War II and two carloads of high-grade ore were reportedly shipped from the outcrop of a deposit near the Oregon shaft. The next known production of Mn ore was made in 1953 or 1954 when the Tombstone Development Co. shipped 452 long tons of ore from the Prompter mine to the government purchasing depot in Deming, New Mexico. Farnham and others (1961) reported that when they visited Tombstone in August 1957, lessees operating the Oregon-Prompter mine had produced 900 tons or more of sorted Mn ore between February and August 1957.

Production figures estimated by Stanley Keith (2000) in the MagmaChem Model Book and Grade/Ton CD contain estimates for the various mines in the district. This table also includes a summary of Tombstone district production by Keith and one by Singer (Table 6-4).

6.3 Tombstone District Prior Ownership

Numerous companies owned or operated the many Tombstone mines over the years, and ownership changed frequently. Known previous owners of the principal mines are shown in Table 6-2, although dates of ownership are poorly documented. None of these previous mines are located in the Hay Mountain area of interest, although there are small prospect pits in the area.

A search of the Arizona Corporation Commission on the Internet found three Arizona companies that were active in the area in the 1980s and into the 1990s: Tombstone Silver Mines, Tombstone Exploration Inc. (TEI), Tombstone Silver Mines, Inc., and Tombstone Extension Mining, Inc. TEI was incorporated April 21, 1980, and filed annual reports in 1982, 1983, 1985, but the corporation was revoked 1986. TEI conducted open pit mining and heap leaching of low grade shallow Ag ores (the wall rocks remaining after the historic high-grade Ag was mined) in the main district just south of the town of Tombstone. Tombstone Extension Mining, Inc. was incorporated Feb. 17, 1983, but the corporation was revoked August 10, 1984. Tombstone Silver Mines, Inc. was incorporated March 6, 1984, but the corporation was revoked December 10, 1993.

There were no historic mines in the Hay Mountain area, although there are several small prospect pits. The most recent activity in the district is exploration by Tombstone Exploration Corporation (TEC), which posted information about a geophysical survey on their website.

6.4 Hay Mountain Project Ownership

The land in the project area is a mix of State and private with state land constituting the largest percentage. Liberty Star currently has no ownership or lease agreements in place. Liberty Star has retained Environmental Field Services to investigate the mineral exploration rights to the Hay Mountain project. Liberty Star plans to apply for Mineral Exploration Permits on the state land.

6.5 Project Expenditures

Few of the procured historical project data have an accounting of the total exploration dollars expended in the Tombstone district. An unknown amount was spent in the Zebra and Redrock Canyon Au exploration projects in parts of the Hay Mountain area of interest. Liberty Star expenditures are related to land and claim status research and preparation of this Technical Report.

6.6 Historic Mineral Resource and Reserve Estimates

No historic or current estimates of mineral reserves and mineral resources have been developed for the Hay Mountain project. This is an exploration project and developing mineral reserves and resources estimates await drilling results.

Table 6-1 Production summary, 1879-1970, Cochise County

Commodity	County Total	Tombstone Total
Ore (1,000 short tons)	156,658	1,500
Copper (1,000 lbs)	7,832,490	3,018
Lead (1,000 lbs)	386,269	45,000
Zinc (1,000 lbs)	487,144	1,179
Gold (oz)	3,091,742	240,000
Silver (100 oz)	146,416	30,000
Total Value (1,000s)	$1,937,825	$38,800

Source: Keith, 1973

Table 6-2 Production and owners of principal mines in Tombstone mining district

Mine	Location	Mineral Products	Property Owners (dates mostly unknown)	Estimated Production
Alkie mine (Escapule)	T21S, R22E, SW ¼ Sec. 6	Pb-, Cu-, Ag-	-	10 tons ore 1938, 1951-2
Anchor mine	T20S,R22E, W. Cen. Sec. 14	Mn, Ag	-	Small production 1916-1917
Arlington mine	T20S, R22E, SE ¼ Sec. 32	Pb, Cu, Ag, Au	-	About 110 tons produced 1924
Argenta mine	T20S, R22E, NW ¼ Sec. 16	Cu, Pb, Ag, Au	-	184 tons of ore shipped during 1922-1924.
African Queen mine (Last chance)	T20S, R22E, SE ¼, Sec. 11	Ag, Pb-, Au-	Tombstone Development Co.	Est. 30,00 tons ore produced pre 1938
Bald Eagle mine	T20S, R21E, SE¼, Sec. 25	Pb-, Ag	-	About 45 tons produced 1949
Blacktail mine group	T20S, R22E, S. Cent. Sec. 14	Mn, Ag	-	Some Mn-Ag ore shipped pre-1956
Bonanza group	T20S-R22E NE ¼ Sec. 16	Ag, Pb, Cu-, Au-	Mellgren Mining Tombstone Silver Fields Co.	5,000 tons of ore produced intermittently 1919 to 1941
Bunker Hill mine (Mammoth, Rattlesnake)	T20S, R22E, SE¼, Sec. 14	Ag, Pb, Zn, Mn, Cu-	Rattlesnake Co., Bunker Hill Mining Co., Bunker Hill Mines Co., Tombstone Gold-Silver Mines Co., Tombstone Development Co.	Several hundred thousand tons Ag-Pb ore and a few thousand pounds Mn-Ag ore produced 1880s-1952
Chance mine	T20S, R22E, Cen. Sec. 16	Ag, Au	Tombstone Consolidated Mining Company (TCMC) Bunker Hill Mines Company Mellgren Mining	140 tons of ore produced in 1935
Charleston Lead mine (Woolrey, Brother George, Mary Jo group)	T20S, R21E, N. Cen. Sec. 36	Pb, Zn, Ag, Cu, scrap mica, clay (As)	Tombstone Gold & Silver Mines Inc., Charleston Lead Mines Co., Tombstone Mica Co.	Few thousand tons Pb-Zn ore produced 1930s-1940s. some clay and scrap mica produced pre 1973
Comet & Black Eagle mines (Big Comet, Little Comet)	T20S, R22E, NE¼, Sec. 23	Mn, Ag, Pb-	Old Glory Mining Co., Tombstone Consolidated Mines Co., Tombstone Development Co.	At least 10,000 tons ore produced from late 1800s to 1920s
Contact mine	T20S, R22E, SE¼, Sec. 15	Mn, Ag-, Cu-	Tombstone Development Co.	Small amount of Mn ore produced in early 1900s

Table 6-2 (cont.) Production and owners of principal mines in Tombstone mining district

Mine	Location	Mineral Products	Property Owners (dates mostly unknown)	Estimated Production
Contention-Grand Central mine group (Head Center, Flora Morrison, Tranquility, Pump Shaft, Yellow Jacket)	T20S, R22E, SE¼ Sec. 11, NE¼ Sec. 14	Ag, Au, Pb, Cu-, Zn-	Western Mining Co., Grand Central Mining Co., Tombstone Mill & Mining Co., Head Center Co., Head Center & Tranquility Co., Contention Mining Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Co., Tombstone Development Co.	Over $10,000,000 produced prior to 1886 and several hundred thousand tons produced from 1880s to early 1900s. Some sporadic production up to 1929. Additional production from open pit 1970s-80s rumoured to be $15 million
Defense mine	T20S, R22E, S. Cen. Sec. 11	Ag, Pb, Au-	Tombstone Mill & Mining Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Co., Tombstone Development Co.	A few thousand tons of ore produced
Dry Hill mine	T20S, R22E, SW¼, Sec. 15	Ag, Mn, Cu-, Au-	Tombstone Development Co.	Up to 10,000 tons Mn-Ag ore produced late 1800s to about 1937
Eagle Roost mine	T20S, R22E, NE¼, Sec. 23	Mn, Ag	-	Small tonnage produced prior to 1957
East Side mine (East Side, East Side No. 2)	T20S, R22E, NW¼, Sec. 14	Ag, Mn, Pb-, Au-	Tombstone Mill & Mining Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Co., Tombstone Development Co.	A few thousand tons ore produced in early 1900s
Emerald & Silver Plume mine group	T20S, R22E, NW¼, Sec. 23	Pb, Zn, Ag, Au, Cu-, Mo-	Grand Central Mining Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Co., Tombstone Development Co.	Up to 40,000 tons ore produced in 1880s and smaller amounts produced intermittently up to 1928
Empire mine	T20S, R22E, E. Cen. Sec. 11	Ag, Pb, Cu-, Zn-, Mo-	Tombstone Mill & Mining Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Co., Tombstone Development Co.	Over 10,000 tons of ore produced in late 1800s, but output included with adjoining mines
Florida mine group	T20S, R22E, Cen. Sec. 32	Mn	-	Small amount Mn ore produced around 1954
Free Coinage mine	T20S, R22E S. Center Sec. 9 N. Center Sec 16	Ag, Au, Mn-	Mellgren Mining	500 tons of ore produced intermittently since 1890s, mainly 1920-1922.
Gallagher Vanadium & Rare Minerals Corporation mine (Bradsher, Stella, Vogel, Buena Vista)	T20S, R21E, SE¼, Sec. 36	Pb-,m V-, Ag-, Au-, Cu-	Gallagher Vanadium & Rare Minerals Corporation	Some 670 tons ore produced mainly in 1952

Table 6-2 (cont.) Production and owners of principal mines in Tombstone mining district

Mine	Location	Mineral Products	Property Owners (dates mostly unknown)	Estimated Production
Galvez mine (Wolcott)	T20S, R22E, SW¼, Sec. 22	Pb, Cu, Ag, Au	-	About 695 tons of ore produced in 1911
Girard mine	T20S, R22E, Cen. Sec. 11	Ag, Pb	Girard Mining Co., Tombstone Mill & Mining Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Co., Tombstone Development Co.	Several thousand tons ore produced in late 1880s
Goodenough mine (Combination, No. 6)	T20S, R22E, NE¼, Sec. 11	Ag, Pb, Au-	Tombstone Mill & Mining Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Co., Tombstone Development Co.	Up to 100,000 tons of ore produced, mainly from 1884-1896
Ground Hog mine	T20S, R22E SW ¼ Sec. 22	Ag	Wallace S. Eavenson and Associates (1950s)	Produced ore in the late 1880s and in 1935.
Hawk Eye mine (Little Wonder)	T20S, R22E, E. Cen. Sec. 11	Ag, Pb, Au-	-	Several thousand tons ore produced in early 1900s
Herschel mine	T20S, R22E, SW¼, Sec. 11	Ag, Pb, Au-, Mn-	Herschel Mining Co.	Some 5,000 tons ore produced mainly between 1905 and 1935
Ingersol mine (Bob Ingersol, Blue Monday)	T20S, R22E, SW ¼, Sec. 11	Pb, Ag, Zn, Au, Cu-, Mn-, (Cd)	Hearst-Hagen Estate, VMP Leasing Co.	Several thousand tons ore produced in 1880s and a few thousand intermittently from 1918-1932
Intervener mine (Silver Bill)	T20S, R22E, Cen. Sec. 11	Ag, Pb, Au-	Costello, Giacoma Bros.	Small sporadic production in late 1800s and early 1900s and a few hundred tons in the 1940s
Luck Sure mine	T20S, R22E, NW¼, Sec. 14	Ag, Mn, Au-, Pb-	Old Glory Mining Co., Bunker Hill Mines Co., Tombstone Development Co.	A few thousand tons of Mn smelter flux produced in 1881 - 1884, and some 1600 tons in 1905-1906
Lucky Cuss mine (Escondido, McCann, Wedge)	T20S, R22E, NW¼, Sec. 14	Ag, Mn, Au-, Pb-	Tombstone Mill & Mining Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Co., Tombstone Development Co.	At least 100,000 tons ore produced since 1880s
Mamie mine	T20S, R22E E. Cen. Sec. 11	Ag	Mellgren Mining Tombstone Silver Fields Co.	Several hundred tons produced intermittently in the late 1800s and during the 1920s and 1930s.

Table 6-2 (cont.) Production and owners of principal mines in Tombstone mining district

Mine	Location	Mineral Products	Property Owners (dates mostly unknown)	Estimated Production
Manganese Silver mine	T20S, R22E, N. Cen. Sec. 23	Cu, Ag, Au-, Mn-	-	Some 60 tons ore produced 1941-1942
Merrimac mine	T20S,R22E, S. Cen. Sec. 9	Ag, Au	Tombstone Silver Fields Co.	A few hundred tons of ore produced sporadically between the 1880s and 1930s.
Montezuma mine	T20S, R22E, SW¼, Sec. 17	Ag, Au	-	A few hundred tons ore produced during late 1880s
Morning Star mine	T20S, R22E, Cen. Border Sec. 13-14	Pb, Ag, Au, Cu-	-	About 100 tons ore produced in late 1930s and early 1940s
Mustang mine (Escapule)	T20S, R22E, W. Cen. Sec. 30	Pb, Ag	-	About 114 tons of ore produced in 1942-1943
Old Guard mine (Royal Guard)	T20S., R22E, SW¼, Sec. 11	Ag, Au-, Pb-, Mn-	Old Guard Mining Co., Imperial Guard Mining Co., Silver Bar Mining Co., Tombstone Silver Fields Mining Co.	Some 2,000 tons of ore produced intermittently between 1905-1940
Oregon-Prompter mines (Knoxville, Stonewall, Florodoro)	T20S, R22E, S. Border, Sec. 14-15	Ag, Mn, Au-	Boston & Arizona Smelting & Reduction Co., Tombstone Development Co.	A few tens of thousands of tons of ore produced at irregular intervals from 1883-1950
Owl's Nest mine	T20S, R22E, NW¼, Sec. 14	Ag, Pb	-	Some production in the 1880s
Plain View mine (Escapule)	T20S, R22E., S. Cen., Sec. 14	Mn, Ag	-	Some Ag ore produced in the 1880s and about 50 tons Mn ore in the 1950s
Randolph mine (Mellgren group)	T20S, R22E, SE ¼ Sec .16	Ag	Mellgren Mining Tombstone Silver Fields Co.	A few hundred tons produced intermittently from 1880s to 1917
Rattling Boy & Sidewheel mines	T20S., R22E, SE¼, Sec. 16	Ag	Tombstone Silver Fields Co.	A few hundred tons produced intermittently from 1880s to 1917
Rocky Bar mine	T20S, R22E, SW¼, Sec. 15	Mn, Ag, Cu-, Au-	-	A few hundred tons ore produced in the 1880s and about 530 tons in 1920-1924
Sailor mine	T20S, R22E, SE¼, Sec. 16	Ag	-	A few hundred tons ore produced during 1880s and 1890s

Table 6-2 (cont.) Production and owners of principal mines in Tombstone mining district

Mine	Location	Mineral Products	Property Owners (dates mostly unknown)	Estimated Production
San Pedro mine	T20S, R22E, SE ¼ Sec. 8	Au, Au, Mn, Cu-	San Pedro Leasing Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Company, San Pedro Leasing Co., Mellgren Mining	Several thousand tons of ore produced in the 1880s and 1890s. A sporadic production of about 2,900 tons from 1936 to 1950
Silver Thread mine	T20S, R22E, W. Cen. Sec. 12	Pb, Ag, Zn, Au (As, Cd, Sb)	Tombstone Mill & Mining Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Co., Tombstone Development Co.	A few thousand tons ore produced in the late 1880s and a few hundred tons in the 1920s
Soltice mine (Mellgren group)	T20S, R22E, SE ¼ Sec. 9	Ag, Pb, Cu-, Au-	Mellgren Mining, Soltice Mining & Milling Co., Tombstone Silver Fields Co.	Some 425 tons or ore produced intermittently from 1911 to 1940
State of Maine mine	T20S,R22E, W. Cen. Sec. 16	Ag, Au, Mn, Cu, Pb	Grand Central Mining Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Company, San Pedro Leasing Co., Escapule family & W.W. Grace	Some 30,000 tons of ore produced during the 1880s and a few hundred tons intermittently since then
Sulphuret mine	T20S, R22E, SE¼ Sec. 11	Ag, Pb, Zn, Au, Cu-	Contention Mining Co., Western Mining Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Co., Tombstone Development Co.	Some 20,000 tons ore produced, mainly in the early 1900s
Sunset mine	T20S., R22E, SW¼, Sec. 15	Ag, Pb, Mn, Cu-, Au-	-	A few tons of high grade silver ore produced in early 1880s and some 400 tons ore intermittently from 1921 to 1927
Telephone mine	T20S, R22E, Cen. Sec. 14	Ag, Mn	-	A few hundred tons produced in late 1800s
Tombstone Extension mines (Carper, San Diego, La Grande)	T20S, R22E, E. Cen. Sec. 13	Pb, Ag, Au, Cu-	Woronoco Co., Tombstone Mining Co., American Smelting & Refining Co.	Some intermittent production in early 1900s and over 40,000 tons ore produced from 1930 through 1954
Toughnut mine (Northwest, Hoodoo stopes)	T20S, R22E, Cen. Sec. 11	Pb, Ag, Zn-, Cu-, Au- (Cd)	Tombstone Mill & Mining Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Co., Tombstone Development Co.	Several thousand tons produced in late 1800s and early 1900s
Tribute mine	T20S, R22E., S. Cen. Sec. 11	Pb, Ag, Au, Cu-, Mo-	Tombstone Mill & Mining Co., Tombstone Consolidated Mines Co., Bunker Hill Mines Co., Tombstone Development Co.	Several hundred tons ore produced in 1880s and a small tonnage intermittently since then

Table 6-2 Production and owners of principal mines in Tombstone mining district (cont.)

Mine	Location	Mineral Products	Property Owners (dates mostly unknown)	Estimated Production
Vizina mine	T20S, R22E, N. Cen. Sec. 11	Ag, Pb, Au-	Vizina Consolidated Mining Co.	Over 10,000 tons ore produced in late 1800s
Way Up mine	T20S, R22E, NE¼, Sec. 11	Ag, Pb, Au-	Tombstone Development Co.	Over 550 tons ore produced in the 1880s
West Side mine	T20S, R22E, NE¼, Sec. 11	Pb, Ag, Au	-	Several tens of thousands of tons of ore produced, mainly in the late 1880s and early 1900s

Source: Keith (1973); table prepared by SRK Consulting
Note: - = No available data

Table 6-3 Production history, Tombstone mining district

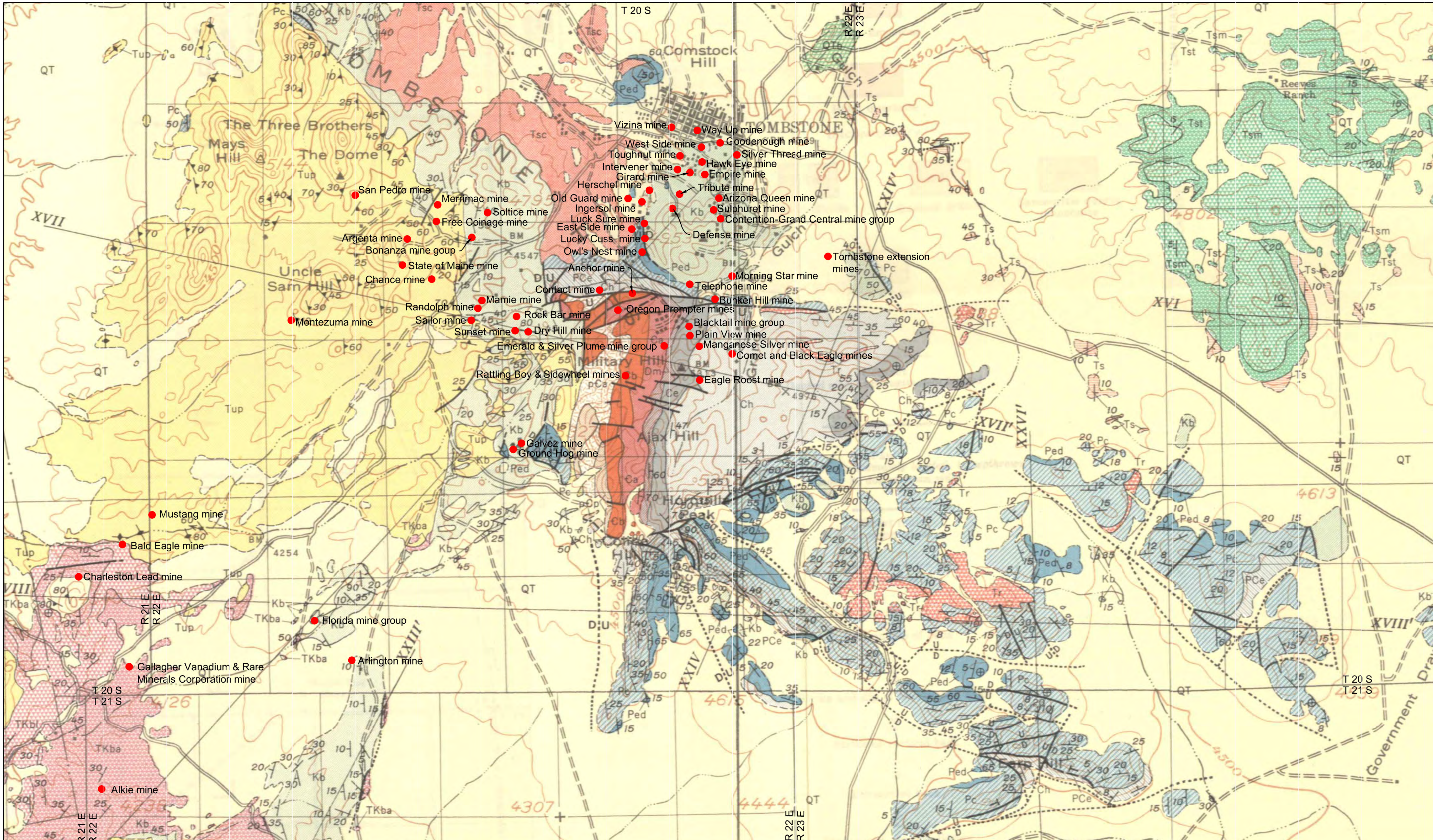
Period	Price of Silver (USD)	Production	Remarks
1877–80	1.15 – 1.20	$2,318,567	Discovery and early development. Mills built on San Pedro River.
1881–86	0.99 – 1.14	16,877,175	Active development and large production. Water encountered in mines in 1882, and mills built at Tombstone.
1887–96	0.63 – 1.05	4,564,650	Decreased production due to depletion of many of the large ore bodies above water level.
1897–1911	0.52 – 0.68	5,575,900	Consolidation of principal properties and attempted de-watering of district by a 1,000-foot pump shaft.
1912–14	0.553 – 0.615	379,917	Lessee operations.
1915–17	0.507 – 0.824	1,117,687	War period. Considerable production of manganiferous silver ore and concentrates.
1918–32	0.282 – 1.12	5,150,789	Mainly lessee operations. Production of silver during 1918 –22 stimulated by Pittman Act.
1933–36	0.35 – 0.77	1,118,325	Production stimulated by increased price of gold and silver.

Source: Butler and others, 1938, p. 39

Table 6-4 Estimated mine production, Tombstone district

Mineral System/ Synonym (Mineral Zone)	Model[2]	Production Period (years)	Ore (short tons)	Au (oz)	Ag (oz)	Cu (lb)	Pb (lb)	Zn (lb)
Argenta	24JB	1922-1924	184	10	3,539	1,225	206	
Bunker Hill	24JD	1889-1931	382,330	32,404	4,407,706	2,963,902	7,461,919	45,192
Contention	25H	1880-1885	98,252		5,240,721			
Contention/ Grand Central	24JC	1881-1950	306,090	7,815	5,377,798	286,771	6,345,686	
Galvez	24JC	1910-1924	295	81	4,382	2,149	1,796,733	
Good Enough	24JC	1884-1913	174,603	7,560	5,367,114	21,109	1,560,100	
Herschel	24JC	1905-1935	11,430	2,060	320,085	48,068	1,167,270	
Ingersol	24JC	1922-1932	1,359	378	39,273	11,689	227,393	
Lucksure	24JD	1905-1918	2,324		24,817	1,445		
Old Guard	24JC, 24JD	1905-1935	2,644	383	59,516	61,574	186,887	
Rocky Bar	24JD	1920-1924	510	7	17,954	2,497	91	
Soltice	24JC	1914-1940	475	107	20,761	841	133,865	
State of Maine		1921-1950	30,343	9	104,696		2,667	
Sunset	24JD	1919-1927	419	3	11,443	5,644	10,458	
Tombstone Extension	24JC	1930-1954	26,680	1,308	222,106	90,930	14,304,882	
Tombstone Group	24JC	1903-1957	451,927	64,302	4,907,169	3,879,915	13,566,470	214,517
Toughnut-Empire	24JC	1879-1936	108,697	4,006	4,260,112	32,850	1,222,400	
Vizina	25H	1880-1891	12,726		517,079			
Tombstone (combined)[1]	24J		2,677,138	240,844	25,926,156	5,354,277	107,085,538	2,141,711
Tombstone (combined)	24J	1879-1981	2,953,296	131,468	32,076,966	7,763,447	49,854,350	555,527

[1]Source: Singer (1993)
[2] Model numbers are explained in Table 9-2
Source: Keith (2000)



0 .5 1 1.5 2 2.5
Scale in Kilometers

GENERAL NOTES

1. GUILLULY AND KEITH 1993 MAP SCALED AND PLACED BY SRK USING USGS 7½ MINUTE QUADRANGLE MAPS: UTM ZONE 12 PROJECTION, NAD 27 DATUM, METERS. THIS MAP IS FOR ILLUSTRATIVE PURPOSES ONLY. SCALE AND LOCATIONS ARE APPROXIMATE.

REFERENCES

1. GEOLOGY MAP OF PARTS OF THE BENSON AND PEARCE QUADRANGLES, ARIZONA, USGS (1948): GEOLOGY BY JAMES GILLULY, R.S. CANNON, JR., W.B. MYERS, S.C. CREASEY, F.S. SIMONS, J.H. WIESE AND EDGAR BOWLES, 1936-1947
2. MINE LOCATIONS FROM KEITH, 1973.

srk consulting

LIBERTY STAR URANIUM & METALS CORP.

Tombstone, Arizona

General location of mines in the Tombstone district

SRK JOB NO.: 173300.03 Task 600	Internal Control Number 3	Hay Mountain Exploration Report
FILE NAME: 6-1 GENERAL LOCATION OF MINES IN THE TOMBSTONE DISTRICT		

DATE:	APPROVED:	FIGURE:	REVISION NO.
June 2011	JR	6-1	1

7 Geological Setting (Item 9)

The regional geology of southern Arizona (Figure 7-1) and local Tombstone district geology are discussed in this section. The Ag mineralization is related to a 74 Ma Early Laramide caldera system and associated structural activity. The Cu mineralization is thought to be related to a 63 Ma Late Laramide rhyolite and associated Comstock quartz monzonite porphyry that took advantage of the faults and other structures related to the collapse of the earlier caldera system.

The geologic setting of southern Arizona can best be understood in the context of the plate tectonic setting of the southwestern United States. Numerous orogenic (mountain building) episodes that generated mineralization (Table 7-1) were driven by the position of the area on the leading edge of a continent that was subjected to volcanism and plutonism that rose from the plate that was being subducted under the advancing continent.

The ages of rocks in the Tombstone Hills range from Proterozoic (Late Precambrian) to Quaternary. They consist of schist, granite, limestone, dolomite, shale, sandstone, and conglomerate of Precambrian through Mesozoic age, and younger granodiorite, tuff or rhyolite sills, plugs and dikes, andesite dikes, basin fill, and a basalt plug. The stratigraphic sequence and formation characteristics are provided in Figure 7-2. Drewes (1980) mapped the detailed geology of central Cochise County (Figure 7-3) and Gilluly (1956) mapped the detailed geology of the Tombstone Hills (Figure 7-4 and the explanation in Figure 7-5).

7.1 Precambrian (1,800 - 542 Ma)

The Proterozoic (Late Precambrian) rocks exposed in the vicinity of Tombstone consist of the Pinal Schist and a granodiorite intrusive rock. The Precambrian rocks are unconformably overlain by sedimentary units of Paleozoic age.

The oldest Precambrian rocks in southeastern Arizona are represented by fine-grained, greenish-gray Pinal Schist (approximately 1,700 Ma) and unnamed granitic rocks (1,625 Ma or 1,400 Ma). Precambrian rocks are exposed locally in a north-south elongate window in younger sediments and volcanic rocks in the south-central part of the Tombstone district. The Pinal Schist is exposed in the Tombstone Hills in an area near Ajax Hill. The rock is a dark greenish gray to brownish gray, moderately to well foliated, fine-grained, quartz sericite schist. Foliation within the schist trends northeast and dips about 60° E. Although Gilluly (1956) proposed that the schist is at least several thousand feet thick, only 150 to 200 ft crop out at Tombstone. The schist was intruded by an unnamed Precambrian granitic rock.

The Pinal Schist in the nearby Dragoon quadrangle consists of a thick section (8,200 to 20,000 ft) of graywacke–slate sequences containing graded bedding, abundant volcanic debris, and intercalated volcanic flows (Cooper and Silver, 1964). The Pinal Schist in the nearby Little Dragoon Mountains was dated at 1,695 ± 15 Ma (Silver, 1967). This is consistent with the regional age range of the Pinal Schist in southern Arizona from approximately 1,710 to 1,675 Ma (Silver, 1978).

Throughout southeastern Arizona, the Pinal Schist was intruded by a granodiorite of the Mazatzal orogeny, which was active between 1,675 and 1,625 Ma (Conway and Silver, 1989). In the nearby Johnny Lyon Hills, the Pinal Schist was intruded by the Johnny Lyon Granodiorite, which was dated at 1,625 ± 10 Ma (Silver and Deutsch, 1963; Silver, 1978). In the Tombstone Hills, an unnamed Precambrian granitic rock is exposed immediately west of Ajax Hill. It has been called a granodiorite or albite granite by different investigators. The granodiorite is a pinkish gray to light gray, medium-grained biotite granite with gneissic texture.

The earlier Precambrian rocks of Arizona were intruded by granites that are usually described as “anorogenic” (Anderson, 1989). These granites are characterized by large K-feldspar (orthoclase) crystals in a porphyritic texture. The Tungsten King Granite in the nearby Little Dragoon Mountains was dated at 1,420 ± 10 Ma (Silver, 1978). This episode of magmatism and tectonics is important to the Laramide porphyry copper mineralization throughout Arizona because of the imposed structurally weak zones in a west-northwest (WNW) to west direction that was used by the Laramide mineralization. These WNW-striking zones were characterized by left-slip displacements in the Texas Zone (Swan and Keith, 1986). A subordinate set of northeast-striking shear zones may have developed at the same time in the Precambrian. Both these Precambrian directions of structural weakness were used by the mineralizing solutions in the Tombstone district.

The Middle Proterozoic rocks of the Apache Group of central Arizona crop out in the nearby Little Dragoon Mountains, although they do not crop out in the Tombstone district. The diabase that intruded the Apache Group was dated at 1,120 ± 10 Ma in the Little Dragoon Mountains (Silver, 1978).

After a long period of erosion, both the Pinal Schist and Precambrian granitic rocks were buried beneath the Bolsa Quartzite of Cambrian age.

7.2 Paleozoic Passive Margin (542-251.5 Ma)

Arizona was on the trailing edge of the North American continent during the Paleozoic, and therefore experienced passive margin or miogeoclinal sedimentation of sandstone, shale, and limestone. The plate tectonic regime during the Paleozoic involved the North American plate moving eastward over a westward-subducting plate in at least three main orogenies with active volcanism along the east coast. These included the Taconic orogeny (490-445 Ma), the Acadian (or Caledonian) orogeny (410-380 Ma), and the Alleghenian (or Ouachita) orogeny (325-220 Ma) (Janke, 2010).

The principal effect of these orogenies on southern Arizona was in the nature of the sediments being shed from the continental areas in the east and the incursions of shallow seaways from the west, which resulted in the deposition of limestone. Characteristics of Paleozoic formations in southeastern Arizona are summarized in Bryant (1968) and in the Tombstone Hills by Gilluly (1956). Limestone is generally reactive to hydrothermal solutions and, in the Tombstone Hills, was instrumental in trapping mineralized solutions. Throughout southern Arizona, the lower Paleozoic formations generally contain the richer primary Cu mineralization.

The Bolsa Quartzite (Middle Cambrian [~521-499 Ma]) crops out south of Tombstone, on and near Ajax Hill. The Bolsa Quartzite is pale orange on a fresh surface to light brown on a weathered surface. It unconformably overlies the Pinal Schist and the Precambrian granitic rock. The major part of the unit consists of thick- to very thick-bedded, medium- to very coarse-grained, slightly cross-bedded quartzite.

The Abrigo Formation (Middle to Upper Cambrian [~515-488 Ma]) crops out south of Tombstone in the valley east of Ajax Hill. The Abrigo Formation is notable for its grayish olive-green to dark greenish gray limestone with worm borings and conspicuous thin beds of conglomerates. The basal unit consists of 400 ft of interbedded shale, limestone, and conglomerates. The central 150 ft consists of thin- to very thin-bedded crystalline limestone. The upper 300 ft consists of medium- to thick-bedded sandy limestone that is frequently cross-bedded. A 2-ft thick bed of quartzite marks the top of the Abrigo.

The Martin Formation (Late Devonian [~386-375 Ma]) is exposed in the valley between Ajax Hill and Military Hill. The rocks are typically dark gray to brownish black and consist of chert, limestone, sandstone, and shale. In the Tombstone Hills, more than half the Martin Formation is represented by sandstone and shale. The upper and lower surfaces are disconformities and the upper contact with the Escabrosa Limestone is arbitrarily placed where the color changes from dark gray to light gray.

The Escabrosa Limestone (Early Mississippian [~353-340 Ma]) is a cliff-former and forms a major 2-mile long ridge through Military Hill. It crops out east of Military Hill and along SR 80, about 2.5

mi southeast of Tombstone. The massive lower beds commonly form prominent cliffs and the higher beds typically form dip slopes. Two chert horizons exist in the formation. The lower zone, 250 ft above the base, consists of dark gray to black beds that are 1–6 inches thick. The second zone, about 550 ft above the base, consists of brown nodules that are about 6 inches thick. Fossil crinoid fragments, corals, and brachiopods are abundant.

The Naco Group (Pennsylvanian - Permian) consists of the Horquilla Limestone, Earp Formation, Colina Limestone, Epitaph Dolomite, Scherrer Formation, and Concha Limestone in the Tombstone Hills (Gilluly and others, 1954). The maximum thickness of the Naco Group exceeds 3,250 ft, but its original thickness is unknown because the upper limit is an erosion surface.

The Horquilla Limestone (Middle to Late Pennsylvanian [318-299 Ma]) consists of thin-bedded, blue-gray limestones alternating with thin beds of red shale and shaly limestone. Its weathered appearance from a distance looks like steps. The maximum thickness is 1,000 ft and the formation crops out about 1 mile southeast of Ajax Hill.

Earp Formation (Late Pennsylvanian [~302-283 Ma]) consists of thin shaly limestones, reddish shales, thick limestone, and dolomite beds that weather orange or reddish. The maximum thickness is 1,000 ft. The Earp Formation crops out along a prominent northwest-striking ridge about 2 mi southeast of Ajax Hill and it is also present north of the Prompter fault, near the Prompter and Oregon mines.

The Colina Limestone (late Early Permian [~283-277 Ma]) consists of dense, black limestone with some major beds of shale and sandstone. The Colina Limestone often contains small fossil snail shells and has a maximum thickness of 635 ft. The Colina Limestone crops out along the east-striking Colina Ridge, about 2 mi south of Ajax Hill (Wilt, 1969).

The Epitaph Dolomite (late Early Permian [~279-275 Ma]) consists of dolomite with knots of silica, limestone, red shale, thin sandy layers. The maximum thickness of the Epitaph Dolomite is 785 ft, although the thickness varies as dolomitization of the Colina units are included in the Epitaph. It crops out at several localities on the dip slope of Colina Ridge and along State Route (SR) 80, in outcrops south of the Lucky Cuss mine and on Comstock Hill at the northwest edge of Tombstone (Patch, 1969, 1973).

The Scherrer Formation (late Early Permian [~275-272 Ma]) consists of three units from bottom to top: red siltstone, dolomitic limestone, and massive sandstone. Its maximum thickness is 660 ft. The Scherrer Formation crops out on two small hills about 1.5 mi northwest of the Schieffelin Monument.

The Concha Formation (late Early Permian [~272-270 Ma]) consists of light gray cherty limestone with some sand layers at base. Its maximum thickness is 125 ft. The Concha Formation crops out at four sites within about 1 mile of the Schieffelin Monument.

After the major continent-continent collision of North America, Europe, and Africa created the supercontinent Pangea and the Appalachian-Ouachita Mountains, the tectonic plates were forced to reorganize. As Pangea began to split apart, separating the eastern North American plate apart from Africa, the western coast of North America became the leading edge of the northwestward moving North American continent. The resulting subduction of the northeast-dipping Farallon oceanic plate under the North American plate caused volcanism and accompanying mineralization throughout the western U.S. In the Tombstone area, rocks of the Naco Group are unconformably overlain by Bisbee Group rocks of Cretaceous age and are cut by numerous Mesozoic volcanic and plutonic rocks.

7.3 Jurassic Nevadan Orogeny (205-145 Ma)

The first sedimentary and volcanic rocks of the Jurassic Nevadan orogeny were deposited in western Arizona at approximately 205 Ma (Tosdal and others, 1989). In southeastern Arizona, plutonic rocks of quartz alkalic magma chemistry are known from Bisbee (Warren mining district) and from the Courtland-Gleeson area (Turquoise mining district) (Keith and others, 1983), both of which are within 35 mi of Tombstone.

The porphyry Cu-Au mineralization at Bisbee is associated with the Sacramento stock, dated at approximately 190 Ma. The Juniper Flat granite north of Bisbee was emplaced at 171 ± 7 Ma (Marvin and others, 1973) or 182 ± 2 Ma (Creasey and Kistler, 1962). The Gleeson Quartz Monzonite in the Dragoon Mountains was emplaced at about the same time (185 ± 4 Ma by Marvin and Cole, 1978; or 183 ± 5 Ma by Marvin and others, 1973, 1978). Rocks of this age have not been identified in the Tombstone mining district, although structures probably were active at this time and created some of the plumbing system for the later mineralizing solutions.

7.3.1 Rocks of the Nevadan Orogeny at Tombstone

In the Tombstone Hills, the Naco Group sedimentary rocks were intruded by a few dikes and sheets of quartz-rich porphyry that are now generally decomposed. The dikes were probably erupted prior to deposition of the Mesozoic sedimentary rocks. Butler and others (1938) characterized these rocks as rhyolite porphyry and stated that they appear to have no connection with ore deposition.

Triassic and Jurassic rocks are mostly missing in the Tombstone district, although the basal Bisbee Group conglomerate may be correlated with the Jurassic part of the Glance Conglomerate. The Glance Conglomerate records a major tectonic episode in southeastern Arizona during the Middle to Late Jurassic. A volcanic unit in the northern Canelo Hills that is intercalated with the Glance Conglomerate was dated at 151 ± 2 Ma (Kluth and others, 1982). The change in thickness and composition of the Glance Conglomerate across major northwest- and west-striking normal faults records a major uplift and extension event near the end of the Nevadan orogeny. For example, in the nearby Mule Mountains at Bisbee, north of the Dividend fault, the Glance is thin (100 ft) and composed of clasts of underlying Juniper Flat Granite or Pinal Schist. South of the Abrigo-Bisbee-West faults at Bisbee, the Glance is up to 3,300 ft thick and is composed of clasts from the entire Paleozoic section (Bilodeau, 1978).

In the Tombstone Hills, the Glance Conglomerate is included in the basal part of the Bisbee Group. The base of the Bisbee Group in the Tombstone area consists of conglomerate beds that are 55 to 70 ft thick and that contain pebbles and cobbles from the Naco, Escabrosa, Abrigo, and Bolsa units. This basal unit has been correlated with the Glance Conglomerate. Early miners called this unit Novaculite, as it was metamorphosed shale and calcareous sandstone that was similar to a novaculite (fine-grained siliceous rock).

7.3.2 Structures of the Nevadan Orogeny at Tombstone

The west-striking structures in the Tombstone Hills that were inherited from the Precambrian, mainly the Texas Zone elements, were active during the Nevadan orogeny. These faults included the west-striking Prompter fault in the northern part of the district and the Horquilla fault near Horquilla Peak. Evidence for the Nevadan (pre-Bisbee Group) movement on the Prompter fault is that total displacement across the fault is about 4,000 ft, but displacement of the Bisbee Group is only about 2,800 ft (Guilbert, 1993).

Additional west-striking faults that could have experienced normal fault movement into uplifted blocks and down-dropped blocks during the Nevadan orogeny include the Government Butte fault between Tombstone and Bisbee and the west-striking faults at Earp Hill, just north of Government Butte. The widely varying thickness of the Glance Conglomerate in the Bisbee area and other areas was proof of this structural activity (Bilodeau, 1978). These zones of weakness were pathways for the Jurassic-aged Cu-Au mineralization at Bisbee.

7.4 Cretaceous Sevier Orogeny (140-89 Ma)

The stable (non-migrating and non-flattening) magmatic arc of the Sevier orogeny was located in California, with the back arc basins located in Arizona and similar regions east of the magmatic arc. The best documented basin in Arizona is represented by continental and shallow marine sediments of the Bisbee Group and its correlative sedimentary sequences. These sandstones, siltstones, and limestones were deposited in a seaway that transgressed from the southeast, depositing the Mural Limestone in the Bisbee area (Dickinson and others, 1989). In the Tombstone Hills, the Bisbee Group is represented by several thin limestones that host ore and numerous sandstone and siltstone units.

The Bisbee Group is a series of mostly clastic rocks that include maroon mudstone and siltstone, brown to buff sandstone, and a few thin limestone beds containing marine and fresh-water fossils. Force (1996) divided the Bisbee Group rocks in the Tombstone area into a lower unit of mostly sedimentary megabreccia and conglomerate, with lesser basal fossiliferous limestone and interbedded pale argillite, and an upper unit that coarsens upward from mostly argillite to mostly sandstone.

The two most extensive areas of Bisbee Group exposure are the Tombstone Basin, which is south of Tombstone, and an area west of the Ajax Hill fault that is north and east of Uncle Sam Hill and the State of Maine mine. The area south of Tombstone is roughly circular, about 1¼ mi in diameter, and contains many of the principal mines. The area west of the Ajax Hill fault is larger and irregular in shape. It lies between the Uncle Sam Tuff on the west and the Schieffelin Granodiorite and Precambrian and Paleozoic rocks of the Tombstone basin area about 1.5 km to the east. The western area of Bisbee Group rocks contains smaller mines such as the Mamie and Bonanza group. Although a complete section of the Bisbee Group is not exposed in the western area, Force (1996) stated that the lower unit in the western area is at least 500 ft thick and the upper unit is at least 850 ft thick.

The limestones of the lower 128 ft of the Bisbee Group were important for mineral deposition. The lower sequence consists of the Novaculite unit, which is metamorphosed basal Bisbee Group. The Novaculite contains 60 ft of basal shale and limey sandstone with localized limestone conglomerate. Above the Novaculite is the 34-ft thick Blue limestone, 24 ft of shale, and a 10-ft thick bed of limestone (Butler and others, 1938; Gilluly, 1956).

The Bisbee Group of the western area was considered by Lipman and Sawyer (1985) to be the floor of a caldera filled by younger Uncle Sam Tuff, having one margin at the Ajax Hill fault. Force (1996) postulated that the Bisbee Group of the western area may lie between two concentric structural walls of this caldera.

7.5 Cretaceous, Earliest Laramide (85-80 Ma) – Cu-Au Mineralization

Because the subduction zone became flatter throughout the Laramide orogeny (89 – 43 Ma), the magmatic arc migrated eastward through geologic time. Thus, later magmatism and mineralization overprinted the earlier episodes. The Laramide orogeny has been subdivided into three phases: the early, middle, and late phases (Keith and Wilt, 1986).

The earliest phase of the Laramide orogeny (called the Hillsboro Assemblage) in southern Arizona is represented by small stocks of quartz alkalic chemistry, generally latites and monzonites with small volcanic centers. Examples are the Copper Flat stock at Hillsboro in New Mexico and others in western Arizona. The structural features typical of this Hillsboro Assemblage are west- or west-northwest-striking block uplifts along high-angle reverse faults.

The Government Butte uplift south of Tombstone may be an example of this tectonism, although it may have also experienced movement during the Nevadan orogeny. It is bounded on the south by north-dipping to vertical faults with reverse separation that push Paleozoic rocks southward over Bisbee Group strata of the northern Mule Mountains.

Evidence for this north-south compression of Gilluly (1956) exists in the western end of the Tombstone Hills in the Bronco Hill area (also called Brunckow Hill), where the east-striking Bisbee Group is angularly overlain by Bronco Volcanics. This north-south compression event of Gilluly (1956) is equivalent to the early Late Cretaceous disturbance of Hayes (1970). The structural development of the Hillsboro Assemblage was mainly by reverse slip on pre-existing elements of the west-northwest-striking Texas zone of Proterozoic age. Folding of the Bisbee Group in the central portion of the Tombstone district into the east-west-striking Tombstone basin is an example of this north-south compression event. Fold trends are cut by the Schieffelin Granodiorite. There are isoclinal folds in basal Bisbee Group sediments north of the Uncle Sam shaft in the State of Maine area (Briscoe, 1973). East-striking beds and folds in the Horquilla Limestone indicate a period of probably reverse movement possibly associated with this episode of north-south compression (Keith and Wilt, 1978).

The Ajax Hill fault also experienced movement before the extrusion of the volcanics in the Tombstone Hills. The Ajax Hill fault is younger than and cuts the Prompter fault. The Ajax Hill fault is older than and is cut by the Schieffelin Granodiorite. The Ajax Hill fault bounds the western margin of the Tombstone Basin.

7.6 Cretaceous, Early Laramide (79-67 Ma) – Pb-Zn-Ag Mineralization

The early Laramide phase is represented by Pb-Zn-Ag mineralization associated with the caldera development of alkali-calcic volcanism and plutonism in southern Arizona. This phase was called the Tombstone Assemblage by Keith and Wilt (1986) and the following description is excerpted from that paper. Age dates on igneous rocks in the Tombstone Hills are shown on Figure 7-6.

7.6.1 Calderas of Early Laramide Orogeny in Southern Arizona

Throughout southern Arizona, the Tombstone Assemblage is characterized by large volcanic centers (calderas) that experienced large volumes of explosive volcanism (Figure 7-7). The basal sedimentary rocks are continental fluvial sandstones and conglomerates containing large exotic blocks ranging in size from cobbles to house-sized boulders of pre-existing rocks and having a volcanic matrix. Examples include the Tucson Mountain Chaos, the Claflin Ranch Formation in the Silver Bell Mountains, the lower Salero Formation in the Santa Rita Mountains, and the Bronco Volcanics in the Tombstone Hills. These sedimentary rocks containing exotic blocks are generally interpreted as caldera infill or moat deposits from the collapse of the volcanic edifice. The basal exotic block member is typically an andesitic to dacitic breccia with a pyroclastic breccia texture. In the Tombstone area, some of these have been mapped as breccia pipes. The unit containing exotic blocks conformably grades upward into dacitic to ignimbritic rhyolitic flows or ash flows. The predominant rock types of the Tombstone Assemblage are the pyroclastic volcanic rocks that are up to 5,000 ft thick.

Numerous areas in southern Arizona contain the roots of this caldera volcanism in the form of monzo-dioritic to quartz monzonitic plutons that are locally associated with Pb-Zn-Ag mineralization. Examples of Tombstone Assemblage plutons include the Josephine Canyon Diorite in the Santa Rita Mountains, the Schieffelin Granodiorite and Uncle Sam Tuff of the Tombstone Hills, and the Silver Bell Dacite in the Silver Bell Mountains. Although some of these have been interpreted either as laccolithic sills emplaced into their volcanic cover or as ash flow sheets, they are clearly related to the caldera volcanism. These igneous rocks plot in the alkali-calcic field of a K_2O

versus (vs) SiO_2 variation diagram and are associated with Pb-Zn-Ag vein and replacement mineralization (Wilt, 1993).

The igneous activity of the Tombstone Assemblage is younger in eastern Arizona than in western Arizona. This indicates the alkali-calcic portion of arc magmatism moved eastward through time, as the subducting Farallon plate became shallower. Tombstone Assemblage magmatism in the vicinity of Tucson is about 80 to 70 Ma, whereas similar magmatism in New Mexico is 70 to 64 Ma. In the Tombstone Hills, the Tombstone Assemblage magmatism is 76 to 72 Ma.

7.6.2 Rocks of Early Laramide (79-67 Ma) at Tombstone

The earliest evidence of early Laramide caldera volcanism at Tombstone is the extrusion of the Bronco Volcanics, which includes the basal Bronco andesite, followed by extrusion of the Bronco rhyolite. The Bronco andesite erupted through the Bisbee Group. Subdued exposures of the Bronco Volcanics crop out at many scattered locations between the Ajax Hill fault and the San Pedro River. Diamond core holes near the Charleston Lead mine indicate thicknesses of between 1,200 and 1,400 ft of the rhyolite ignimbrite. The lower Bronco andesites were extruded as flows, flow breccias, and probable lahars.

The Bronco Volcanics are overlain by rhyolitic tuffs and flows. The Bronco rhyolite cuts the andesite, immediately north of the Charleston Lead mine. The Bronco rhyolite, which is composed of tuffaceous beds and flows, crops out between Charleston and the Charleston Lead mine. It has a minimum thickness of 900 ft. The Bronco rhyolite is slightly more resistant to erosion than the andesite and forms low hills and gentle slopes. It has been intruded by the Uncle Sam Tuff, and thus is older than 72 Ma. Briscoe (1988) suggested that the upper rhyolites, at least in part, may be a series of coalescing rhyolite domes, as they exhibit contorted flow and, in places, flow breccia structures (Guilbert, 1993).

The north-striking andesite porphyry dikes may have been intruded next, as the dikes cut folds within the Bisbee Group. The dikes occur in sedimentary rocks which contain the Schieffelin Granodiorite at depth, but the dikes do not cut the Schieffelin Granodiorite.

Next, there may have been renewed movement along the Prompter fault, as the Prompter fault cuts andesite porphyry dikes. The Prompter fault offsets the Ajax Hill fault, so also has later movement.

The main pulse of caldera volcanism is recorded in the intrusion of the Schieffelin Granodiorite and emplacement and extrusion of the co-magmatic Uncle Sam Tuff. The Schieffelin Granodiorite was dated at 72 Ma (Creasey and Kistler, 1962). The Uncle Sam Tuff is younger than the Bronco Volcanics, because the Uncle Sam Tuff cuts the Bronco Volcanics in Sec. 28, T20S, R22E, and Sec. 25, T20S, R21E. Although the Uncle Sam Tuff is more siliceous than the Schieffelin Granodiorite, a potassium-argon date (71.9 ± 2.4 Ma, Drewes, 1971) on the Uncle Sam Tuff indicates it is the same age as the Schieffelin Granodiorite. The Uncle Sam Tuff follows the Ajax Hill fault and the Schieffelin Granodiorite intrudes the Ajax Hill fault.

The Schieffelin Granodiorite and the Uncle Sam Tuff also intruded sandstone and shale of the Bisbee Group west of Ajax Hills. The Schieffelin Granodiorite, which is exposed over an area about 2 mi wide, was described as a stock-like body that caused contact metamorphism as a result of its intrusion and solidification (Butler and others, 1938). The Schieffelin Granodiorite is intrusive into all of the older rocks with which it is in contact. Limestone beds of the Naco Group have been recrystallized to marble. Farther west the granodiorite intruded and cut off the Ajax Hill fault.

The Uncle Sam Tuff has been variously described as a quartz latite, rhyolite, and tuff. It has a dacitic composition and a porphyritic texture (Force, 1996). Newell (1974) proposed the Uncle Sam Tuff and Schieffelin Granodiorite are related co-magmatically, the Uncle Sam Tuff being a later differentiate of the same magma that formed the Schieffelin Granodiorite. Force (1996) presented abundant evidence that the Uncle Sam Tuff and Schieffelin Granodiorite are broadly coeval and are closely related. The Schieffelin Granodiorite and the Uncle Sam Tuff are exposed in the western and southern part of the district, and granodiorite dikes are found throughout the central part of the district. The intrusive rocks are cut by dikes of hornblende andesite.

The Uncle Sam Tuff invaded upper Naco Group and lower Cretaceous units east of Bronco Hill. In turn, the Uncle Sam Tuff was intruded by the rhyodacite west of Ajax Hill and by numerous hornblende andesite dikes between Charleston and the State of Maine mine. West of Ajax Hill, the Uncle Sam Tuff was observed to be in both cross-cutting and flow relations with Bisbee Group rocks. In other areas (Sec. 29, T20S, R22E and west of the San Pedro River), small intrusive breccia bodies in the Uncle Sam Tuff were mapped by Newell and Gilluly (Newell, 1974). However, mapping by Briscoe indicated that these were exotic blocks that had fallen into the caldera tuff deposits.

The extrusion of the Uncle Sam Tuff over the Bronco Volcanics probably started from the area of the Bronco Hills. This resulted in partial evacuation of the underlying magma chamber and caldera collapse, with later resurgent extrusion of more quartz latite tuffs (Briscoe, 1988). The Ajax fault, with some 5,280 ft of stratigraphic throw, formed the eastern margin of the caldera, and probably localized some of the 'Uncle Sam' vents, as well as later intrusive rocks (Figure 7-8). Apophyses of the parent magma intruded along the northeasterly portion of the caldera, forming the present outcrops of Schieffelin Granodiorite southwest of Tombstone. Additional apophyses of Schieffelin Granodiorite intruded along the caldera margin at Bronco Hill, near Fairbank, and on the west side of the San Pedro River on the Ft. Huachuca Military Reservation. These probable intrusions are thought to be the source of aeromagnetic anomalies. The Prompter and Horquilla faults may, in part, be radiating tension fractures due to doming before the extrusion of the Uncle Sam Tuff. Several episodes of explosive eruption are indicated by multiple cooling units of Uncle Sam Tuff, that are best exposed in the Charleston area (Guilbert, 1993).

The Uncle Sam Tuff cuts the Bronco andesite (center Sec. 28, T20S, R22E). The Uncle Sam Tuff intrudes the Ajax Hill fault. The Ajax Hill fault is not in contact with the Bronco Volcanics, and the possibility exists that these volcanics predate the Ajax Hill fault. The Ajax Hill fault cuts the Prompter fault and is cut by the Schieffelin Granodiorite.

After the caldera resurgence, quartz latite porphyry was emplaced. It cuts the Bronco Volcanics and is compositionally very similar to the Uncle Sam Tuff and may be an equivalent. However, textural evidence suggests that the quartz latite porphyry did not vent to the surface.

Steeply dipping porphyry dikes that strike about N30°E cut the Uncle Sam Tuff, the Schieffelin Granodiorite, and their contacts with the Bisbee Group. The dikes appear to closely postdate the Uncle Sam Tuff and the Schieffelin Granodiorite. The andesite porphyry dikes in the central part of the Tombstone district consist of five major dikes of granodioritic to dioritic composition with a general strike of N12°E. From east to west, the dikes are named the Michigan Central, the Grand Central-Contention-Empire, the Sulphuret, the Boss, and the Tribute. The dike rock consists of about 30 percent phenocrysts in an aphanitic groundmass of felted plagioclase laths. These dikes are generally intensely altered and their outcrops are typically obscure. Alteration minerals are chlorite, calcite, epidote, and sericite, which indicate propylitic alteration. The Contention dike, which is one of the best Ag-producing properties in the district, is the only dike that contains a border phase and a more felsic central portion. The other andesite porphyry dikes have relatively uniform lithologies.

Newell (1974) proposed that the dikes originated from an early differentiate of the Schieffelin Granodiorite and were probably emplaced slightly prior to the final intrusive stages of the Schieffelin. Force (1996) noted that some of the dikes intrude along pre-Schieffelin Granodiorite, post-Uncle Sam Tuff faults. The dikes cut the Uncle Sam Tuff, the Schieffelin Granodiorite, and their contacts with the Bisbee Group. On the basis of the similar phenocryst mineralogy and morphology of all three units, Force postulated the dikes closely postdate the Uncle Sam Tuff and the Schieffelin.

A granophyre dike crops out immediately west of Ajax Hill. The dike is relatively resistant to erosion, and can be followed along strike about 3,500 ft. The granophyre intruded along the Ajax Hill fault and also invaded the Precambrian granite. The dike is probably slightly older than a rhyodacite, from which it is separated by the fault. The granophyre is intensely altered, although the alteration may have resulted from the emplacement of the rhyodacite. The rhyodacite intrudes the Ajax Hill fault and the Uncle Sam Tuff. The rhyodacite probably altered the granophyre and the hornblende andesite dikes above. The rhyodacite is exposed west of Ajax Hill and along the west side of the Ajax Hill fault. It is closely associated with the granophyric dike and it also intruded the Uncle Sam Tuff.

Fracturing along northeast-striking fissures in the Uncle Sam Tuff and the Schieffelin Granodiorite preceded emplacement of northeast-striking, hornblende andesite dikes (Newell, 1974). A hornblende andesite dike cuts the Schieffelin Granodiorite and the Uncle Sam Tuff north of Bronco Hill. The fissures cut the Uncle Sam Tuff and are intruded by the hornblende andesite dikes.

Fractures in the cooling volcanic and related plutonic rocks at depth gave pathways for the rise of mineralization within and adjacent to the caldera. Phreatic explosions and venting probably gave rise to the breccia pipes in the Robbers' Roost-Charleston Lead mine area. Similar mechanisms occurred in the Silver Bell district, in which the andesite, dacite, and Mt. Lord ignimbrite sequence is the same type and sequence of volcanics as are present at Tombstone, i.e., the Bronco andesite, Bronco rhyolite, and Uncle Sam Tuff. At Silver Bell, quartz monzonites intrude the caldera fault, to be later mineralized by Cu-, Mo-, Ag-, Pb-, and Zn-bearing hydrothermal solutions (Guilbert, 1993).

Taking advantage of the caldera-related faults and other zones of weakness open at the time, Pb-Zn-Ag hydrothermal solutions were emplaced into the district. This mineralization has been dated at Charleston and at Tombstone. Hydrothermal sericite from an open cut of the Charleston Lead mine in the Charleston Hills yielded recalculated potassium-argon (K-Ar) date of 75.4 ± 3 Ma (Newell, 1978) from an east-west vein structure that cuts Bronco Volcanics at the mine and cuts Uncle Sam Tuff along strike. Hydrothermal sericite from a northeast-striking vein structure which to the northeast carries Ag mineralization at the State of Maine mine yielded a recalculated K-Ar date of 73.95 Ma (Newell, 1978). Alteration along the Contention dike yielded a K-Ar date of about 72.7 Ma (Gustafson, personal communication to J. Guilbert, 1993).

Numerous dikes of hornblende andesite occur in the area between the San Pedro River and Tombstone. They are probably genetically related to a hornblende andesite intrusive that crops out about 1 mile east of Bronco Hill. The dike rocks intrude the Bisbee, the Bronco Volcanics, the Schieffelin Granodiorite, and the Uncle Sam Tuff.

Metamorphism in the Tombstone mining district occurred with the intrusion of the Schieffelin Granodiorite and prepared the Bisbee and Naco Group rocks for subsequent mineralization. The total thickness of metamorphosed rocks is about 850 ft. The Bisbee Group in the western area is locally more intensely metamorphosed than it is in the Tombstone basin. Shale and sandstone of the Bisbee Group were converted to hornfels and quartzite that fractured well and helped develop long continuous tension fractures during subsequent periods of faulting. Limestone of the Bisbee and Naco Groups were recrystallized, while the Novaculite (the basal member of the Bisbee) was altered to a jasperoid.

7.6.3 Structures of the Early Laramide (79-67 Ma) at Tombstone

Structures that developed during the early phase of the Laramide orogeny tend to be folds and thrusts that strike northwest and have experienced northeast-directed transport of short distances. During this phase, the west-northwest-striking Texas Zone elements functioned as reverse slip or left-slip tear faults during northeast-southwest shortening on folds and small-scale thrust faults (Keith and Wilt, 1986). This deformation was probably responsible for large features visible in the district today, including the Empire anticline and the N50ºE fractures (Guilbert, 1993).

7.7 Tertiary, Middle Laramide (66-55 Ma) - Porphyry Cu Mineralization

The middle Laramide phase is represented by porphyry copper deposits associated with porphyritic stocks of quartz diorite to granodiorite composition of calc-alkalic magma chemistry in southern Arizona. This phase was called the Morenci Assemblage by Keith and Wilt (1986) and the following description is excerpted from that paper.

Numerous age dates on these porphyry copper deposits show that the deposits are also younger in the east than in the west. This indicates the calc-alkalic portion of arc magmatism moved eastward through time, as the subducting Farallon plate became shallower. Morenci Assemblage magmatism in northwestern Arizona is 75 to 70 Ma, in the Morenci area is 62 to 51 Ma, in eastern Arizona and New Mexico is 60 to 52 Ma, and in the Tombstone Hills is 66 to 62 Ma.

Mineralization of the Morenci Assemblage consists of the porphyry copper deposits that are the major source of historic Cu production in Arizona. Examples near Tombstone include the Pima district (Twin Buttes, Sierrita-Esperanza, and Mission-Pima mines) south of Tucson and the Silver Bell mine northwest of Tucson. These are large, disseminated, mesothermal, annular zones of Cu-Mo mineralization in or adjacent to porphyritic, epizonal, calc-alkalic stocks. The systems are extremely large and commonly exhibit zoning outward from the Cu-rich core in this sequence: Cu-Zn, Zn-Pb-Ag-Au, Pb-Ag, and Ag-Mn. These disseminated systems locally contain skarn and vein deposits. Cu-Zn skarns occur adjacent to the plutons and Cu-Zn-Ag veins, skarns or replacements are more marginal to the plutons, with Mn occurrences are more distal.

7.7.1 Rocks of Middle Laramide at Tombstone

The principal rock types of the Morenci Assemblage in southern Arizona are plutonic, epizonal, porphyritic stocks of quartz diorite to granodiorite composition. These plutons have more total hydrous minerals (8 to 25%) than the earlier Tombstone Assemblage plutons (6 to 15%). Whole rock geochemical data from these plutons plot in the metaluminous, calc-alkalic, iron-poor, hydrous, and oxidized fields on variation diagrams. No sedimentary rocks are known from the Morenci Assemblage and abundant volcanics are generally lacking, although rhyolitic or rhyodacitic volcanics occur at Red Mountain in the Patagonia Mountains, Safford, and Tombstone Hills (Keith and Wilt, 1986).

Approximately 6 to 10 million years after the caldera volcanism and associated Pb-Zn-Ag mineralization at Tombstone, a different type of magmatism was emplaced into the fractures and zones of weakness established by the caldera activity and Precambrian Texas Zone faults. Evidence of this later, slightly more calc-alkalic magmatic activity is the emplacement of the rhyolite porphyry and its associated dikes and sills in the eastern part of the Tombstone district.

This younger rhyolite porphyry occurs as sills, plugs, and dikes south and east of the main part of the Tombstone district. The rock is pinkish gray and made up of medium- to fine-grained phenocrysts in devitrified ground-mass. The texture is hypocrystalline, being typically porphyritic aphanitic (DeVere, 1978). This rhyolite porphyry intruded the Prompter fault zone and is widely exposed as sills in the eastern part of the district. The unnamed rhyolite porphyry crops out about 3 mi southeast of Tombstone along SR 80 in the Hay Mountain area and as several sills between Ajax Hill and Military Hill.

7.7.2 Age of Middle Laramide at Tombstone

Geologic evidence for the later emplacement of the rhyolite porphyry plug and dikes at about 63 Ma is that a rhyolite intruded the Prompter fault zone. A rhyolite dike cuts an andesite porphyry dike immediately west of Military Hill. The rhyolite intrudes many of the Paleozoic formations in the district, and many of the intrusive contacts are nearly conformable with the bedding. The rhyolite has clearly cut across an andesite porphyry dike west of Military Hill, and south of Tombstone it has intruded the Prompter fault.

There are numerous age dates on this late rhyolite in the eastern part of the Tombstone district. A K-Ar date on K-feldspar from a north-northwest-striking dike that cuts hornblende-biotite rhyodacite porphyry dike south of the Prompter fault yielded a date of 62.69 ± 2.3 Ma (Anaconda unpublished data reported in Reynolds and others, 1986; Newell, 1978). This is similar to the rhyolite dated at 62.1 Ma by Creasey and Kistler (1962). Additional age dates on the "Tombstone rhyolite" are a K-Ar date on sanidine of 65.1 ± 1.6 (Marvin and Cole, 1978) and a K-Ar date on biotite of 66.3 ± 1.6 Ma (Marvin and Cole, 1978) from rhyolite porphyry on the west side of the highway north of Colina Ridge (Figure 7-9).

The age date of 63 Ma by Creasey and others (1962) by K-Ar on rhyolite intimately associated with Mn south of the Emerald mine suggests that the age of Mn mineralization (at least in the Military Hill-Emerald mine area south of the Prompter Fault) is approximately 10 Ma younger than mineralization in the Contention dike and at Charleston.

In 1982, Briscoe mapped a previously unnoticed apophysis of quartz monzonite porphyry in the Tombstone Extension area, and dikes of the same material in the Comstock Hill area, northwest of the Tombstone townsite. In 1985, Drewes reported that this rock, the Comstock porphyry, has an age of 62.6 ± 2.8 Ma. This intrusive may be the source of the rhyolite dated by Creasey that intruded the Prompter fault and that occurs as dikes south of the Prompter fault, as well as sill-like bodies southeast of Tombstone near the municipal airport. Quartz monzonite porphyry rocks are associated with the 62 Ma Cu mineralization at porphyry copper mines throughout southern Arizona.

7.7.3 Mineralization of Middle Laramide at Tombstone

Mineralization was associated with this middle Laramide rhyolite, as shown by the emplacement of the rhyolite porphyry (also called the Extension/Comstock quartz monzonite porphyry) in the eastern part of the district. K-Ar dating of a hornblende in this rock yielded a date of 62.8 ± 2.6 Ma (Drewes, 1985).

A deeper zone of porphyry copper mineralization is indicated by the intersection of secondary K-feldspar, biotite, purple anhydrite, disseminated pyrite, chalcopyrite and molybdenite in ASARCO drill holes in the Robbers' Roost area in the southwest part of the district. A cupola of quartz monzonite porphyry was also intersected in ASARCO drill holes in Robbers' Roost area. Deep exploration drill holes in this area confirm unexposed apophyses of porphyritic quartz monzonite below these altered areas (Guilbert, 1993). Many porphyry copper deposits in southern Arizona are associated with quartz monzonite porphyry that is differentiated from earlier, more mafic granodiorite and quartz diorite.

The introduction of Mn mineralization in the southern part of the district was closely associated with emplacement of the rhyolite (Butler and others, 1938; Newell, 1974). Mn mineralization is intimately associated with the rhyolite porphyry in the Side Wheel mine west of Military Hill. Quartz veinlets were observed paralleling the ore fissure which cuts the rhyolite dike west of Military Hill (Guilbert, 1993). The Mn deposits are closely associated with the Prompter fault (Butler and others, 1938) and the rhyolite porphyry has intruded along the Prompter fault.

The quartz monzonite porphyry (Comstock porphyry) may be the source of rhyolite dikes associated with mineralization in the State of Maine mine area. The age of the later Tombstone mineralization is an important link to porphyry copper mineralization. As mineralization at Tombstone is contemporaneous with other productive porphyry copper deposits in the area, the long-term potential for deeper Cu mineralization is promising (Guilbert, 1993).

7.7.4 Structures of Middle Laramide at Tombstone

Structural features of the Morenci Assemblage consist of regional, east-west to northeast-striking dike and vein swarms and prominent, east-west to east-northeast-striking, through-going joints in and near calc-alkalic plutons. The dike and vein swarms appear to be concentrated between elements of the Texas Zone that exhibited left-slip movement during the middle Laramide phase.

Minor fracturing and additional movement on the Prompter fault followed intrusion of the rhyolite at Tombstone (Newell, 1978). There was also renewed minor fracturing along the northeast-striking fissures, as shown by the rhyolite dike west of Military Hill that is cut by a northeast-striking fissure. Renewed movement along the Prompter fault is shown by the rhyolite porphyry dike that is cut and offset left laterally about 200 ft by the Prompter fault system. The Free Coinage vein in the State of Maine area is offset 200 ft left laterally by the northern bifurcation of the Prompter fault. The northeast-striking fissures do not cross faults belonging to the Prompter system.

7.8 Tertiary, Late Laramide (54-43 Ma) – Tungsten (W) Mineralization

The latest Laramide phase in southern Arizona is represented by tungsten or quartz vein deposits associated with garnet-muscovite granitoid stocks and pegmatite dikes of peraluminous, magma chemistry. This phase was called the Wilderness Assemblage by Keith and Wilt (1986) and the following description is excerpted from that paper. There are no sedimentary or volcanic rocks in the Wilderness Assemblage. Instead there are large volumes of peraluminous, muscovite- and garnet-bearing granitoids that commonly contain late alaskitic pegmatite sills and later cross-cutting dikes.

Many Wilderness Assemblage plutons are associated with well-developed mylonitic fabrics in or adjacent to the plutons and appear to be synkinematically intruded into southwest-directed mylonitic shear zones. This may represent a widespread southwest-directed thrust system caused by underthrusting the Farallon plate toward the northeast under the Colorado Plateau, thus raising the area to be eroded into the Eocene erosion surface. This thrust faulting episode may be represented in the Little Dragoon Mountains by the Lime Peak thrust fault.

The Wilderness Assemblage plutons and pegmatitic dikes and quartz veins intrude the earlier porphyry copper-related plutons and are generally younger to the east. This indicates the peraluminous portion of arc magmatism moved eastward through time, as the subducting Farallon plate became so shallow that it was nearly flat. In the nearby Little Dragoon Mountains, the main phase of the Texas Canyon pluton was intruded by the peraluminous Adams Peak leucogranite. The age dates on the peraluminous plutons in the Coyote Mountains in southwestern Arizona is 58 Ma, and age dates on the Wilderness Granite in the Santa Catalina Mountains are 44-50 Ma.

In the nearby Huachuca Mountains, tungsten mineralization is probably related to the muscovite-bearing peraluminous alaskites that locally occur in southwest-directed thrust faults. Hydrothermal sericite related to the tungsten mineralization is dated at 48 Ma. These rocks do not crop out in the Tombstone Hills. The nearest Wilderness Assemblage mineralization to the Tombstone Hills is probably the Bluebird leucogranite in the Texas Canyon area.

7.9 Middle to Late Tertiary Orogenies (43 - 0 Ma)

To the east of the Tombstone district, the pediment of the Tombstone Hills is covered by Gila Conglomerate, which is hundreds of feet thick. The youngest rock in the area is a basalt plug that intrudes the Gila Conglomerate on the northeast edge of the town of Tombstone.

7.9.1 Cenozoic (43-0 Ma) Undivided Rocks at Tombstone

Rocks and basin-fill deposits of Cenozoic age include the Gila Conglomerate or its equivalent, and modern gravel and alluvial deposits. Rocks that are probably equivalent to the Gila Conglomerate are in fault contact with the Bisbee Group east of Tombstone in Sec. 7, T20S, R23E. North of Tombstone, the conglomerates are at least 700 ft thick and appear to be considerably thicker east of Walnut Gulch. The Gila Conglomerate equivalent is covered by a thin layer of modern terrace gravels and gravel and alluvium in washes and arroyos.

A small basalt dome and phonolite dike crop out along the east side of Walnut Gulch about 1 mi northeast of Tombstone, where they intrude gravels of the Tertiary or Quaternary(?) Gila Conglomerate. This was the latest igneous event in the Tombstone Hills. The elliptically shaped plug is dark gray to greenish black in color and is made up of fine-grained olivine, diopside and enstatite that occur in the interstices between felted plagioclase laths (Newell, 1974; DeVere, 1978). The basalt is only moderately resistant to erosion and the exposed surface is about level with the surrounding conglomerates and gravels. The contact is well exposed in places and the basalt has clearly intruded the sediments. Newell (1974) believed the basalt was intruded along a zone of weakness at the intersection of the northeast-striking fissures with a large fault buried beneath the gravels in Walnut Gulch. Enclosed within the basalt, near its southwest corner, is a phonolite dike that is about 200 ft long and 5 to 10 ft wide.

7.9.2 Mid-Tertiary Orogeny (43-15 Ma)

The mid-Tertiary orogeny was subdivided into three phases as the subducting slab became steeper and the magmatic arc moved from the east to the west, in the reverse pattern from the Laramide (Keith and Wilt, 1985). The following description is excerpted from that paper.

The mid-Tertiary (also known as Galiuro) orogeny is subdivided into early, middle, and late phases. The early phase of the Galiuro orogeny was deposited in local basins containing minor volcanics, local conglomerates and lacustrine deposits of carbonates and gypsum and clay, with minor uranium, secondary Cu, and industrial mineral deposits. The middle phase of the Galiuro orogeny consists of widespread volcanism and stocks of calc-alkalic and later alkali-calcic chemistry. The earlier calc-alkalic phase contains epithermal Au-Cu veins associated with microdiorite dike swarms. The later alkali-calcic phase contains Pb-Zn-Ag skarns and replacements in contact zones of stocks and small batholiths, associated with large caldera systems. The late phase of the Galiuro orogeny consists of coarse clastics and local volcanics and stocks of quartz-alkalic magma chemistry, associated with large, low-angle, normal, detachment faults. Mineral resources consist of Cu-Au-Ag specularite replacement lenses, veins and disseminations in low-angle faults, and syngenetic stratabound uranium in lake beds and tuffs. Possible Galiuro orogeny Pb-Zn-Ag mineralization near Tombstone may occur in the nearby Middle Pass region of the Dragoon Mountains.

Later, possibly in the late Laramide or mid-Tertiary, there was partial Tombstone district tilting to the northeast, possibly associated with the northwest faulting. The Gila Conglomerate beds (possibly Pliocene or Quaternary in age) along Walnut Gulch dip 40º northeast. Northwest-striking faults (Grand Central, East Boundary, and Walnut Gulch) have progressively lowered the district to the northeast. These northwest-striking faults post-date the mineralization (Butler and others, 1938).

7.9.3 Basin and Range Disturbance (14-0 Ma)

The Basin and Range Disturbance is a result of the subducting Farallon slab being cut off by the strike-slip action on the San Andreas fault/transform boundary. As the underlying slab continued to descend and was missing in places, the overlying slab foundered and parts sank along steep normal faults creating the Basin and Range topographic province. This break-up allowed the intrusion of mantle basalt, which is largely devoid of mineralization, although some industrial minerals were deposited in the basins.

7.10 Tombstone District Structures

Regional structures that were emplaced during the Precambrian have a continuing influence on the loci of structures and the emplacement of ore deposits. The west-northwest-striking Texas Zone and intersecting northeast-striking fractures are commonly opened whenever the plate motion vectors were slightly oblique to these underlying structurally weak zones. Calderas are commonly located at the intersection of these structures.

The structure of the Tombstone mining district is complex, although the western area appears to be less so than the eastern area, because the west area is generally covered by Uncle Sam Tuff. However, the underlying limestones are complexly folded into interference folds. Blake (1882a) described the control on mineralization by northeast-striking fault and fissure systems and porphyritic dikes, the importance of folding, with localization of ore deposits at the crest of many of the folds, and the importance of bedded masses of rich Ag ore in black limestone. Force (1996) pointed out that the Bisbee Group in the western area was deformed into dome-and-basin folds but lacks complex faulting.

Many of the Tombstone ore bodies have been shown to be structurally controlled. The major structural features are tension fractures and fissures, folds, faults, and igneous intrusions.

7.10.1 Fracture Zones

The Cretaceous rocks in the western part of the district are cut by andesite porphyry dikes and northeast-striking fissures. The fissures have moderate to steep dips to the west. Mineralization occurs in pods and lenses localized along the fissure zones.

Following intrusion of the Schieffelin Granodiorite, dikes of similar composition were emplaced along many of the pre-existing faults. The basin was then faulted along northeast-striking faults that created numerous, widespread northeast-striking fractures that commonly strike N30-55°E across the district. East of the Ajax fault, the fractures dip steeply southwest; west of the fault they generally dip northwest. Butler and others (1938) have shown that these fractures served as channels for the Ag-bearing hydrothermal solutions.

Mineralized fissures in the Tombstone district strike consistently northeast, although the angle varies between about N15ºE and N55ºE. Many of the fissures exhibit consistent orientation for hundreds of feet along strike and many fissures have parallel orientations, forming fissure sets.

The reopening of the northeast-striking fracture zones occurred in the main part of the Tombstone district, the State of Maine area, the Robbers’ Roost breccia pipe area, and the Charleston Lead mine area. These fractures may also be responsible for the mesquite-twig Mo geochemical anomalies at Government Draw and Lewis Springs (Newell, 1974) and the magnetic anomalies at the Charleston crossing, on the Huachuca Military Reservation, west of the San Pedro River, and at Fairbank (Guilbert, 1993).

7.10.2 Folds

North of the Ajax Hill horst is the Tombstone basin, which is a broad synclinal warp with an axis that trends east-west and plunges gently to the east. The syncline is complicated by three broad northwest-trending anticlines and associated synclines (called rolls by the early miners) that developed in the central portion of the district. These broad folds plunge slightly to the southeast and are truncated by the Schieffelin Granodiorite to the northwest. Because the anticlines are tight, with brecciated crests at some horizons, they are favorable entrapment sites where they are bounded above by impermeable argillitic cap rocks (Force, 1996).

7.10.3 Faults

Prior to intrusion of the Schieffelin Granodiorite, the Tombstone basin was subject to east-west and north-south faulting. The major faults in the Tombstone district are the Prompter, Horquilla Peak, Ajax Hill and East boundary faults. The west-striking Prompter fault zone is a reverse fault that dips 60 to 80° S. The Prompter fault has at least 4,000 ft of stratigraphic displacement near its western margin and about 1,500 ft of offset farther to the east. The Horquilla Peak normal fault is located south of Ajax Hill and has about 2,000 ft of displacement from the Bisbee Group in the floor of the caldera to the Precambrian at the base of Military Hill. The Ajax Hill is a normal fault that lies immediately west of Ajax Hill and trends north-south. The East Boundary fault is the eastern equivalent of the Ajax Hill fault.

There have been at least three periods of movement on the Prompter system. One period is probably pre-Cretaceous. A second period post-dates the Ajax Hill fault (about 2,800 ft), and a third period post-dates the emplacement of the rhyolite porphyry dike immediately south of the Prompter shaft (SE ¼ Sec. 14, T20S, R22E). The projected trend of the Prompter fault beneath the Bisbee Group and the Uncle Sam Tuff is of interest since the Prompter fault zone is known to contain sizeable historic ore bodies (Oregon-Prompter, Bunker Hill, Dry Hill, and Contact mines).

7.10.4 Texas Zone Elements

The west-northwest-striking Texas Zone is approximately 100 mi wide and strikes about N75˚W across west Texas, southwest New Mexico, southern Arizona, and southern California. During the early Laramide (85 to 72 Ma), the Texas Zone elements experienced reverse movement and during the middle Laramide (72 to 56 Ma), they experienced regional distributed left shear (Swan and Keith, 1986). The Prompter fault in the northern part of the Tombstone mining district is an example of a Texas Zone element.

7.10.5 Caldera Structures

Recent USGS and dissertation studies have improved understanding of caldera systems, their extrusive volcanic environment and of associated intrusive systems (Figure 7-7). The Tombstone volcanic terrain is an example of such a Laramide caldera complex (Briscoe and Waldrip, 1982; Lipman and Sawyer, 1985). The Uncle Sam Tuff has been interpreted as an intracaldera tuff (Figure 7-8).

Briscoe had observed the caldera volcanism located in the area of the Silver Bell porphyry copper deposit located northwest of Tucson, when he worked there in the 1960s. Extensive geochemical sampling of the Silver Bell and Tombstone districts in the 1990s provided a template of geochemical signatures.

USGS mapping and investigations by Lipman and Sawyer (1985) defined the characteristics of calderas and confirmed the presence of calderas at Silver Bell and Tombstone that had been reported by Briscoe. At Silver Bell, a biotite granite (73 Ma) is overlain by an intracaldera welded tuff of low-silica rhyolite (Sawyer, 1986; Sawyer and Lipman, 1983). This lithic tuff contains large blocks of Paleozoic limestone interpreted as caldera-collapse megabreccia. The lithic tuff is conformably overlain by moat-filling, volcaniclastic sedimentary rocks, which is overlain by post-collapse andesitic and dacitic flows and welded tuff. Later intrusions of quartz monzodiorite to monzogranite (69 Ma) intrude the ring faults and are hosts to the porphyry copper mineralization. An investigation of the geology of the North and West Silver Bell Mountains (Briscoe, 1988) proved the association of porphyry copper mineralization and associated intrusive rocks with faults and ring fracture systems of earlier calderas.

Over a distance of about 7 miles, five of the seven or more porphyry copper centers of the Silver Bell Mountains have been mined to date. Significant mines were developed from 1912 and modern open pit mining began in 1952. The work by Briscoe and Guilbert identified several additional porphyry copper mineralized centers in the West Silver Bell Mountains and additional centers in the East Silver Bell Mountains, all of which were interpreted to follow the caldera moat or rim fractures.

The porphyry copper mineralization centers at Silver Bell could be identified to significant depths (at least 1,000 feet) by extensive trace element geochemical sampling of vegetation and soil. The geochemical sampling was conducted carefully and the accuracy and precision of the analytical laboratory were of high quality. The detection limits of the analytical lab were very low in order to detect these geochemical patterns. The mineralization centers are indicated by a Au halo and by base metal centers. The same response is expected at the Hay Mountain project.

7.11 Tombstone District Geochemistry

As a screening tool during exploration in a particular area, whole rock analyses of the plutonic and volcanic rocks in the district are important in focusing exploration into the correct deposit type (Wilt, 1993). Geochemical surveys are routinely conducted over a district as an adjunct to mapping and geophysical exploration. Two types of geochemical investigations were conducted by Newell (1974) in the Tombstone district to evaluate the area for additional mineralization: the biogeochemistry of mesquite tree twigs and the geochemistry of rock chips from mine dump samples. The discussion of Newell's results is summarized from SRK (2008).

7.11.1 Magma Chemistry Analysis

Numerous whole rock analyses are available on rocks in the Tombstone district, including volcanic rocks (Table 7-2) and plutonic rocks (Table 7-3) of the early Laramide, and rhyolite (Table 7-3) of the middle Laramide (Gilluly, 1956; Dewhurst, 1976; Lang, 1991; Clarke, 1915). The ~74 Ma igneous rocks of the early Laramide (the Bronco Volcanics, Schieffelin Granodiorite, and Uncle Sam Tuff plot in or near the metaluminous, alkali-calcic, oxidized field, when K_2O % is plotted against SiO_2% (Figure 7-10). Alkali-calcic igneous rocks correlate with Pb-Zn-Ag mineralization throughout the world (Wilt, 1993).

However, data from the 62 to 66 Ma rhyolite porphyry in the eastern part of the Tombstone Hills plot in or close to the metaluminous, calc-alkalic, oxidized field (Figure 7-11). The plotted samples are highly altered, as indicated by the high loss on ignition (LOI) values, so they plot with a more alkaline composition than a fresh sample would plot. Calc-alkalic igneous rocks correlate with porphyry copper mineralization throughout the world (Wilt, 1995).

7.11.2 Mesquite Biogeochemical Investigation

Newell (1974) collected 353 mesquite samples from nine different sites along linear features earlier identified on aerial and space photography, and analyzed the samples for Cu, Mo, Ag, Pb, and Zn (Figure 7-12). The analyses were compared to element distributions in rocks, soils, dry wash sediments, and groundwater samples collected from the same areas at the same time. The following discussion is taken from his dissertation (Newell, 1974).

Results of the mesquite investigation indicate that mesquite ash generally contains higher metal concentrations than do the surrounding media. Statistical analysis was used to determine mean values and standard deviations of the sample results, from which anomalous concentrations of each metal were determined (Table 7-4). The results were plotted on maps for interpretation and comparison.

Ag values in mesquite ash ranged from <1 to 8 ppm, with low values from <1 to 2 ppm and high threshold values > 3 ppm. Ag values were generally background and low threshold, although scattered high-threshold Ag concentrations were found (Figure 7-13) (Secs. 13, 14, and 15, T21S, R22E). Newell postulated that a group of closely spaced, low-threshold samples in the Uncle Sam

Tuff (Secs. 20, 29, and 30, T20S, R22E) may indicate high Ag concentrations at depth because the group is surrounded by background values and because the dump from the Mustang mine in Sec. 30 was found to contain about 40 oz/ton Ag. Newell concluded that very low Ag values in mesquite suggest Ag is not well suited to mesquite biogeochemical methods.

Zn in mesquite ash ranged from 120 to 1,600 ppm. Low threshold values were those < 400 ppm and anomalously high values were those exceeding 800 ppm. Zn had anomalous values near Tombstone, and Zn values decreased northwestward away from the town. One anomalous value was collected south of town near the Contention dike, and both high and low threshold values occurred near the intersections of Government Draw-San Pedro and Government Draw-Walnut Gulch (Secs. 2 and 3, T21S, R23E). High threshold and anomalous Zn values were identified near the Horquilla-Ajax intersection (SW¼ Sec. 27, T20S, R22E). Anomalous values also were obtained about 3 mi west-southwest of Tombstone (SW¼ Sec. 9 and NE¼ Sec. 17, T20S, R22E) near the State of Maine and San Pedro mines.

Background concentrations of Pb were found along the northeast-striking fractures in the Uncle Sam Tuff (Secs. 19, 20, 29, and 30, T20S, R22E), but low threshold values tended to form a crude circular pattern around the background values and appeared to correlate with threshold and anomalous concentrations of Cu and Mo, respectively.

Copper values in mesquite ash ranged from 40 to 295 ppm, with a mean value of 119 ppm. Low threshold values were 0 to 150 ppm and high threshold values were 150 to 200 ppm. Anomalous Cu values were found in Government Draw (Figure 7-14). Mo had anomalous values near Tombstone, near Lewis Springs at the San Pedro-Government Draw intersection, and near intrusive breccias in the Uncle Sam Tuff with associated northeast-striking fractures and alteration (Figure 7-15) (Sec. 29, T20S, R22E). Zn had anomalous values in the northern part of the district (Figure 7-16). Newell (1974) recommended the collection of more samples farther west (Secs. 17-20, T21S, R22E) to define the latter anomaly more clearly.

7.11.3 Mine Dump Geochemistry Investigation

Newell (1974) collected 85 samples of ore-grade material from mine dumps in the Tombstone-Charleston area to investigate metal zoning patterns (Figure 7-17). However, none of these mine dumps were located in the Hay Mountain project area.

7.12 Tombstone District Alteration

Descriptions of alteration apply mostly to the oxidized ores, as little mining was done below the water table. The limited descriptions below are taken from Butler and others (1938), Force (1996), and SRK (2008).

All of the rocks in the northeast fissure zone in the western part of the Tombstone mining district weather brownish to reddish, apparently due to the oxidation of small amounts of pyrite. The wall rock of the fissures shows a considerable range in alteration. Some veins crop out several feet above the surrounding rocks along part of their length as a result of silicification. Such outcrops commonly show rather strong stains of Mn. Other wall-rock alteration, such as at the State of Maine vein, is a soft claylike material that erodes readily. The alteration by the mineralized solutions appears to have been mainly sericitization, which was later modified by surface solutions. Intense alteration extends only a few feet from the fissure. Other alteration areas discovered by Briscoe are identified by alignments of mesquite trees on color air photos. These alteration areas are soft and easily eroded, covered entirely by soil, are up to 80 ft wide and up to 3,000 ft long, and contain several ounces of silver.

The ore in the State of Maine vein appears to be confined mainly to narrow stringers in the crushed and sericitized rock of the fissures. Small amounts of vein quartz are present as a gangue mineral in some of the stringers but it is nearly lacking in much of the ore.

Force (1996) noted that metamorphic grades in Bisbee Group rocks range from apparently unaltered rocks to the wollastonite-diopside-garnet assemblage, which is favored by calcic rocks. The contact metamorphic zone containing this assemblage is everywhere in contact with the Schieffelin granodiorite. The structural thickness of the zone is about 65 to 100 ft.

A garnet zone occupies a large area of the Bisbee Group in the western area. Several rock types show garnet either in calcic spots or as part of a matrix in rocks where the spots are epidotic. The garnet zone, at least 300 ft thick, is defined by the presence of garnet but the absence of wollastonite or diopside in calcic assemblages.

An epidote zone is defined by a variety of rocks in the southern part of the western area. It is most obvious in outcrops of spotted hornfels and as rims or complete replacements of limestone pebbles in conglomerate. The thickness of the zone is about 425 ft. Epidote-bearing rocks in contact with the Uncle Sam Tuff in the south area suggest that metamorphism is locally caused by the dike.

7.13 Tombstone District Geophysics

Regional geophysical surveys have been done in southeastern Arizona by the USGS and other researchers (Sauck and Sumner, 1970; Bultman and others, 2002; Andreason and others, 1965; West and others, 1974). These have included aeromagnetic surveys (Figure 7-18) and gravity surveys (Figure 7-19) and a more recent gravity survey (Figure 7-20).

Various mining exploration companies have contracted geophysical surveys. Phelps Dodge conducted induced polarization (IP) surveys in the eastern part of the Tombstone district and these data were re-evaluated by Zonge Engineering, at the request of JABA.

7.14 Hay Mountain Geologic Setting

The Hay Mountain project is an area of low hills with mainly Late Paleozoic limestone bedrock outcrops of Permian Colina Limestone and the underlying Pennsylvanian-Permian Earp Formation. A few hills contain Permian Epitaph Dolomite overlying the Colina Limestone. The Colina Limestone is intruded by Tertiary rhyolitic sills or intrusions. A few outcrops of Cretaceous Bisbee Group sediments crop out on the east side of a north-striking fault. The valleys between the hills are composed of Quaternary-Tertiary gravels and weathered and altered limestone and clay.

The depth to bedrock map of southeastern Arizona (Oppenheimer and Sumner, 1980) shows that the alluvium is relatively shallow under the valleys of the Hay Mountain project. A more recent depth to bedrock study of the upper San Pedro Valley was developed by Gettings and Houser (2000) and a study of bedrock depths in Arizona was published by Richard and others (2007) (Figure 7-21). The depths to bedrock in the Hay Mountain area ranged from 0 to 400 ft.

Table 7-1 Mountain building episodes in southern Arizona

Orogeny	Orogenic Phase	Phase Name	Age (Ma)	Sedimentation	Magmatism	Magma-Chem Alkalinity	Structures	Resources
Basin & Range			13-0	clastics & evaporites in grabens	alkaline anhydrous basaltic volcanism		N-S trending horsts & grabens, bounded by steep normal faults	sand & gravel, salt, zeolites, cinders, gypsum
mid-Tertiary	Late	Whipple	18-13	coarse to fine clastics, megabreccia blocks	alkalic hydrous volcanics & local epizonal stocks	MQA	low-angle normal detachment faults, SSE-trending folds, NW striking thrusts & reverse faults	Cu-Au-Ag in veins, replacement lenses & in detachment faults, epithermal Au-Ag veins, hotspring Mn & U
	Middle	Galiuro Datil facies	28-18	local clastics interfinger with volcanics	alkali-calcic hydrous ignimbritic volcanics & epizonal plutons	MAC	broad NW-trending folds; NW- and NE-trending dikes	Pb-Zn-Ag +/- F in veins, replacements, epithermal Ag, hotspring Mn
	Middle	Galiuro South Mountain facies	30-22	local clastics interfinger with volcanics	calc-alkalic hydrous volcanics & epizonal plutons	MCA	broad NW-trending folds, NW-trending dikes, minor NE-trending dikes	Au +/- Cu-W veins & disseminated deposits
	Early	Mineta	38-28	coarse & fine clastics & evaporites in lake beds	rare volcanics, mostly within 'volcanic gap"		local broad basins; possibly with WNW trend; reverse faults	U, clay, exotic Cu
Laramide	Late	Wilderness	55-43	none	widespread, 2-mica, garnet-muscovite granitoid stocks, batholithic sills, aplo-pegmatite dikes, peraluminous, calc-alkalic	PCA	SW-directed, low-angle thrusts widespread, shallowly dipping mylonitic zones, general SW shear	mesothermal, Pb-Zn-Ag veins, minor Cu-Au veins, Au in quartz veins, kyanite, tungsten
	Middle	Morenci	65-55	none	calc-alkalic hydrous, numerous epizonal stocks & small batholiths, local sporadically preserved volcanics, widespread regional NE to ENE-striking dike swarms	MCA	widespread NE- to ENE-striking regional dike swarms between E-W to ENE striking structural elements of the Texas Zone that moved in left-slip	large disseminated porphyry Cu systems, locally containing skarns & veins; Cu-Zn-Ag veins; Pb-Zn-Ag veins, skarns or replacement marginal to plutons; Cu-Zn skarns adjacent to epizonal porphyritic plutons; composite, epigenetic, mesothermal, zoned disseminated porphyry Cu systems, with several zones in a large system
	Early	Tombstone	85-65	continental clastics; large exotic blocks interbedded volcani-clastics	alkali-calcic, hydrous plutonism & pyroclastics, volcanism, some epizonal quartz monzonite porphyritic stocks; lower= andesite dacite breccia; upper= dacite-rhyolite ignimbrite flows & ash flows	MAC	NW-striking, NE-directed folds & thrusts with 1-10 km shortening	mesothermal, Pb-Zn-Ag veins & replacement deposits
	Earliest	Hillsboro	89-85	coarse continental clastics; generally lacking volcanic components, except in upper parts; angular unconformity over mid-Cretaceous; accumulated in E-W trending basins adjacent to block uplifts; conglomerate & alluvial fans	quartz alkalic hydrous, volcanics 7 small stocks, small volcanic centers, small epizonal porphyritic stocks; volcanics highly brecciated; latites & monzonites	MQA	E-W block uplifts; E-W to WNW-ESE striking high-angle reverse faults (60 degrees) with shortening 5-7 km vertical throw, 1-3 km horizontal throw; bidirectional transport N- or S-directed or NNE= or SSW-directed either side of block uplifts	epigentic Cu-Au hydrothermal
Sevier	Late	-	105-89	Bisbee Group clastics - regression	none			
	Middle	-	120-105	Bisbee Group clastics, limestone	none		gentle NE-striking basin for transgressive seaway	limestone
	Early	-	145-120		volcanic pause			
Nevadan	Late	-	160-145	Lower Glance Conglomerate	Mt. Wrightson Volcanics,	MCA	WNW Texas zones as shear zones	
	Middle	-	205-160	Eolian ss intercalated with volcanics	Canelo Hills volcanics; plutonic rocks	MQA	WNW-striking Texas zones as grabens	porphyry Cu-Au at Bisbee, Gleeson
	Early	-	230-205	continental red beds (ss, sh)				
Passive margin		-	542-205	marine limestone, sandstone, shale, dolomite	none	none	Broad basins and transgressive seaways	Limestone

Source: Keith and Wilt (1985, 1986): MQA=metaluminous quartz alkalic, MAC=metaluminous alkali-calcic; MCA=metaluminous calc-alkalic; PCA=peraluminous calc-alkalic

Table 7-2 Whole rock chemistry of Tombstone volcanic rocks

MC Type	MACo	MACo	MACo	MACo	MACo	MACo	MACo	MACo	MACo	MACo
SAMPLE NO.	T11	T12	T13	M	A1, 1, p. 99	A2, 2 p. 99	T25	T2a2	T2a3	T2a5
reference	Lang 1991	Lang 1991	Lang 1991	Clarke 1915	Gilluly 1956	Gilluly 1956	Lang 1991	Lang 1991	Lang 1991	Lang 1991
Rock name	Bronco Volcanics	Bronco Volcanics	Bronco Volcanics	Uncle Sam rhyolite	Uncle Sam quartz latite	Uncle Sam quartz latite	Uncle Sam	Uncle Sam	Uncle Sam	Uncle Sam
SiO2	53.2	55.1	53.9	68.04	66.59	68.16	62.9	72.4	72.3	71.5
TiO2	1.3	0.7	1	0.42	0.38	0.43	0.85	0.37	0.38	0.39
Al2O3	18.5	16.2	15	15.82	16.77	16.07	16.1	15.1	14.7	14.5
Fe2O3	8.54	5.78	4	2.34	1.94	1.75	6.35	2.12	2.9	0.97
FeO	0.52	1.68	3.33	0.84	1.26	1.15	0.26	0.78	0	1.55
MgO	3.6	3.5	5.07	0.8	1.04	0.9	2.6	0.93	0.92	0.87
MnO	0.13	0.1	0.14	0.07	0.11	0.11	0.11	0.09	0.1	0.1
CaO	8.5	7	5.02	3.26	2.86	2.61	5.5	2.8	2.7	2.5
Na2O	3.1	2.8	4.2	3.93	3.66	3.79	3	3.7	3.4	3.5
K2O	1.1	1.2	2	3.32	3.77	3.64	3	3.5	3.5	3.5
P2O5	0.11	0.16	0.22	0.15	0.26	0.16	0.11	0.06	0.05	0.04
LOI	1.9	6.6	4.64	1.17	1.19	1.26	0.5	0.8	1.1	1
TOTAL	100.5	100.82	98.62	100.24	99.83	100.03	101.28	102.65	102.05	100.42
Plutonic/ volcanic	volcanic	volcanic	volcanic	volcanic	volcanic	volcanic	volcanic	volcanic	volcanic	volcanic
Altered?		Altered LOI	Altered LOI						Altered AI Alteration Index high	

Source: Wilt (1993): MACo = Metaluminous alkali-calcic oxidized

Table 7-3 Whole rock chemistry of Tombstone plutonic rocks and later rhyolite

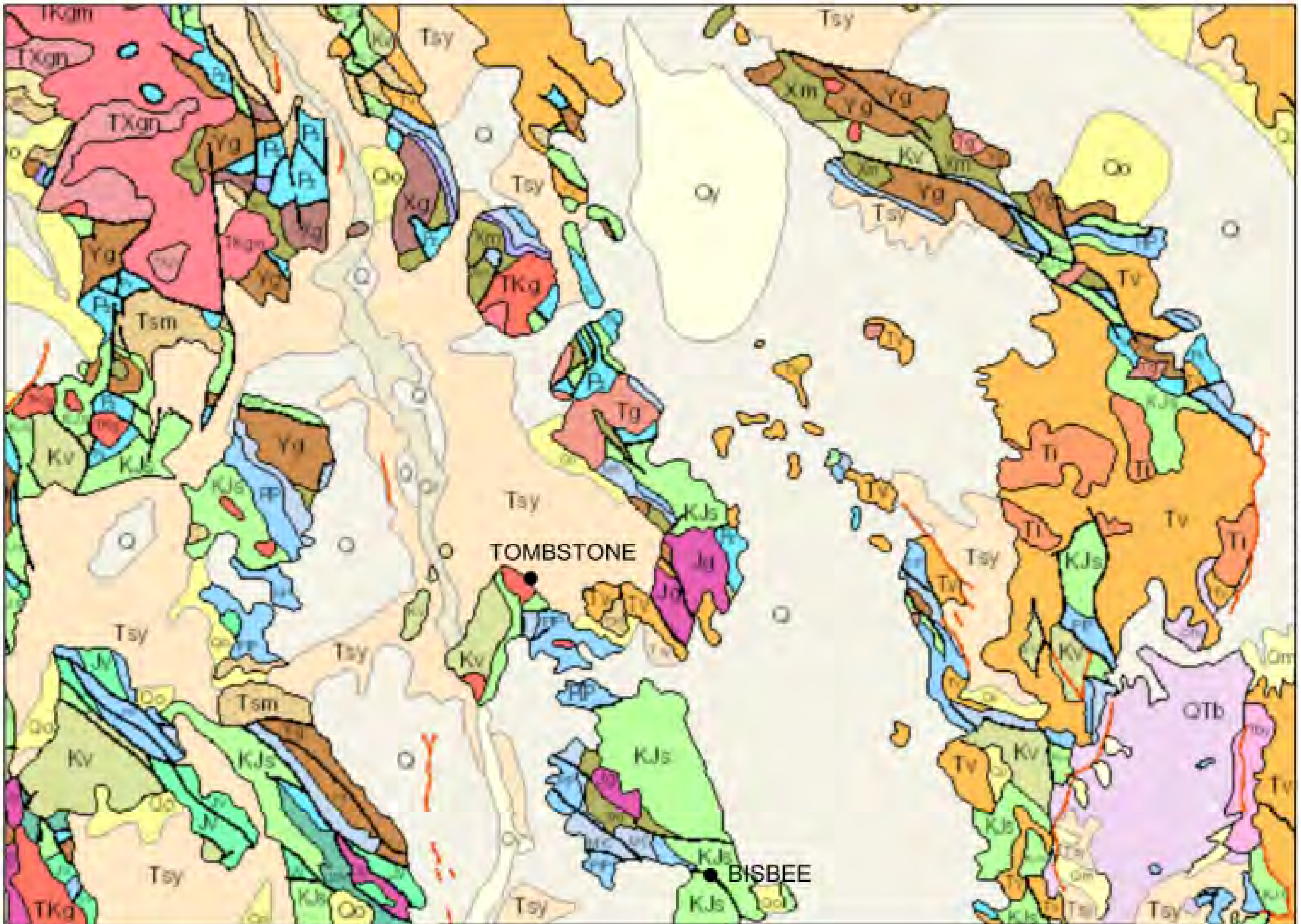
MC Type	MACo	MACo	MACo	MACo	MACo	MACo	MACo	MCAo	MCAo
SAMPLE NO.	N	JD-19	JD-20	T21	T22	T23	T24	T43	T44
reference	Clarke 1915	Dewhurst	Dewhurst	Lang 1991	Lang 1991	Lang 1991	Lang 1991	Lang 1991	Lang 1991
Rock name	Schieffelin Granodiorite	Schieffelin	Schieffelin	Schieffelin	Schieffelin	Schieffelin	Schieffelin	rhyolite porphyry	rhyolite porphyry
SiO2	62.33	63.87	63.03	66.6	64.8	63.7	63.2	78.1	78.9
TiO2	0.63	0.83	0.87	0.66	0.7	0.61	0.85	0.06	0.06
Al2O3	16.92	16.2	15.93	15.7	15.4	15.6	16.2	13.3	13.2
Fe2O3	3.95	NA	NA	3.73	2.63	3.04	5.91	0.62	0.63
FeO	1.24	4.16	4.48	1.29	2.65	2.46	0.39	0	0
MgO	1.97	2.21	2.89	1.9	2.2	2.2	2.5	0.24	0.23
MnO	0.07	NA	NA	0.08	0.09	0.09	0.1	0.08	0.06
CaO	4.48	4.06	3.85	4.5	4.5	4.7	5.4	0.6	0.15
Na2O	3.62	3.44	3.78	3	2.9	2.9	3.1	0.13	0.18
K2O	3.36	3.37	3.42	3.3	3.2	3.3	3	5	5.9
P2O5	0.17	NA	NA	0.1	0.11	0.11	0.11	0.02	0.02
LOI	1.42	NA	NA	0.8	1.3	1.3	0.4	3.2	2.6
TOTAL	100.38	98.14	98.25	101.66	100.48	100	101.16	101.35	101.93
Plutonic/ volcanic	plutonic	plutonic	plutonic	plutonic	plutonic	plutonic	plutonic	volcanic	volcanic
Altered?								Altered LOI	Altered LOI

Notes: LOI=Loss of Ignition NA=Not Analyzed MACo = Metaluminous alkali-calcic oxidized; MCAo = Metaluminous calc-alkalic oxidized
Source: Wilt (1993)

Table 7-4 Anomalous metal values in mesquite samples from structures

Structural Intersections	Metal Responses			
	Cu	Mo	Ag	Zn
San Pedro-Government Draw Sec. 16?, T21S-R22E	Lth–Hth	Hth–A	B	Lth–Hth
Government Draw-Walnut Gulch Secs. 2 and 3, T21S-R23E	A	B	B	Lth–Hth
Walnut Gulch north of Tombstone SE ¼ Sec. 35, T19S-R22E	B–Lth	B	B	B
Prompter fault-Ajax fault Secs. 15 and 16, T20S-R22E	B–Lth	B	B	Lth
Horquilla fault-Ajax fault SW¼ Sec. 27, T20S-R22E	Lth–A	B	B	Hth–A
NE-striking fractures in the Uncle Sam Tuff Secs. 19, 20, 29, and 30, T20S-R22E	B–Lth	B–A	B–Lth	B–Lth

Source: Newell (1974) [A = anomalous; B = background; Hth = high threshold; Lth = low threshold; definitions for each element are described in Section 7.11]



EXPLANATION:

- Q - Quaternary Surficial Deposits, Undivided
- QTb - Holocene to Middle Pliocene Basaltic Rocks
- Qr - Holocene River Alluvium
- Qy - Holocene Surficial Deposits
- Qm - Late and Middle Pleistocene Surficial Deposits
- Qo - Early Pleistocene to Latest Pliocene Surficial Deposits
- Tsy - Pliocene to Middle Miocene Deposits
- Tby - Pliocene to Late miocene Basaltic Rocks
- Tsm - Middle Miocene to Oligocene Sedimentary Rocks
- Tv - Middle Miocene to Oligocene Volcanic Rocks
- Ti - Middle Miocene to Oligocene Shallow Intrusions
- TXgn - Tertiary to Early Proterozoic Gneissic Rocks
- TKgm - Early Tertiary to Late Cretaceous Muscovite-Bearing Granitic Rocks
- TKg - Early Tertiary to Late Cretaceous Granitic Rocks
- Kv - Early Tertiary to Late Cretaceous Volcanic Rocks
- KJs - Cretaceous to Upper Jurassic Sedimentary Rocks with Minor Volcanic Rocks
- Jg - Jurassic Granitic Rocks
- Jv - Jurassic Volcanic Rocks
- P -Permian Sedimentary Rocks
- PIP - Permian to Pennsylvanian Sedimentary Rocks
- Yd - Middle Proterozoic Diabase
- Yg - Middle Proterozoic Granitic Rocks
- Xms - Early Proterozoic Sedimentary Rocks
- Xm - Early Proterozoic Metamorphic Rocks

0 10 20 30 40 50
Scale in Kilometers

N

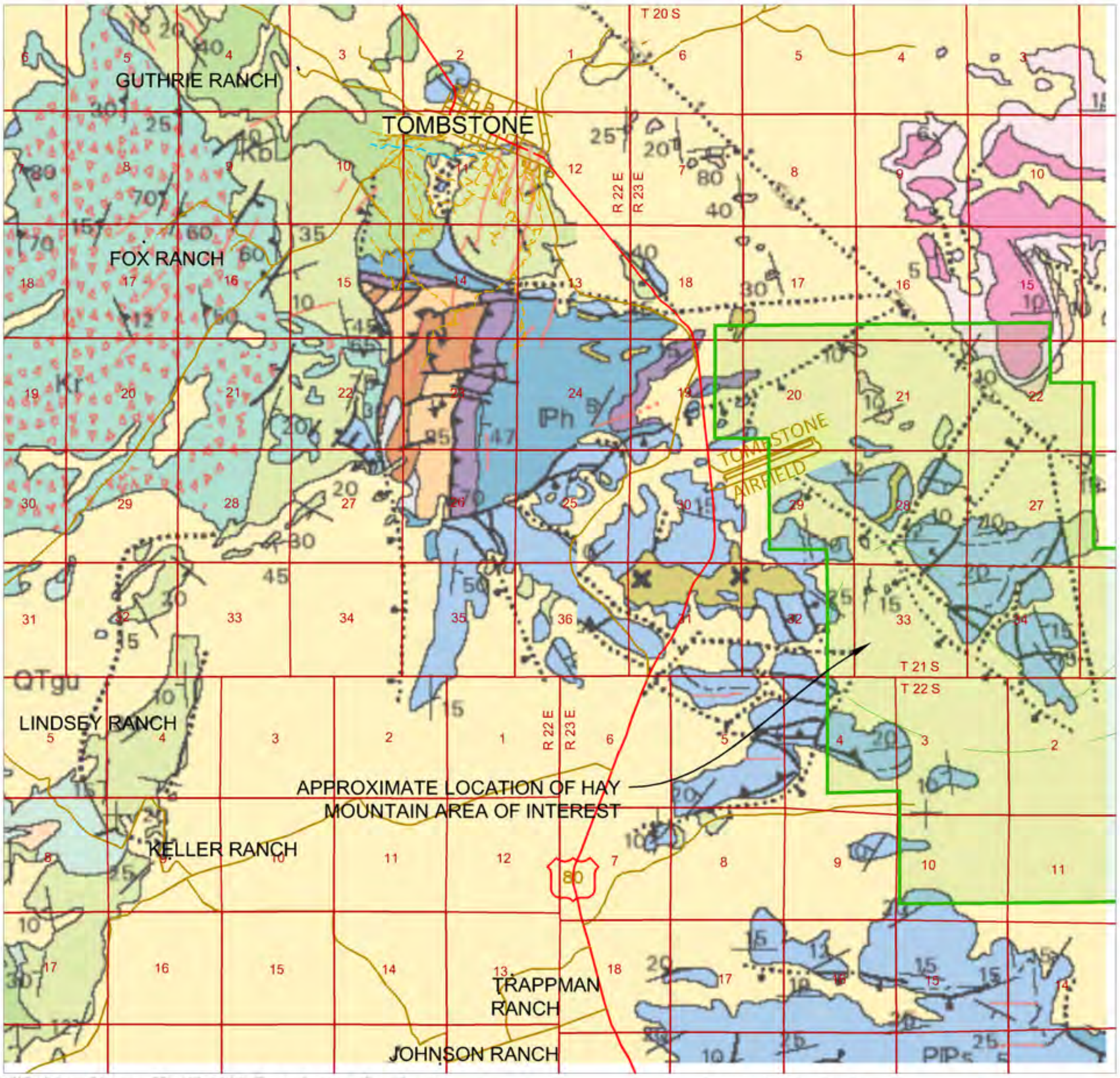
REFERENCE:
ARIZONA GEOLOGICAL SURVEY MAP 35, 2000

srk consulting	LIBERTY STAR URANIUM & METALS CORP.	Tombstone, Arizona
		Regional geology of southeastern Arizona
	Hay Mountain Exploration Report	DATE: June 2011 · APPROVED: JR · FIGURE: 7-1 · REVISION NO: 2

Age			Tombstone Hills
Quaternary			Alluvial deposits. —Unconformity— Basalt, intrusive.
Tertiary	Pliocene		Gila conglomerate: conglomerate, sandstone, silt, clay; several hundred feet. —Unconformity—
Tertiary	Eocene(?) to lower Pliocene		Rhyolite dikes, plugs, sills. —Intrusive contact— Sandstone, conglomerate, mudstone; 80 feet. —Unconformity— Schieffelin granodiorite: quartz-poor granodiorite to quartz monzonite. Andesite porphyry dikes. Uncle Sam porphyry: quartz latite porphyry to quartz monzonite porphyry. —Intrusive contact—
Upper Cretaceous or lower Tertiary			Bronco volcanics: Upper member; quartz latite and quartz latite tuff; 2,500 feet. Lower member; felsophyric andesite flows and flow breccia; 3,500 feet. —Unconformity—
Cretaceous	Comanche series		Bisbee formation: conglomerate, sandstone, mudstone; at base a little limestone; 3,000 feet. —Unconformity—
Triassic or Jurassic			Not recognized.
Permian (?) and Permian		Naco group	Epitaph dolomite: dolomite, sandstone, limestone; 780 feet. (Probably of Leonard age.)
Permian (?) and Permian		Naco group	Colina limestone: limestone, chiefly dark gray, aphanitic; 635 feet (of Wolfcamp and Leonard age).
Pennsylvanian	Upper	Naco group	Earp formation: limestone, shale, limestone conglomerate, and thin dolomite beds; 595 feet.
Pennsylvanian	Lower	Naco group	Horquilla limestone: limestone, chiefly light-gray or pink, aphanitic, a few crinoidal beds; 1,000-1,200 feet. (In places upper Pennsylvanian at top.)
Mississippian	Lower		Escabrosa limestone: massive, crinoidal limestone; 786 feet. (May include upper Mississippian locally.)
Devonian	Upper		Martin limestone: limestone, shale, sandstone, a little chert; 230 feet.
Cambrian	Upper		Abrigo limestone: limestone, limestone mottled with shale, shale, a little quartzite; 844 feet.
Cambrian	Middle		Bolsa quartzite: quartzite, grit, and conglomerate; 440 feet. —Unconformity—
Pre-Cambrian			Albite granite. —Intrusive contact— Pinal schist: muscovite, chlorite, quartz schist, minor amphibolite.

Source: Gilluly, 1956

Figure 7-2 Generalized stratigraphic column in Tombstone district



Modified from Drewes, Harold, 1980, Tectonic map of southeast Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I-1109.

Approximate Scale

0 5 MILES

EXPLANATION

Kb - Upper part of Bisbee Formation or Group, undifferentiated, and related rocks (Bisbee Formation or Group, undifferentiated)

Klq - Lower quartz monzonite and granodiorite (lower Cordilleran (Laramide) igneous and sedimentary rocks)

PIPs - Sedimentary rocks of the Epitaph Dolomite, Colina Limestone, and Earp Formation, undifferentiated (Naco Group)

IPh - Horquilla Limestone (Naco Group)

MDs - Escabrosa Limestone and Martin Formation, undifferentiated

Yg - Granodiorite and quartz monzonite (granitoid rocks)

QTgu - Gravel, sand, and silt (older or undifferentiated surficial deposits)

Tva - Extrusive andesite and dacite (upper igneous and sedimentary rocks)

Tv - Extrusive rhyolite and rhyodacite (upper igneous and sedimentary rocks)

Kr - Rhyodacite tuff and welded tuff (lower Cordilleran (Laramide) igneous and sedimentary rocks)

Ka - Andesitic to dacitic volcanic breccia (lower Cordilleran (Laramide) igneous and sedimentary rocks)

Normal fault, dotted where concealed

Thrust fault; dotted where concealed, teeth on upper plate

REFERENCES: LIBERTY STAR DATA FILES, USGS

srk consulting

LIBERTY STAR URANIUM & METALS CORP.

Tombstone, Arizona

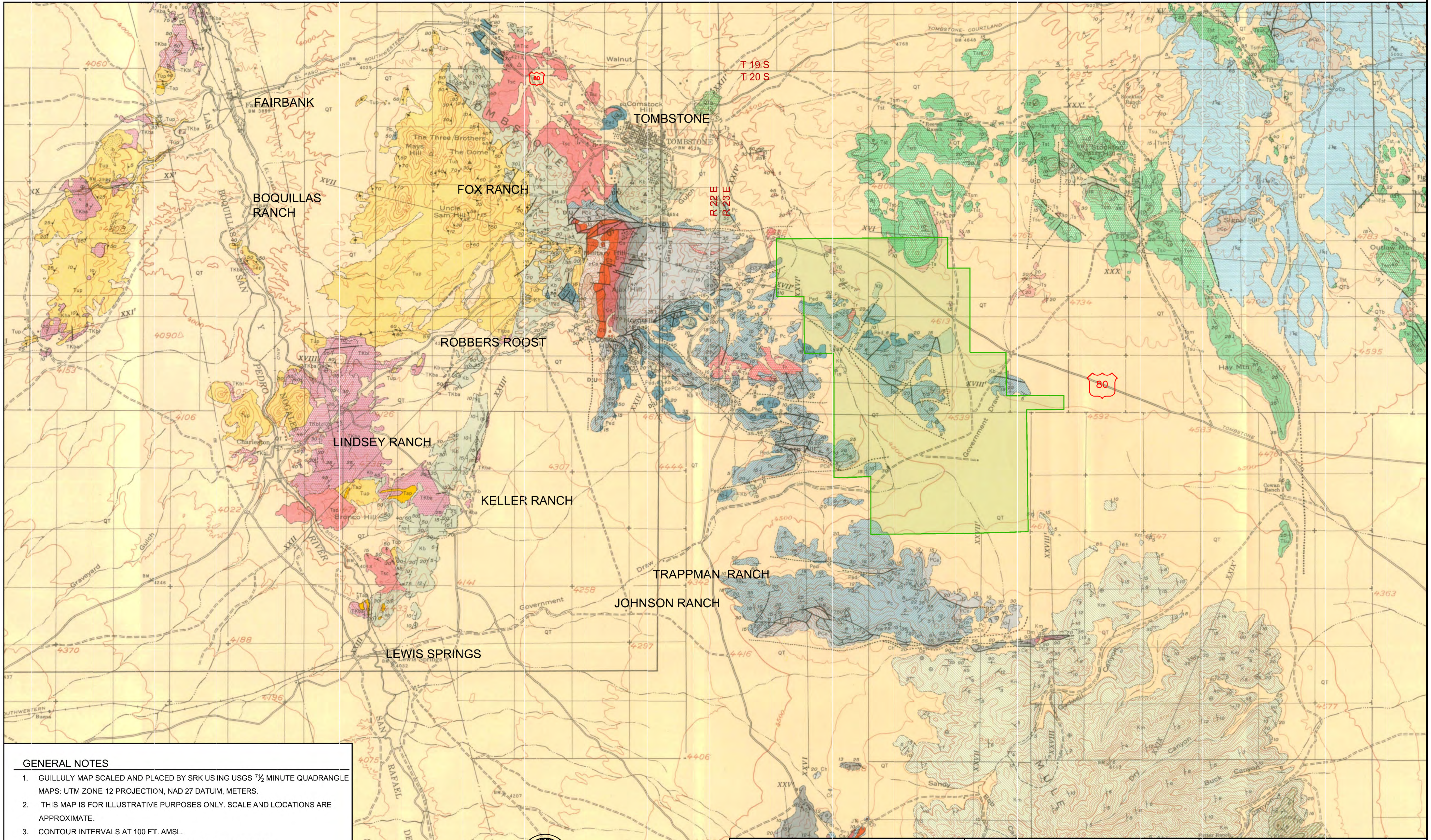
Generalized geology of the Tombstone Hills

SRK JOB NO.: 173300.03 Task 600 Internal Control Number 3

FILE NAME: 7-3 Generalized geology of the Tombstone Hills

Hay Mountain Exploration Report

DATE:	APPROVED:	FIGURE:	REVISION NO.
June 2011	JR	7-3	1



GENERAL NOTES

1. GUILLULY MAP SCALED AND PLACED BY SRK USING USGS 7½ MINUTE QUADRANGLE MAPS: UTM ZONE 12 PROJECTION, NAD 27 DATUM, METERS.
2. THIS MAP IS FOR ILLUSTRATIVE PURPOSES ONLY. SCALE AND LOCATIONS ARE APPROXIMATE.
3. CONTOUR INTERVALS AT 100 FT. AMSL.
4. EXPLANATION OF GEOLOGIC FEATURES ON SEPERATE FIGURE.

REFERENCES

1. GILLULY, 1956, USGS PROFESSIONAL PAPER 281.
2. LIBERTY STAR DATA FILES.
3. USGS (SRK LIBRARY).

N

0 1 2 3 4 5

Scale in Kilometers

srk consulting

LIBERTY STAR URANIUM & METALS CORP.

SRK JOB NO.: 173300.03 Task 600	Internal Control Number 5	
FILE NAME: 7-4 Detailed geology of the Tombstone Hills		

Hay Mountain Exploration Report

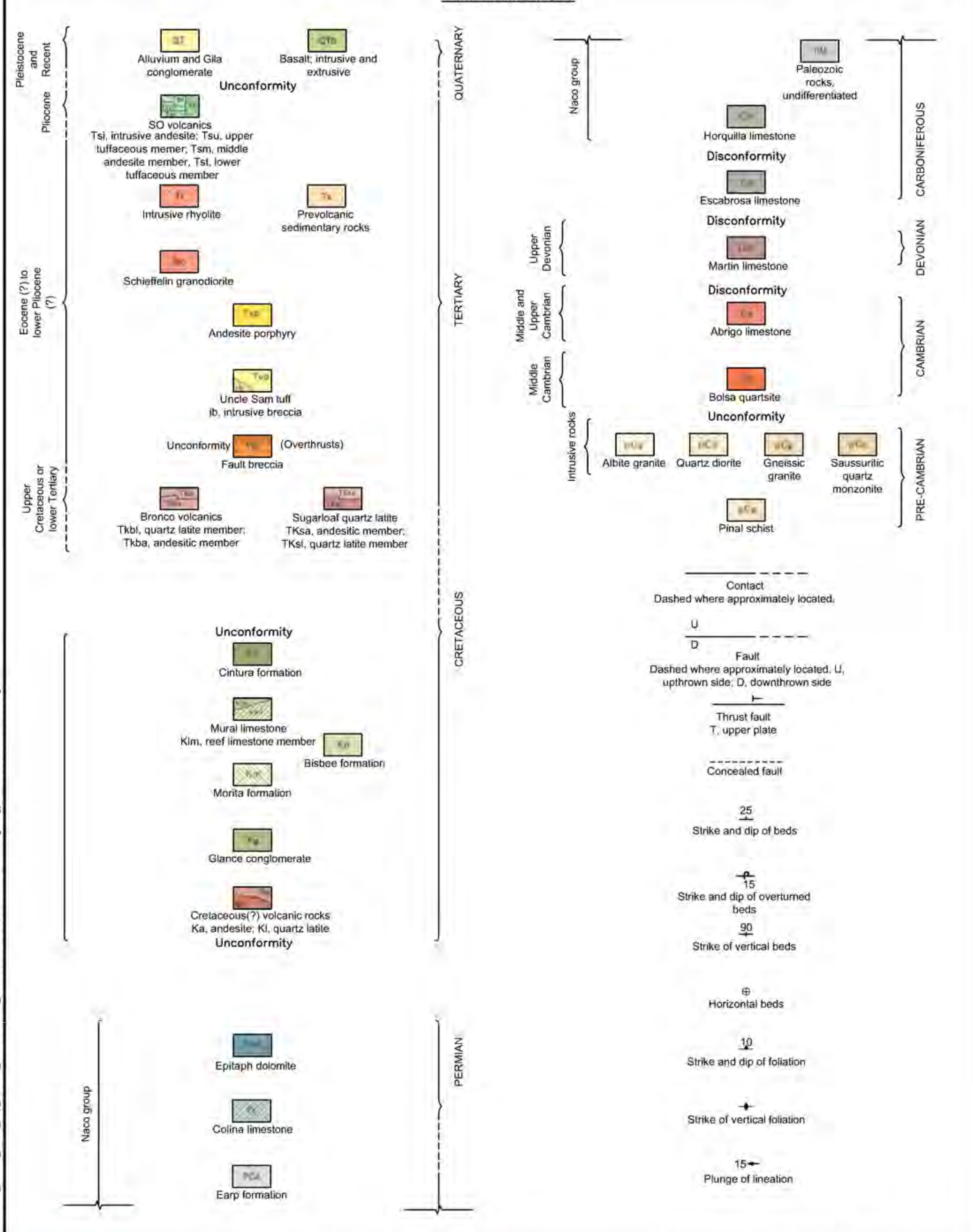
Tombstone, Arizona

Detailed geology of the Tombstone Hills and surrounding areas

DATE:	APPROVED:	FIGURE:	REVISION NO.
June 2011	JR	7-4	1

P:\Liberty_Star_Uranium+Metals\173300.030_Walnut_Creek_Exp_Rpt\040_AutoCAD\HAY_MOUNTAIN\7-4 Detailed geology of the Tombstone Hills.dwg

EXPLANATION



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LIBERTY STAR URANIUM & METALS CORP.

Tombstone, Arizona

Explanation for detailed geology of the Tombstone Hills

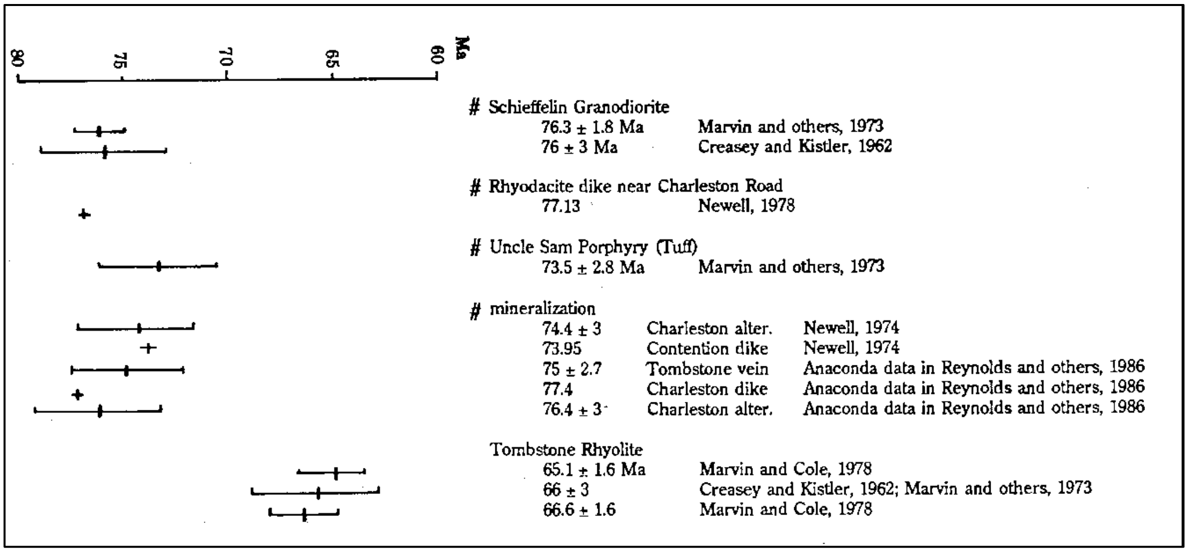
SRK JOB NO.: 173300.03 Task 600 | Internal Control Number 5

FILE NAME: 7-5 Explanation for detailed geology of the Tombstone Hills

Hay Mountain Exploration Report

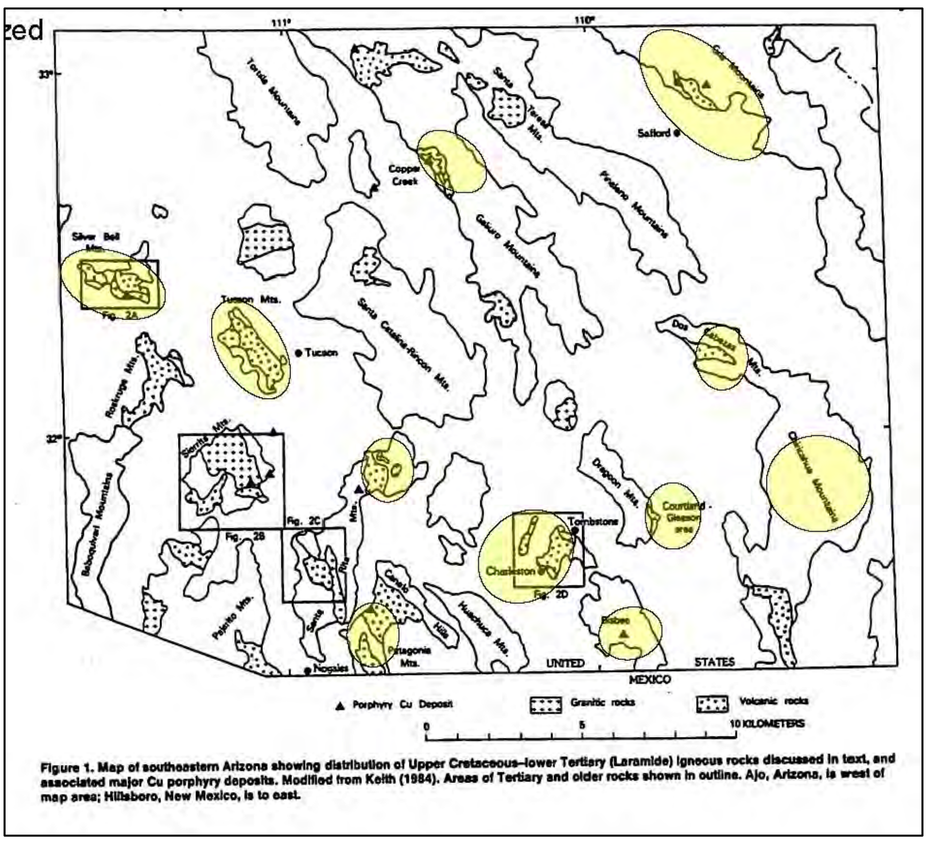
DATE:	APPROVED:	FIGURE:	REVISION NO:
June 2011	JR	7-5	1

P:\Liberty_Star_Uranium+Metals\173300.030_Walnut_Creek_Exp_Rpt\040_AutoCAD\HAY_MOUNTAIN\7-5 Explanation for detailed geology of the Tombstone Hills.dwg



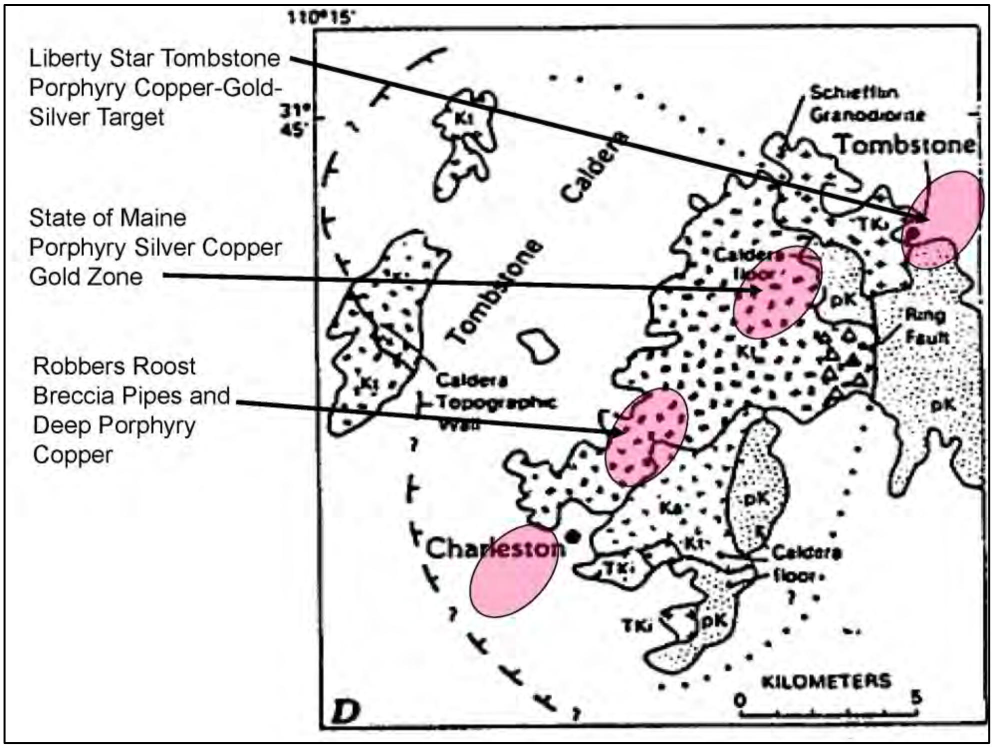
Source: Wilt, 1993

Figure 7-6 Age dates on igneous rocks in Tombstone Hills



Source: Liberty Star data

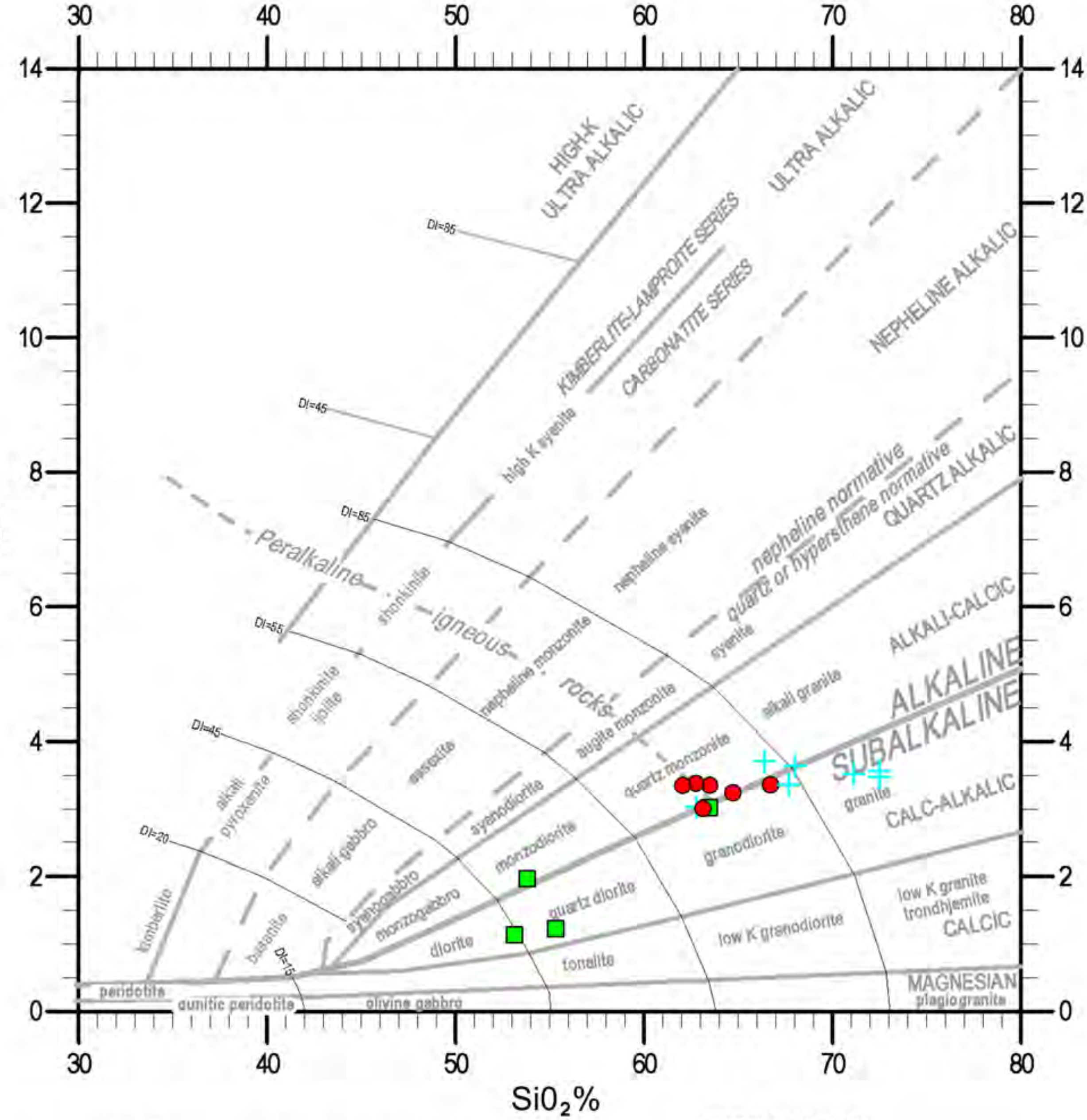
Figure 7-7 Calderas in southern Arizona



Source: Liberty Star data

Figure 7-8 Caldera structures at Tombstone

Figure 7-9 Rhyolite porphyry sill (62 Ma) on west side of SR 80 north of Colina Ridge (looking north)



K_2O vs. wt. % SiO_2. Plot is used to evaluate metaluminous magma series

DI = Differentiation Index from Thorton and Tuttle (1960)
Terminology is modified from Peacock (1931)

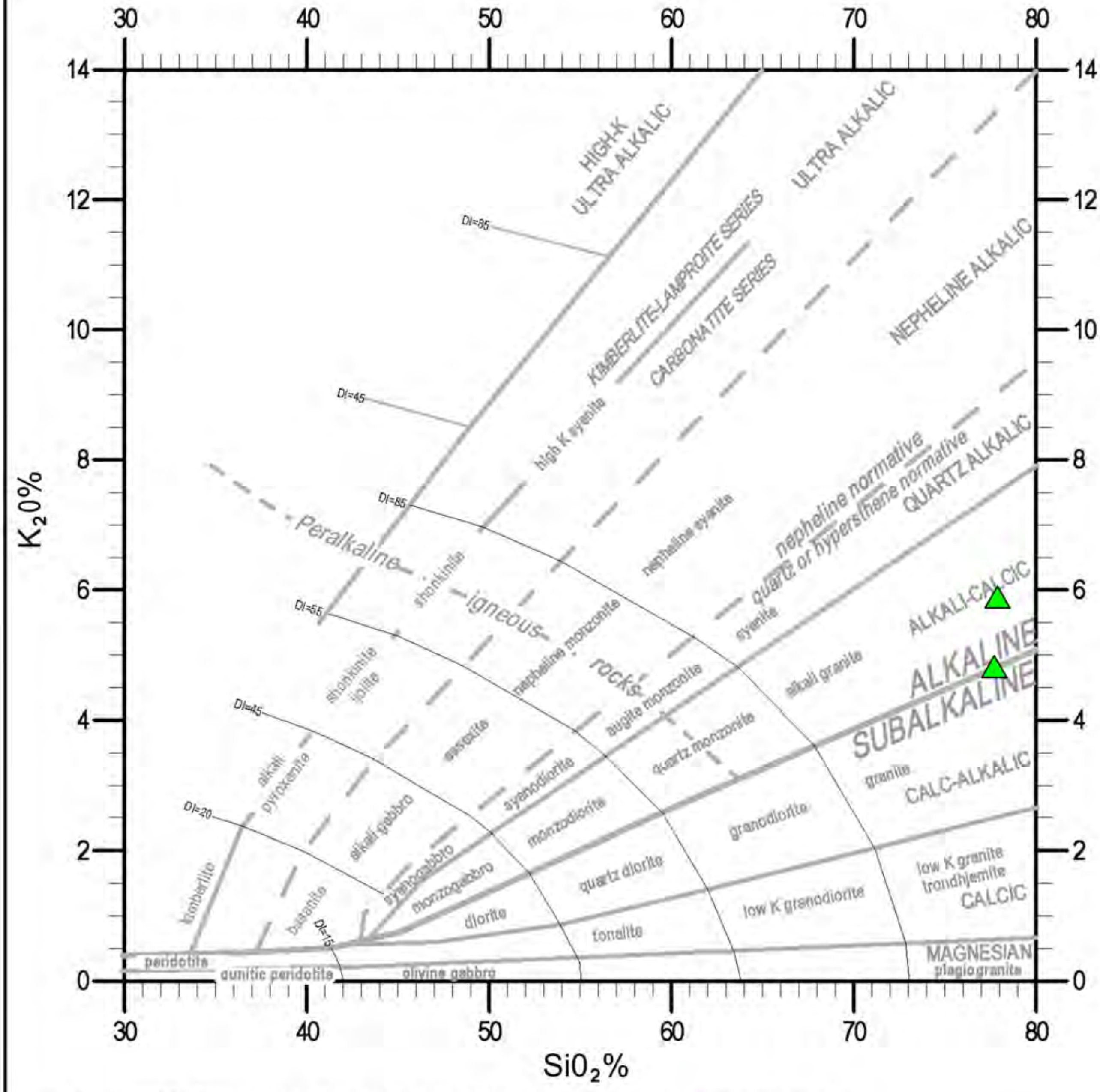
EXPLANATION

- BRONCO VOLCANICS
- SCHIEFFELIN GRANODIORITE
- UNCLE SAM PORPHYRY (Ty)

REFERENCES

1. SOURCE DATA FROM WILT, 1993

srk consulting	LIBERTY STAR URANIUM & METALS CORP.	Tombstone, Arizona — Alkalinity of Early Laramide rocks in the Tombstone Hills
SRK JOB NO.: 173300.03 Task 600 — Internal Control Number: 3	Hay Mountain Exploration Report	DATE: June 2011; APPROVED: JR; FIGURE: 7-10; REVISION NO.: 1
FILE NAME: 7-10 Alkalinity of Early Laramide rocks in the Tombstone Hills		



K_2O vs. wt. % SiO_2. Plot is used to evaluate metaluminous magma series

DI = Differentiation Index from Thorton and Tuttle (1960)
Terminology is modified from Peacock (1931)

EXPLANATION

▲ TOMBSTONE RHYOLITE

REFERENCES

1. SOURCE DATA FROM WILT, 1993 (SAMPLES FAILED THE ALTERATION FILTER, SO THEY PLOT MORE ALKALINE)

srk consulting

LIBERTY STAR URANIUM & METALS CORP.

Tombstone, Arizona

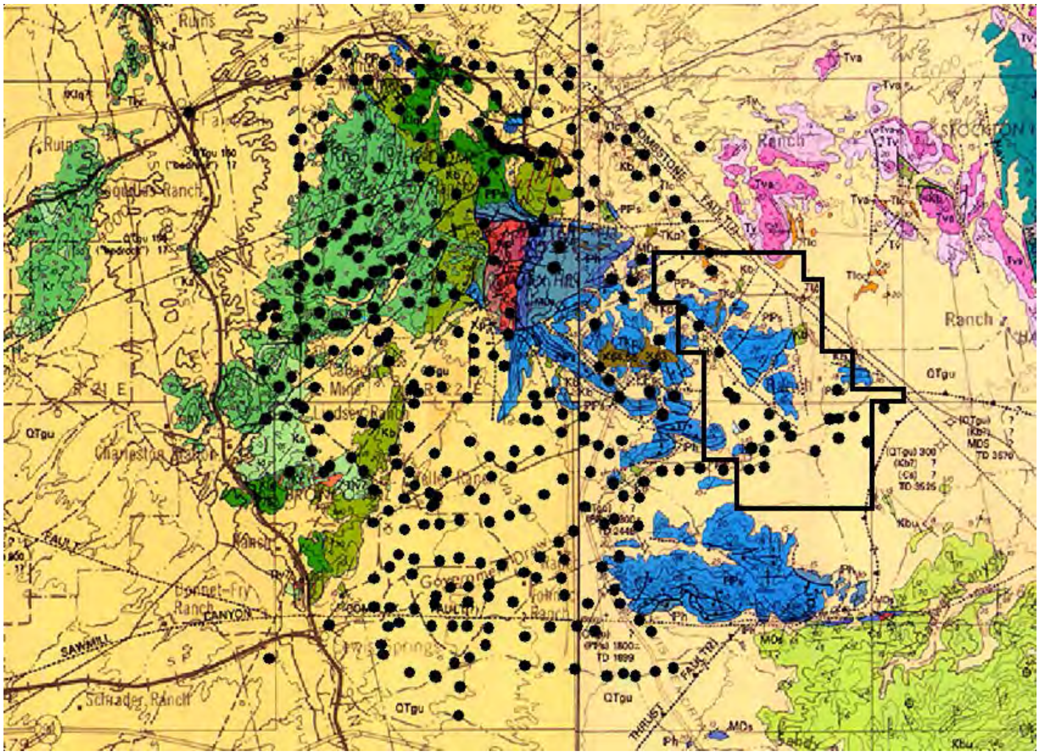
Alkalinity of 62 Ma rhyolite porphyry (Middle Laramide) in the Tombstone Hills

SRK JOB NO.: 173300.03 Task 600 Internal Control Number: 3

FILE NAME: 7-11 Alkalinity of 62 Ma rhyolite porphyry (Middle Laramide)

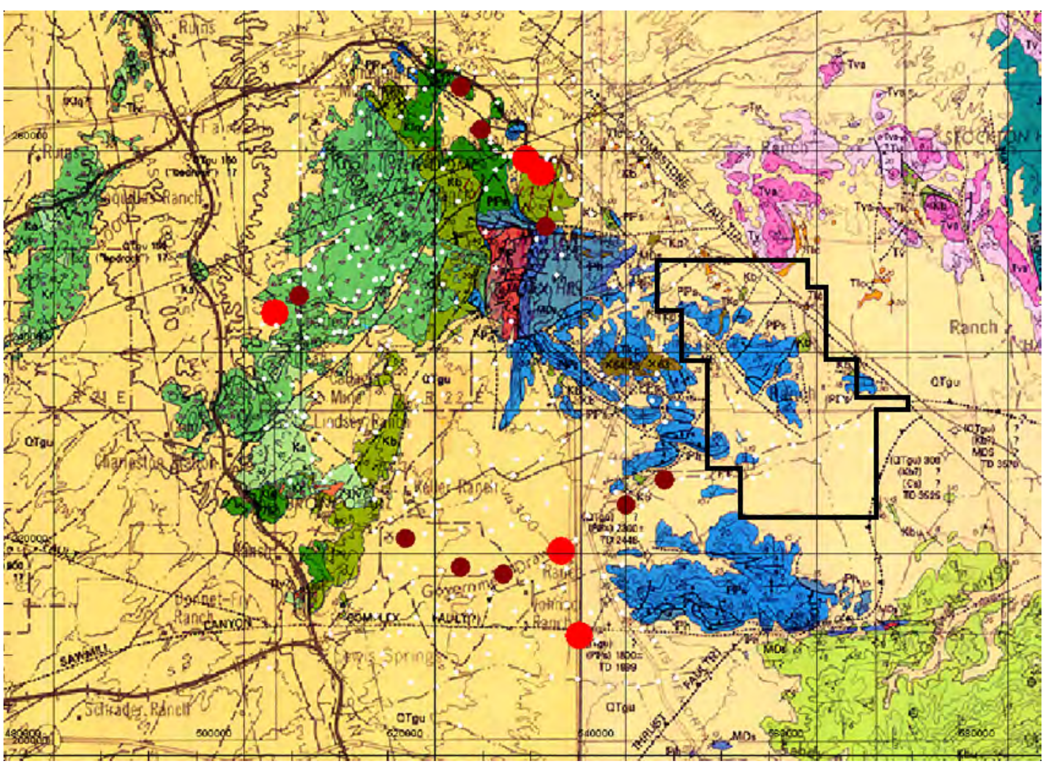
Hay Mountain Exploration Report

DATE:	APPROVED:	FIGURE:	REVISION NO.
June 2011	JR	7-11	1



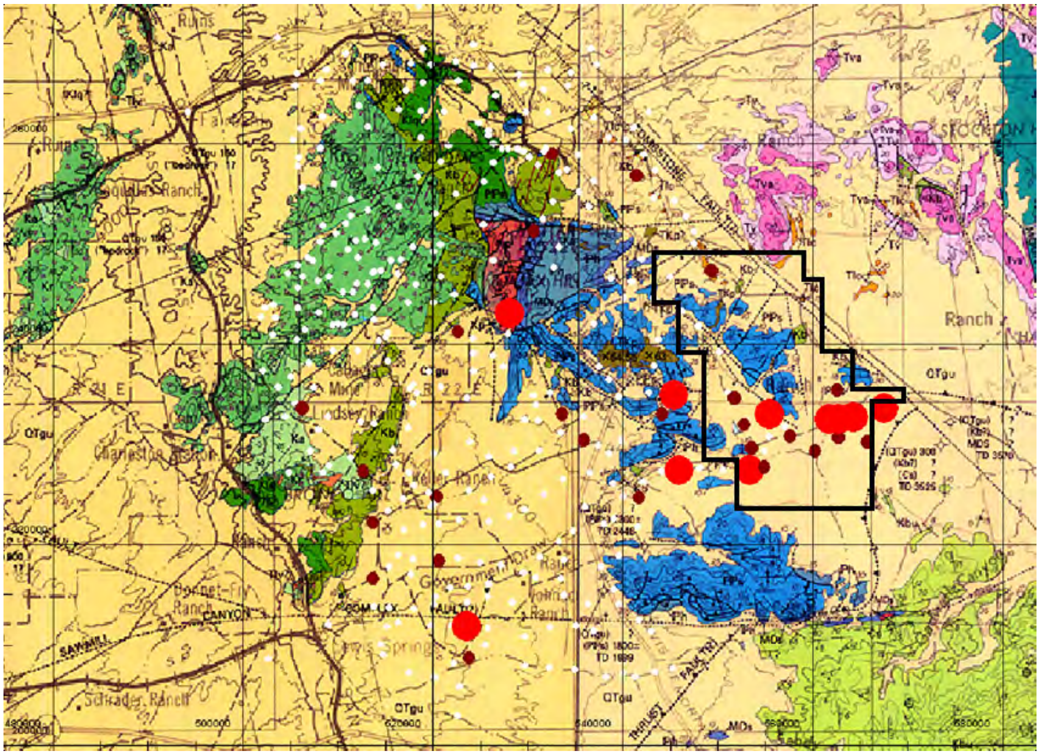
Source: Smith (1999). Blacl dots are sample locations

Figure 7-12 Location map for mesquite samples



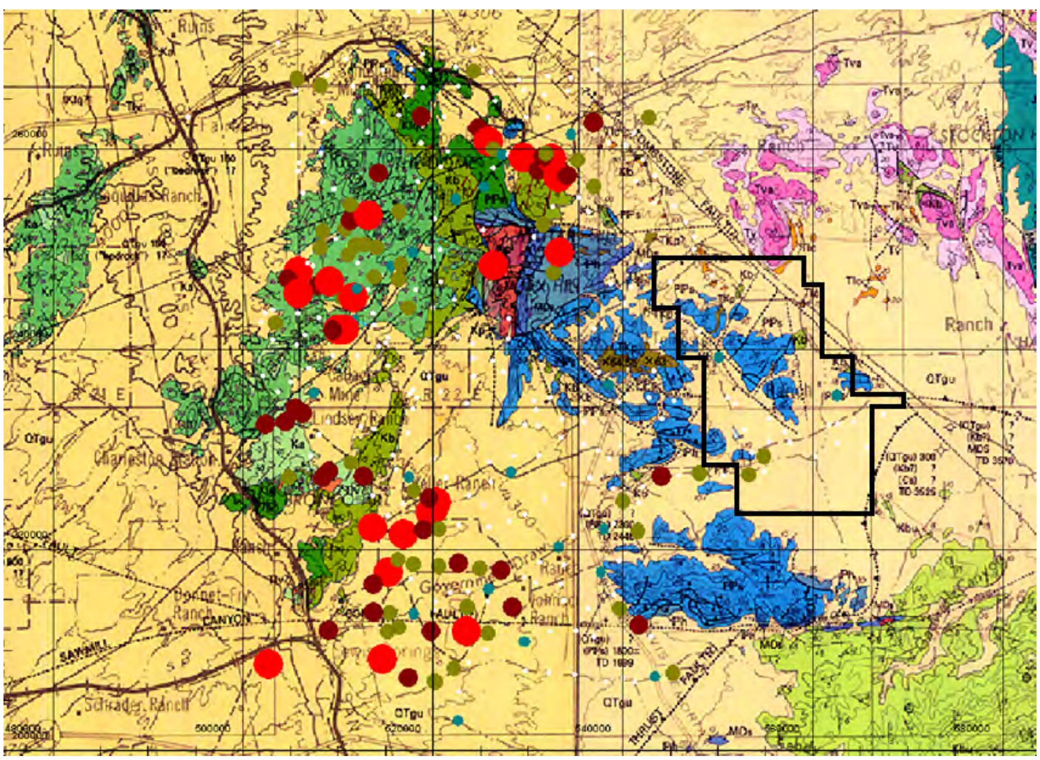
Source: Smith (1999). White = <2 ppm, purple = 2-3 ppm, red=3-4 ppm

Figure 7-13 High Ag in mesquite twigs



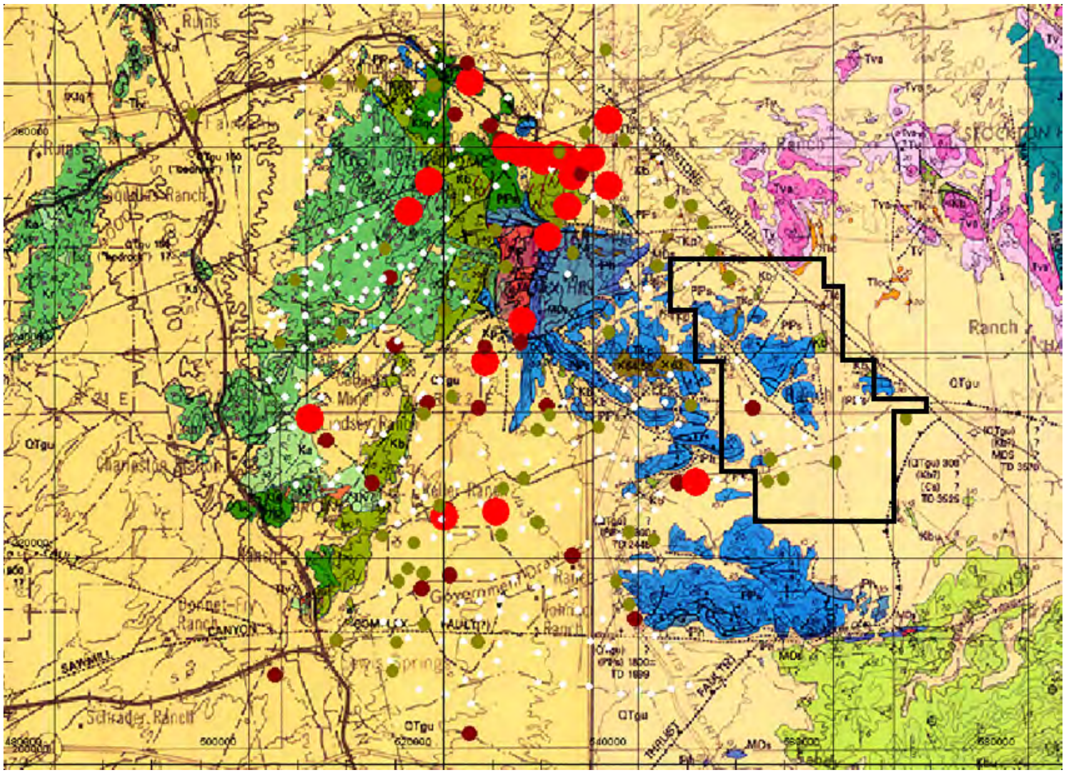
Source: Smith (1999). White <175 ppm; purple = 175-221 ppm, red= 221-295 ppm

Figure 7-14 High Cu in mesquite twigs



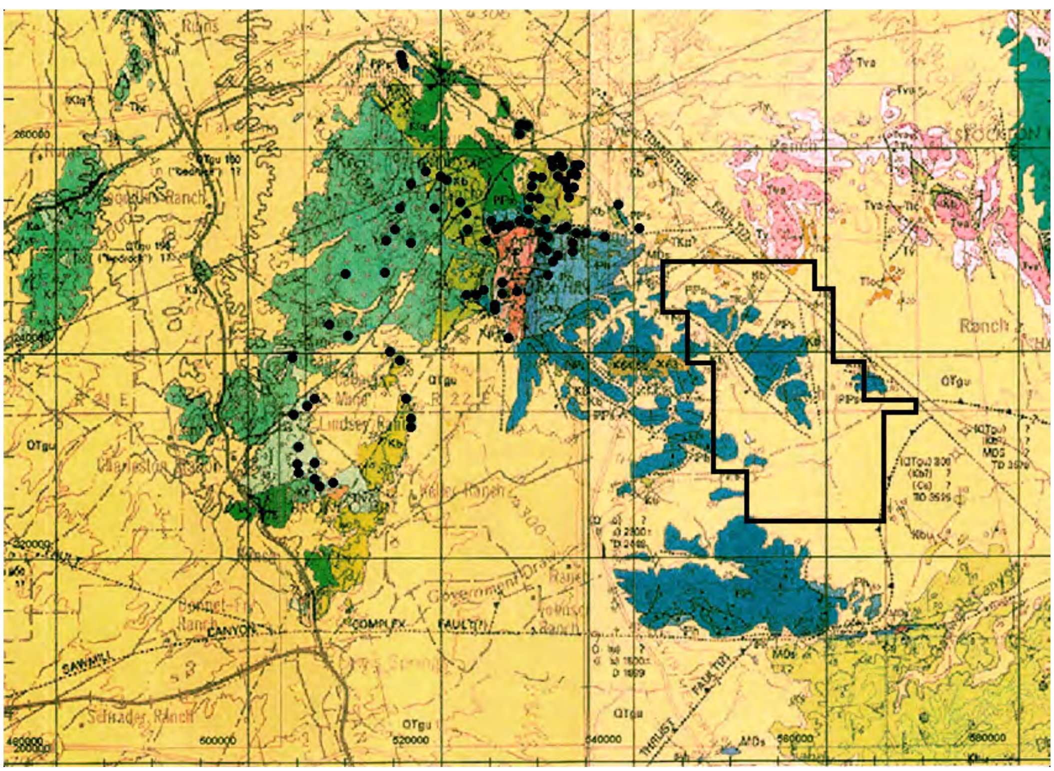
Source: Smith (1999). White <3 oonm tyrqyiuse = 3-5 ppm, green = 5-8 ppm purple = 8-12 ppm, red = 12-36 ppm

Figure 7-15 High Mo in mesquite twigs



Source: Smith (1999). White <460 ppm, green = 460-580 ppm, purple =580-730 ppm, red = 730-1600 ppm

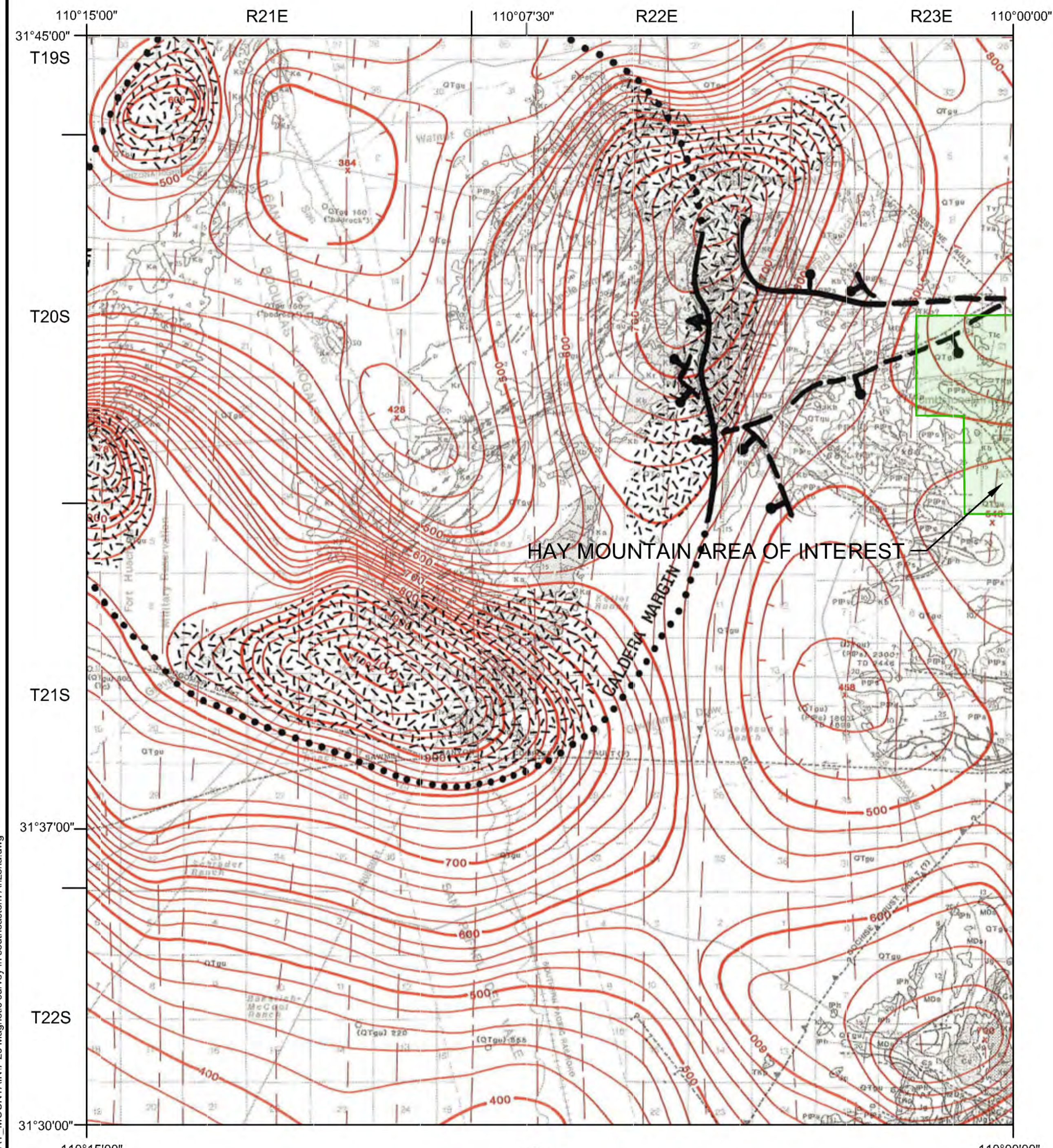
Figure 7-16 High Zn in mesquite twigs

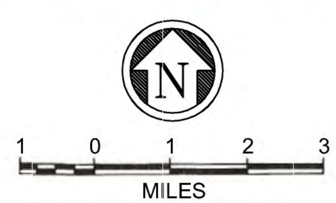


Source: Smith (1999) from Newell (1974 data)

Figure 7-17 Location of mine dump samples

Explanation





Geology

QTgu — OLDER OR UNDIFFERENTIATED SURFICAL DEPOSITS (HOLOCENE TO OLIGOCENE)—Gravel, sand, and silt (Pleistocene and Pliocene—Mainly alluvium of basins; includes some colluvium and landslide deposits. Generally light-pinkish gray, weakly indurated, and with poorly rounded clasts; locally well indurated. Thickness several meters to hundreds of meters.

QTb — Basalt (Pleistocene to Pliocene)—Lava flows, pyroclastic rocks, and some intercalated gravel. Thickness several meters to a few hundred meters in most places. Radiometrically dated at 0.25, 1.0, and 3.2 m.y. old

Tva — Extensive andesite and dacite (Miocene and Upper Oligocene)—Lava flows, pyroclastic rocks, some intercalated epiclastic rocks, and dikes. Mostly gray, fine-grained, porphyritic rocks; includes some very coarse feldspar porphyry andesite (Turkey track porphyry, an informal term of Cooper, 1961). Thickness mostly several meters to several tens of meters. Dated at 24, 25, 27, 33, and 39 m.y.

Tv — Extrusive rhyolite and rhyodacite (Miocene and Upper Oligocene—Lava flows, welded tuff, pyroclastic rocks, and some intercalated epiclastic rocks. Light-gray to grayish-pink, vitric to fine-grained, porphyritic. Commonly a few tens to a few thousand of meters thick. Dated at 23, 24, 25, 26, 26, 26, and 27 m.y. An additional date of 47 m.y., if substantiated, may indicate the presence of Eocene rocks in the lower member of the S O Volcanics of Cochise Co.

Tlc — Lower conglomerate, gravel, and sand (Oligocene and Eocene?)—Alluvium; commonly grayish-red deposits of small, well rounded, nonvolcanic clasts. Mostly several meters to a few tens of meters thick.

Tlv — UPPER CORDILLERAN (LARAMIDE) IGNEOUS ROCKS (LOWER PALEOCENE):—Lower volcanic rocks—Rhyolite to andesite lava flows, pyroclastic rocks, and some intercalated epiclastic rocks. Dated at 57 m.y. Possibly younger age to east.

TKp — MAIN CORDILLERAN (LARAMIDE) IGNEOUS ROCKS:—Porphyritic and aplitic intrusive rocks (Paleocene and Upper Cretaceous)—Mostly latitic porphyry to dacitic porphyry in small stocks and plugs and aplitic bodies not associated with other granitoid stocks. Dated at 61, 63, 63, 64, and 65 m.y.

Kib — Fluidized intrusive breccia - exact age unknown, but penetrates, and thus younger than Uncle Sam porphyry.

Kr — Rhyodacite tuff and welded tuff. - Includes parts of Salero Formation, Sugarloaf Quartz Latite, and Bronco Volcanics, and all of Red Bay Rhyolite, Cat Mountain Rhyolite of Brown (1939) and Uncle Sam Prophyry. Includes local intrusive bodies and locally contains fragments of exotic rocks. Thickness commonly several tens of meters to several hundreds of meters. Dated at 66(?), 70, 72, 73, and 73 m.y. The Uncle Sam, in the Tombstone area, is dated 72 m.y.

Ka — Andesitic to dacitic volcanic breccia.—Includes parts of Solero Formation, Sugarloaf Quartz Latite, and Bronco Volcanics, and all of Demetrie Volcanics and Silverbell Formation of Courtright (1958). Commonly contains large blocks of exotic rocks and locally includes some sedimentary rocks and intrusive rocks. Several tens of meters to several hundreds of meters thick in most places.

Kiq — Lower quartz monzonite and graodiorite—Includes some quartz diorite; appears in small stocks. Locally associated with mineralization. Dated at 70, 71, 72, 73, 74, 74, 74, and 76 m.y. The Schieffin granodorite at Tombstone is 72 m.y.

Kb — BISBEE FORMATION OR GROUP, UNDIFFERENTIATED (LOWER CRETACEOUS):—Upper part of Bisbee Formation or Group, undifferentiated, and related rocks.—Includes upper part of Bisbee Formation, Mural Limestone, Morita, Cintura, Willow Canyon, Apache Canyon, Shellenberger Canyon and Turney Ranch Formations (not listed in stratigraphic sequence) of the Bisbee Group, Amole Arkose of Bryant and Kinnison (1954), and Angelic Arkose. Consists of brownish- to reddish arkose, gray siltstone, sandstone, conglomerate, and some fossiliferous gray limestone. Commonly several hundred meters thick

Jg — GRANITE AND QUARTZ MONZONITE (JURASSIC)—Stocks of pinkish-gray coarse-grained rock. Locally associated with mineralization. Dated at 140, 148, 149, 149, 150, 153, 160, 161, 167, 178, 185 m.y.

PIPs — Sedimentary rocks (Lower Permian and Upper Pennsylvanian)—consists of Epitaph Dolomite (Lower Permian), Colina Limestone (Lower Permian), and Earp Formation (Lower Permian and Upper Pennsylvanian), undifferentiated. Epitaph Dolomite is a dark- to light-gray slightly cherty dolomite, limestone, marl, siltstone, and gypsum, 120-280 meters thick. Colina Limestone is a medium gray, thick-bedded, sparsely cherty, and sparsely fossiliferous limestone 120-280 meters thick. Earp Formation is a pale-red siltstone, mudstone, shale, and limestone, 120-240 meters thick.

IPh — Horquilla Limestone (Upper and Middle Pennsylvanian)—Light-pinkish-gray, thick- to thin-bedded, cherty, fossiliferous limestone and intercalated pale-brown to pale-reddish-gray siltstone that increases in abundance upward. Typically 300-490 meters thick.

MDs — SEDIMENTARY ROCKS (MISSISSIPPIAN AND DEVONIAN)—Consists mainly of Escabrosa Limestone (Mississippian)—locally (Armstrong and Silberman, 1974) called Escabrosa Group—and Martin Formation (Upper Devonian), undifferentiated. In part of the Chiricahua Mountains also includes Paradise Formation (Upper Mississippian) and Portal Formation of Sabins, 1957a (Upper Devonian). In the Little Dragoon Mountains and some adjacent hills also includes Black Prince Limestone, whose fauna and correlation show strongest affinities with Mississippian rocks but which may include some Pennsylvanian rocks. Escabrosa Limestone is a medium-gray, massive to thick-bedded, commonly crinoidal, cherty, fossiliferous limestone 90-310 meters thick. Martin Formation is thick- to thin-bedded, gray to brown dolomite, gray sparsely fossiliferous, and some siltstone and sandstone, 90-120 meters thick. Paradise Formation is a brown, fossiliferous, shaly limestone. Portal Formation is a black shale and limestone 6-105 meters thick. Black Prince Limestone is pinkish-gray limestone with a basal shale and chert conglomerate, as much as 52 meters thick.

O€a — SEDIMENTARY ROCKS (LOWER ORDOVICIAN TO MIDDLE CAMBRIAN):—El Paso Limestone (Lower Ordovician and Upper Cambrian), Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartz (Middle Cambrian), undifferentiated.—El Paso Limestone is a gray, thin-bedded cherty limestone and dolomite 90 meters to about 220 meters thick. Abrigo Formation is a brown, thin-bedded fossiliferous limestone, sandstone, quartzite, and shale, 210-240 meters thick. Bolsa Quartzite is a brown to white or purplish-gray, thick-bedded, coarse-grained quartzite and sandstone with a basal conglomerate, 90-180 meters thick. To the east, equivalents of part of the Abrigo Formation and Bolsa Quartzite are known as the Coronado Sandstone.

€a — Sedimentary rocks (Upper and Middle Cambrian)—Abrigo Formation (Upper and Middle Cambrian), and Bolsa Quartzite (Middle Cambrian), undifferentiated.

Yg — GRANITOID ROCKS (PRECAMBRIAN Y):—Mainly granodiorite and quartz monsonite, unfoliated to foliated, in part metamorphosed. Generally in stocks, which ahve been little studied.

Xp — PINAL SCHIST (PRECAMBRIAN X)—Chlorite schist, phyllite, and some metavolcanic rocks, metavolcanic rocks, metaquartzite, metaquartzite conglomerate, and gneiss. One metavolcanic rock dated at 1715 m.y.

CONTACT—Dotted where concealed.

MARKER HORIZON—Dotted where concealed.

DIKES—Showing dip.

FAULTS—Showing dip. Dotted where concealed or intruded; ball and bar on downthrown side.

70

45 Normal

Reverse 45

Strike slip—Arrow couple shows relative displacement. Single arrow shows movement of active block.

Major thrust fault—Sawteeth on upper plate.

Thrust fault—Sawteeth on upper plate.

Anticline.

Syncline.

30 Inclined strike and dip of beds.

EXOTIC BLOCK BRECCIA—Rock contains chip or block inclusions of rock different from those of host or other blocks nearby. Typically of volcanic-tectonic or sedimentary-tectonic origin; excludes Tertiary megabreccia deposits.

(QTgu) 157 — Site of well or generalized site of several wells, showing unit penetrated, if known, and depth of well, in feet. 100 feet equals 30.5 meters.

72x — COLLECTION SITE—Radiogenically dated rock showing age in millions of years. Query before symbol where precise location uncertain.

Dry wash

Southern Pacific Railroad

Government Reservation Boundary

Aqueduct

A—A' Cross section line

Flight line

Index contour line

Contour line

Contour interval: 25 gammas

GENERAL NOTES

1. UTM ZONE 12 PROJECTION, NAD 27 DATUM, FEET
2. FOR ILLUSTRATIVE PURPOSES ONLY. DIMENSIONS AND LOCATIONS ARE APPROXIMATE.

REFERENCES

1. AGS FIELD GUIDEBOOK 1988-10

srk consulting	LIBERTY STAR URANIUM & METALS CORP.	Tombstone, Arizona
SRK JOB NO.: 173300.03 Task 600 — Internal Control Number 3	Hay Mountain Exploration Report	Magnetic survey in southeastern Arizona
FILE NAME: 7-23 Magnetic survey in southeastern Arizona		DATE: June 2011 · APPROVED: JR · FIGURE: 7-18 · REVISION NO. 1

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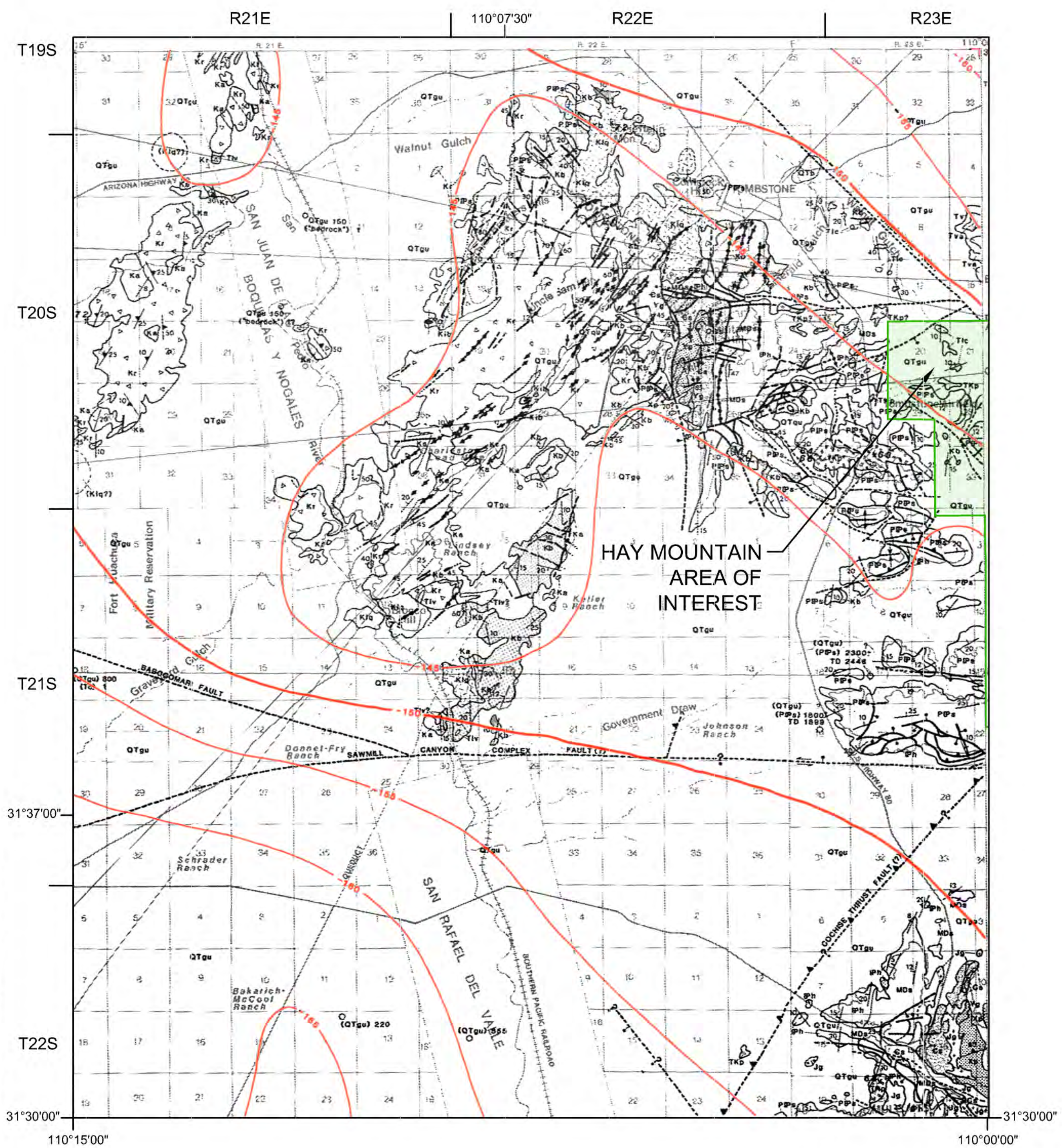

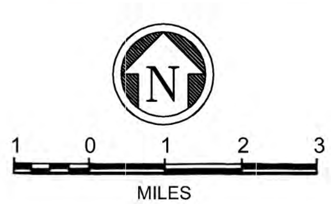

GENERAL NOTES

UTM ZONE 12 PROJECTION, NAD 27 DATUM, FEET

REFERENCES

1. AGS FIELD GUIDEBOOK 1988-10

Explanation

Geology

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CONTACT—Dotted where concealed.

MARKER HORIZON—Dotted where concealed.

DIKES—Showing dip.

FAULTS—Showing dip. Dotted where concealed or intruded, ball and bar on downthrown side. (70)

Normal (45)

Reverse (45)

Strike-slip—Arrow couple shows relative displacement. Single arrow shows movement of active block.

Major thrust fault—Sawteeth on upper plate.

Thrust fault—Sawteeth on upper plate.

Anticline.

Syncline.

(30) Inclined strike and dip of beds.

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(QTgu) 157 — Site of well or generalized site of several wells, showing unit penetrated, if known, and depth of well, in feet. 100 feet equals 30.5 meters.

72x — COLLECTION SITE—Radiogenically dated rock showing age in millions of years. Query before symbol where precise location uncertain.

Dry wash

Southern Pacific Railroad

Government Reservation Boundary

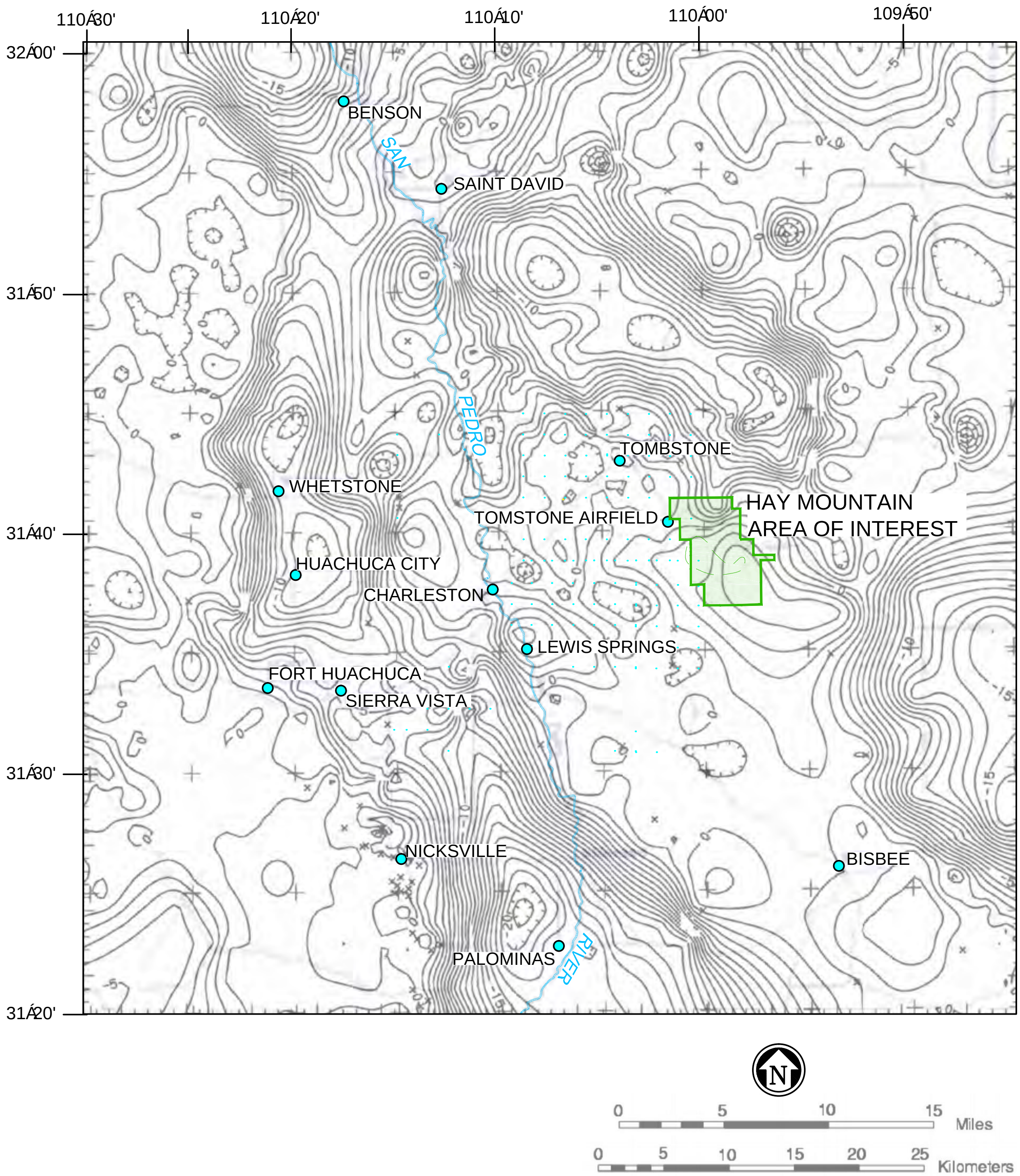
Aqueduct

Cross section line

-150 Gravity contour line

Contour interval: 5 milligals

srk consulting	LIBERTY STAR URANIUM & METALS CORP.	Tombstone, Arizona
SRK JOB NO.: 173300.03 Task 600 — Internal Control Number 3	Hay Mountain Exploration Report	Gravity survey in Tomstone Hills
FILE NAME: 7-19 Gravity survey in Tomstone Hills		DATE: June 2011; APPROVED: JR; FIGURE: 7-19; REVISION NO. 1



EXPLANATION

Residual gravity anomaly map, upper San Pedro basin, southeastern Arizona. Contour interval 1 mGal. Symbols "x" mark location of drillhole penetrating to bedrock. Closed contours of relative low are hatchured. Numbered ticks along horizontal and vertical axes are UTM coordinates relative to 31° north latitude and 111° west longitude.

REFERENCES

1. US DEPARTMENT OF INTERIOR, USGS OPEN FILE REPORT 00-138. GETTINGS AND HAUSER (2000).
2. LIBERTY STAR DATA FILES.

GENERAL NOTES

1. THIS DRAWING IS FOR DESCRIPTIVE PURPOSES ONLY. ALL DIMENSIONS AND LOCATIONS ARE APPROXIMATE BASED ON AVAILABLE INFORMATION.

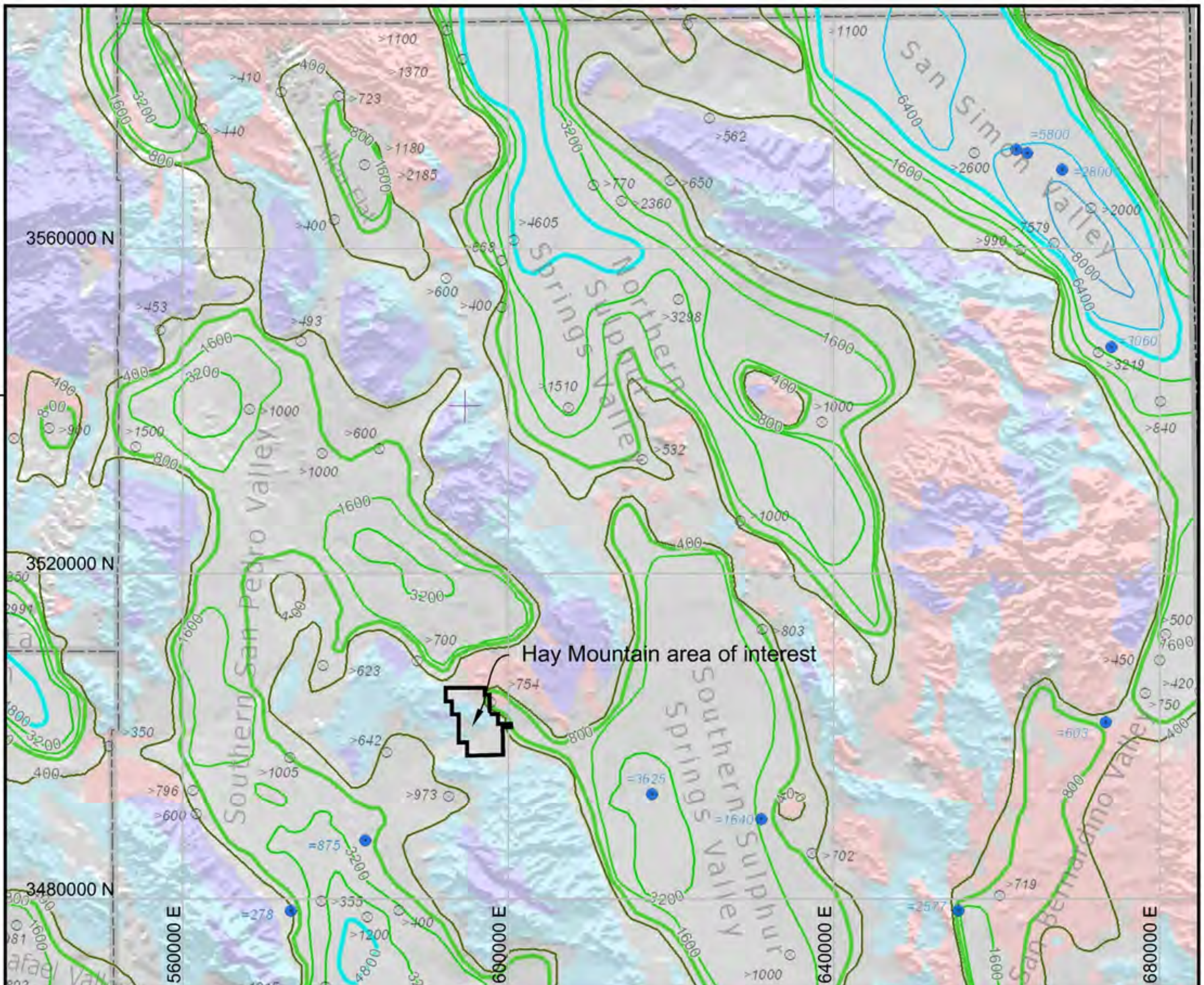
srk consulting

LIBERTY STAR URANIUM & METALS CORP.

Tombstone, Arizona

Residual gravity anomaly map, upper San Pedro basin, southeastern Arizona

SRK JOB NO.: 173300.03 Task 600	Internal Control Number 4	Hay Mountain Exploration Report	DATE: June 2011	APPROVED: JR	FIGURE: 7-20	REVISION NO. 2
FILE NAME: 7-20 Residual gravity anomaly map						



Explanation

Geology

- Quaternary to Late Tertiary basin fill
- Tertiary volcanic and sedimentary rocks
- Sedimentary and volcanic bedrock
- Granitic and metamorphic bedrock

Estimated depth to bedrock contours

400, 800, 1600, 3200, 4800, 6400, 8000, 9600, 11200, 12800, 14400, 17600, 22400, 24000, 25600, 27200

Well control for depth estimates

- Wells penetrating bedrock
- Wells not penetrating bedrock

Depth values posted in feet, '>' indicates minimum depth to bedrock; '=' indicates reported depth of bedrock.
Depth values followed by '*' are problematic typically because of different interpretations of what is bedrock.

General Notes

The views and conclusions contained in this document are those of the authors. Except for depths based on bedrock penetrations reported in bore holes, determination of depth to bedrock is based on interpretation of geophysical data. Solutions for bedrock depth are in general poorly constrained, and the definition of 'bedrock' is subject to interpretation. Estimated depth to bedrock contours on this map should be considered qualitative. Horizontal accuracy of contour location cannot be rigorously quantified, but is estimated to be in the range of +/- 1-3 km. Depth estimates are poorly constrained and should be considered highly uncertain, in the range of +/- 20-30 percent, except in the vicinity of wells penetrating bedrock.

References

Citation information for this map:
Richard, S.M., Shipman, T.C., Greene, Lizbeth, Harris, R.C., 2007, Estimated Depth to Bedrock in Arizona: Tucson, Arizona Geological Survey Digital Geologic Map 52 (DGM-52), version 1.0, 1 Adobe Acrobat (pdf) file (8 p., 1 sheet), design scale 1:1,000,000.

0 10 20 30 40
Kilometers

srk consulting

LIBERTY STAR URANIUM & METALS CORP.

Tombstone, Arizona

Estimated depth to bedrock in the vicinity of Tombstone Hills

SRK JOB NO.: 173300.03 Task 600 | Internal Control Number 3

FILE NAME: 7-21 Estimated depth to bedrock in the vicinity of Tombstone Hills

Hay Mountain Exploration Report

DATE:	APPROVED:	FIGURE:	REVISION NO.
June 2011	JR	7-21	1

8 Deposit Types of Tombstone District (Item 10)

Geochemical and geological analyses of the Tombstone district indicate that there are two deposit types and ages of mineralization. The early Laramide (74 Ma) magmatism and mineralization is responsible for the past production of major amounts of Ag in the polymetallic replacement deposits. The late Laramide (62-65 Ma) magmatism and mineralization is responsible for the porphyry copper mineralization. The Mn occurrences and production are common in the outer zone of both the Ag deposits and the porphyry copper mineralization.

Other indications of porphyry copper mineralization are the typical porphyry copper geochemical and geophysical signatures in the southern and eastern parts of the Tombstone Hills. In addition, a granodiorite porphyry and alteration that is common to porphyry copper deposits was intersected in ASARCO drill holes in the Robbers' Roost area in the southwestern Tombstone Hills.

8.1 Deposit Type of Ag Mineralization

The USGS classification of ore deposit models lists the Ag mineralization at Tombstone as model 19a or polymetallic replacement deposits (Cox and Singer, 1992). These are described as hydrothermal, epigenetic, Ag, Pb, Zn, Cu mineralization in massive lenses, pipes and veins in limestone, dolomite, or other soluble rock near igneous intrusions. They are in sedimentary rocks that are commonly overlain by volcanic rocks and intruded by porphyritic plutons. These deposits are formed by replacement by solutions emanating from volcanic centers and epizonal plutons, with calderas favorable.

The nearest equivalent Canadian mineral deposit model type is Geological Survey of Canada type 16, the clastic metasediment-hosted vein Ag-Pb-Zn (Beaudoin and Sangster, 1995). The related deposit types are listed as Ag-Pb-Zn carbonate replacement and manto deposits. Most of the following description of the Tombstone Ag deposits is taken from Butler and others (1938) and from SRK (2008).

Ag deposits at Tombstone are associated with north-striking fissures and dikes. The north-south fissuring added to the fracturing produced by folding, and the rocks were further disturbed by the intrusion of dikes. Northeast fissuring was the final preparation of the ground for mineralization. The ore shoots are localized within the zones at the intersection of the northeast fissures with dikes. The ore is in fissures within the dikes, in the fissure zones occupied by the dikes, and in replaced beds, especially limestone beds extending away from the dikes. The ore shoots extend to several hundred feet stratigraphically above the Paleozoic-Mesozoic contact. The northeast fissures do not cross the north-south fissures directly on strike but tend to swing into them, follow them for some distance, and then appear on the opposite side of the normal strike in an apparent offset.

Ag deposits are also associated with faults that have caused slipping along the beds near limestone-shale contacts. The slipping resulted in fracturing the rocks and thickening or duplication of some of the beds, partly by faulting, partly by drag folding. Within the fault zones, the ore shoots are at and near the intersection of northeast fissures.

Ag deposits are especially associated with the fractured anticlines and rolls. These deposits are located in the rolls or drag folds on the anticlines within the Tombstone basin, generally where the bends in the beds are sharpest. This may not be at the apex of the fold. Several factors have influenced the location of these ore deposits. The overlying shale is a relatively impermeable cap. The novaculite (siliceous shale) is the most brecciated and permeable rock. The upper portion of the Naco Group limestone, the novaculite, and the Blue limestone are the most chemically favorable for replacement. The north-south fissuring and the intrusion of dikes further brecciated the rocks after folding. The northeast fissuring completed the preparation of the ground for mineralization. The mineralizing fluids rose through the northeast fissures and passed into the permeable zones.

There are also Ag deposits with no obvious control other than northeast-striking fissures. Deposits in northeast-striking fissures (commonly strike N30°E to N55°E) have been productive in the Uncle Sam Tuff in the western part of the district and in the Bisbee Group. In the Uncle Sam Tuff, the mineralized deposits are simple fissure fillings. In the Bisbee Group sedimentary rocks, mineralization is in the fissures and extends outward from the fissures along favorable beds. These fissures have been more productive in the anticlinal areas than in the synclinal areas. The presence of gouge and striations on the walls of the fissures indicates they are faults. The ore fissures cut all rocks older than the Quaternary gravels.

The most productive part of the sedimentary section at Tombstone extends from somewhat below the top of the Naco Group limestone upward to a few hundred feet above the base of the Mesozoic beds. Much of the production has come from within 200 ft stratigraphically of the boundary of the Paleozoic and Mesozoic rocks. However, there are some deposits deep in the Paleozoic and some high in the Mesozoic section. The nearer surface deposits have been subject to oxidation and supergene enrichment, thus making them easier to process and mine.

Deposits with northeast-striking fissures are especially favorable deposit types. The main mines in this area occur along northeast-striking fissures, with some fissures cutting Bisbee Group rocks (Bonanza Group mines, Chance mine, Ground Hog mine, Mamie mine, Randolph mine, and Soltice mine) and some fissures cutting Uncle Sam Tuff (Free Coinage, Merrimac, Sailor, and San Pedro mines). The State of Maine mine occurs in fissures that cut both Bisbee sediments and Uncle Sam Tuff.

8.2 Deposit Type of Porphyry Copper Mineralization

Analysis of the geologic, geochemical, and geophysical studies by Briscoe in 1999, suggest that the Hay Mountain project area is a potential porphyry copper center.

The USGS classification (Cox and Singer, 1992) of the potential porphyry copper mineralization at Tombstone could be either model 17 (porphyry Cu) or 21a (porphyry Cu-Mo) (Cox, 1992). Because there are elevated analyses of Mo in the mesquite twigs, the 21a mineral deposit type of porphyry Cu-Mo is more likely. Similar nearby porphyry Cu-Mo type deposits in this model are the Silver Bell mine northwest of Tucson and the Twin Buttes and Sierrita-Esperanza mines in the Pima mining district south of Tucson. This model type is described as stockwork veinlets of quartz, chalcopyrite, and molybdenite in or near a porphyritic intrusion, with rock types of porphyritic tonalite to monzogranite stocks and breccia pipes intrusive into batholithic, volcanic or sedimentary rocks. The typical mineralogy consists of chalcopyrite, pyrite, and molybdenite, with peripheral vein or replacement deposits with chalcopyrite, sphalerite, galena, and gold, with outermost zone of veins of Cu-Ag-Sb-sulfides, barite, and gold. Typical alteration consists of quartz, K-feldspar, biotite, chlorite, and anhydrite (potassic alteration) grading outward to propylitic alteration. Late white mica and clay (phyllic) alteration may form capping or outer zones or may affect the entire deposit.

The Canadian mineral deposit type is porphyry Cu-Mo or model 19.2 Cu-Mo (±Au, Ag). Examples of this deposit type are Esperanza, Sierrita, and Mineral Park, Arizona (Kirkham and Sinclair, 1995). Porphyry copper and porphyry Cu-Mo deposits have the principal ore minerals of chalcopyrite, bornite, chalcocite, tennantite, enargite, other copper sulfides and sulfosalts, molybdenite, and electrum. These deposits normally have Ag, Pb, Zn, and Au halos surrounding the Cu-Mo central portions of the deposits (Figure 8-1).

8.2.1 General Characteristics

The calc-alkalic oxidized magma-metal deposit type contains world-class porphyry copper deposits with the best grade and tonnage characteristics (Wilt, 1995). These mesothermal high-sulfur porphyry deposits are primarily Cu-Ag-Mo deposits. The central zones of these districts contain porphyry Cu-Zn-Mo deposits. These central zones are surrounded by zones of Cu-Zn mines, which are in turn surrounded by zones of Pb-Zn-Ag mines. Furthest from the central zones are zones of Ag-Mn mines or prospects. Examples from Arizona of this deposit type include Bagdad, Christmas, Miami-Inspiration, Ray, Mineral Park, San Manuel, Sierrita-Esperanza, Silver Bell, and Twin Buttes-Mission.

This deposit type has major porphyry copper production, significant Zn and Pb production, Ag production greater than Au, some Mo and Mn production, and lesser amounts of arsenic (As), boron (B), and tungsten (W). Typical ratios include the following: Cu/(Pb+Zn) is 4:1 to 450:1; Ag:Au is >40:1; and the base:precious metal ratio is 1,000:1 to 9,000:1.

Typical mineralogy of the calc-alkalic oxidized class contains abundant common sulfides (pyrite, chalcopyrite, galena, sphalerite, and bornite). Cu minerals are common, as is molybdenite. Of the tungsten (Sn) minerals, scheelite is common, but wolframite is rare. Native Ag and Au and argentite are very minor. There is usually no mention of Pb or Zn minerals, Ag halides, Ag sulfosalts, or Ag tellurides. Magnetite, hematite, and limonite are common. Arsenopyrite is reported and antimony (Sb) is sometimes present. Bismuthinite is rare. There is generally no As, tin (Sn), cobalt (Co), cadmium (Cd), nickel (Ni), thallium (Tl), mercury (Hg), or tellurium (Te) reported.

The calc-alkalic oxidized porphyry copper deposit type is characteristically emplaced at medium temperatures (mesothermal), and is a high-sulfur porphyry Cu/Ag/Mo (+ rhenium) deposit with fringing mesothermal Pb-Zn-Ag-Au (Sb-Hg-As-W-Mo-Ti) veins, skarns, and replacements. These deposits are associated with epizonal, biotite granodiorite porphyries (this is the third stage in the differentiation of a mesozonal/ hypabyssal sequence). Potassic zones lack magnetite and contain molybdenite. Red rutile that is formed from the breakdown of original hornblende, biotite, and magnetite is characteristic of, and may be unique to, the potassic zone. Boron (as tourmaline) locally occurs in distal phyllic zones. Early Stage 3 is characterized by biotite-chalcopyrite (trace magnetite-chalcopyrite). Molybdenites in calc-alkalic deposits are more rhenium-rich compared to molybdenite occurring in alkali-calcic deposits. This deposit type is associated with asymmetrically differentiated, biotite granodiorite porphyry phases of hornblende-bearing, metaluminous calc-alkalic, porphyry intrusive sequences emplaced into transpressive, deep-seated, strike-slip fault systems within tectonically mature oxidized sialic crust. This tectonic regime is commonly coincident with flattening ‘compressive’ subduction, where convergence rates generally exceed 8 cm/yr. Giant size deposits are associated with granodiorite porphyry intrusions where hornblende crystallizes early and before biotite and where the ground mass component commonly exceeds 50% of the rock volume (Keith, 2002).

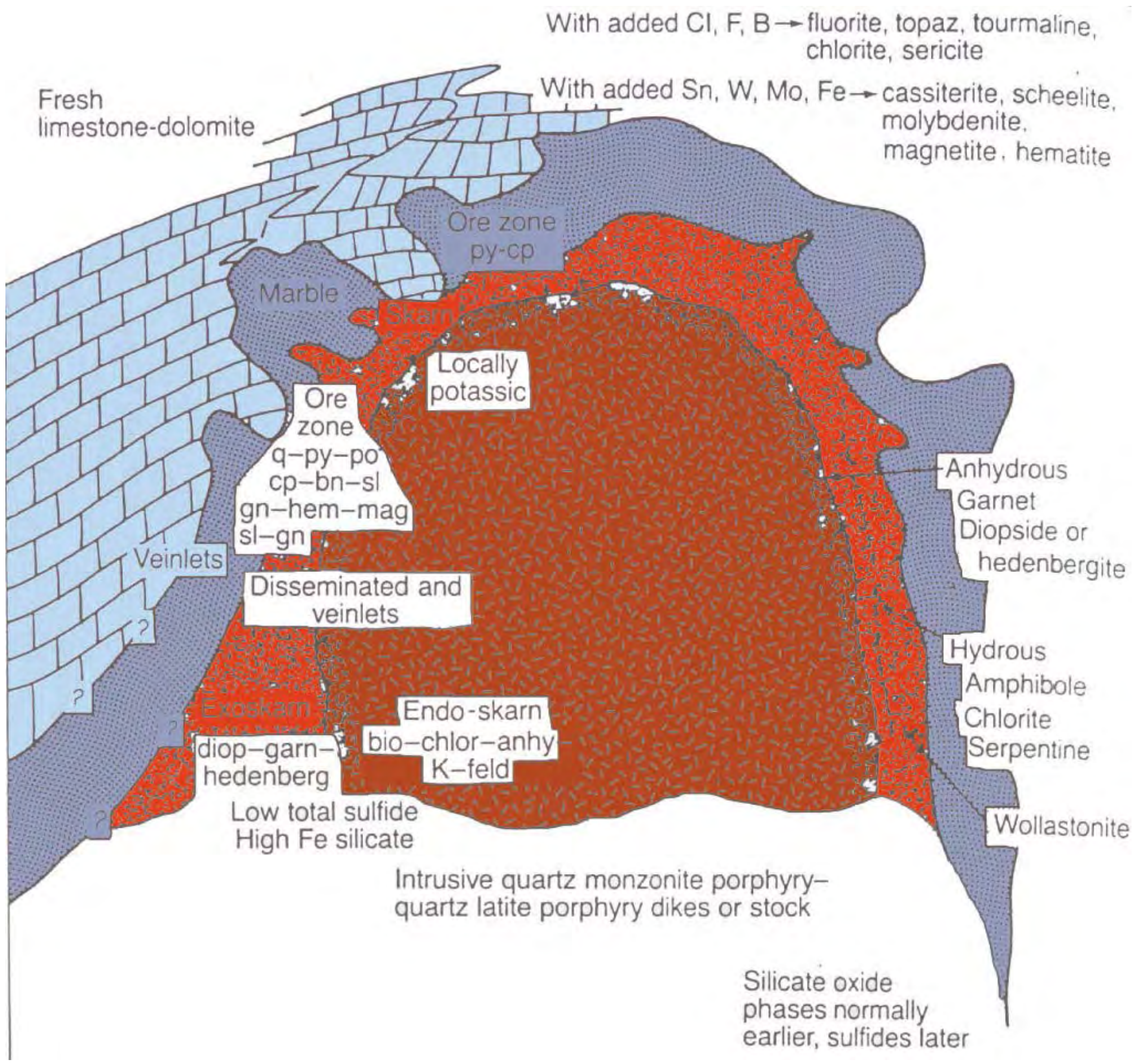
8.2.2 Evidence for Porphyry Copper at Hay Mountain

The primary evidence for porphyry copper mineralization in the Hay Mountain area are the geochemical sampling results that indicate Cu values are above background. Additional evidence for porphyry copper mineralization in the Tombstone Hills is the presence of the Tombstone rhyolite (called Comstock rhyolite or quartz monzonite by Drewes). This rock type at Tombstone is the same age and chemistry as the majority of the porphyry copper deposits in Arizona. This rhyolite plots near and in the calc-alkalic oxidized field on a K_2O vs SiO_2 diagram and has been dated at about 63 Ma (Section 7.7.2).

The large volume of this rhyolite in exposures in the eastern part of the Tombstone district and in the limestone hills to the east of SR 80 is especially significant. Quartz feldspar porphyry or rhyolite is usually a late differentiate (stage 4) of an evolving intrusive sequence in most porphyry copper districts. The porphyry copper deposits are usually associated with earlier, deeper biotite hornblende granodiorite to quartz monzonite plutons (stage 3) (Figure 8-2). That there is such a large volume of a stage 4 felsic volcanic rock suggests that there is a very large quantity of stage 3 granodiorite plutons below or near the rhyolite outcrops. Although in some cases the intrusion sequence and alteration and mineralization zoning are around a vertical core, in many of the Arizona porphyry copper deposits, the intrusion sequence follows a zone of weakness in west-northwest elements of the Texas Zone and in northeast-striking dikes. The differentiation sequence in many of these deposits is thus spread out along a linear zone.

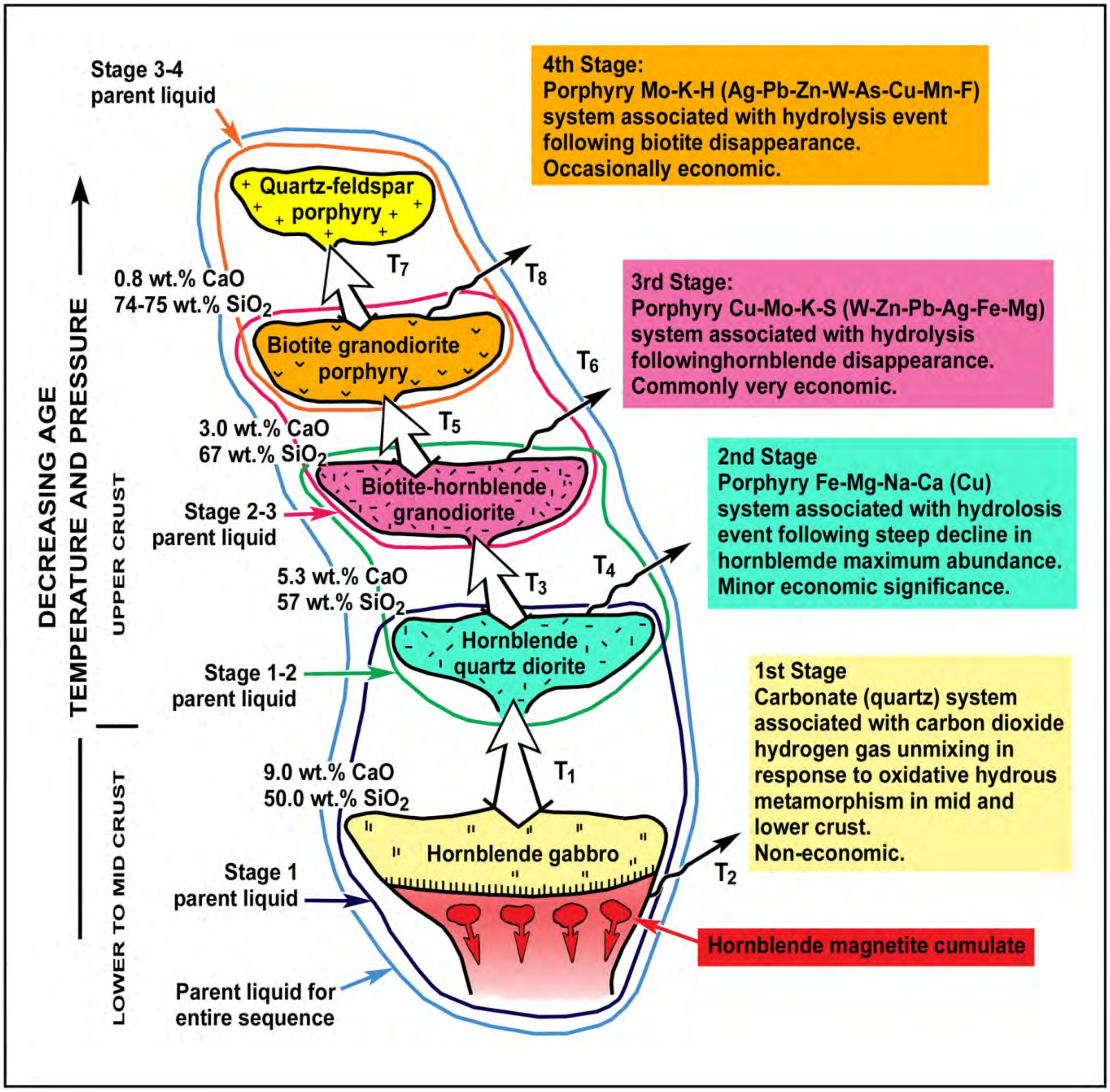
The presence of the later age dates on rhyolite and Mn mineralization in the south and east parts of the Tombstone district suggests that these intrusions were emplaced to the south and east of the Tombstone Ag-producing areas. It is possible that the structures that were filled by the Ag mineralization were already filled and thus not open or available for the later Cu mineralizing hydrothermal solutions. The plate motions at the later time would have been at a slight angle to the earlier plate motions, such that different fracture sets were open, particularly the ring and radial fractures associated with the earlier caldera collapse. The west-northwest striking elements of the Texas Zone, as well as the northeast-striking conjugate fractures, were open for the Cu mineralizing hydrothermal solutions during the later Laramide at most porphyry copper districts in Arizona, as they probably were at Tombstone.

Geochemical evidence in Newell (1974) suggested that the Government Butte area southeast of the town of Tombstone had high potential as a porphyry copper center and Newell suggested that area as a prime drill target. Gilbert (1993) also concluded that, from a variety of evidence, including characteristic alteration zoning, mineralization zoning, and geochemical halos, there are several potential porphyry centers within and around the Tombstone caldera complex.



Source: Liberty Star data; from Lowell and Guilbert (1970)

Figure 8-1 Lowell-Guilbert zoning model of porphyry copper deposits



Source: Keith (2002)

Figure 8-2 Differentiation sequence in porphyry copper systems

9 Mineralization (Item 11)

As the Hay Mountain project is in the grass-roots exploration stage, mineralization on the area of interest has not yet been characterized. For the main Tombstone district Ag production, there are a large number (156) of minerals and a wide assortment of Ag minerals. In addition, a great variety of Pb, Ag, Cu, and Zn minerals have been described along with Mn, tellurium (Te), Mo, and V minerals. The more important and principal minerals in the district include those listed in Table 9-1. Much of the following discussion is taken from SRK (2008).

Ag mineralization is directly associated with favorable structures, particularly the north-south (dike) fissures, faults, anticlines and rolls, and northeast-striking fissures. Cu mineralization is associated with deeper zones of potassic, propylitic, and argillic alteration, granodiorite and rhyolite porphyry intrusions, and Cu minerals.

9.1 Ag-Pb-Zn Mineralization

Butler and Wilson (1938) noted that Tombstone is essentially a precious-metal district. The dominant mineralization of potentially economic interest is native Ag, bromargyrite (obsolete names were bromyrite or bromeyerite), cerargyrite, argentite, and argentiferous tetrahedrite. Also of potential economic interest are the following commodities: Au; Cu mineralization as chalcopyrite; Mn mineralized as psilomelane, pyrolusite, and polianite; Pb mineralization as cerussite and galena; and Zn mineralization as sphalerite. The main gangue minerals are quartz, pyrite, and occasionally barite. Tellurates have been reported from Tombstone (Williams, 1978).

The ores in different parts of the district vary greatly in content of the different metals, and whether they were recovered historically depended somewhat upon the degree of oxidation. Zn has been recovered only from sulfide ores. Mn was produced only from oxidized ores, although alabandite, a rare manganese sulfide, has been reported from the Tombstone district.

The distribution of metals in the district suggested to Butler and Wilson (1938) "…an area of intense mineralization in the northeastern part of the district with a rough zoning outward. The most definite of the metal zones are the central Au zone and the marginal Mn-Ag zone."

Force (1996) described mineralization associated with Bisbee Group rocks in the western area, grouping deposits according to associated structures. In general, the western area mineralization occurs along steep faults as lensoid quartz veins and thin selvages of sheared and altered wallrock, including porphyry dikes. Mn oxide coatings are prominent. Briscoe notes that the only difference between the eastern and western areas is the host rocks. The veins in the western district are in intra-caldera tuffs, whereas the veins in the eastern district occur in sedimentary rocks and are extra-caldera, where the tuff has been eroded.

General descriptions of mineralization in the Tombstone Hills and Charleston area of the Tombstone district, given below, are taken from Keith (1973) and Newell (1974). Ag mineralization is closely associated with north-striking dikes and cross-cutting northeast-striking fissures. Dips are westward at angles from vertical to 60 degrees. Where either dikes or fissures intersect anticlinal structures, mineralization often developed along the crests of the folds as bedded replacement deposits. Native Ag has been identified in slickensided material as disseminated flakes, somewhat flattened along the slip planes. Other occurrences of native Ag include small masses of fine wire Ag clinging to iron-stained drusy quartz, and, in a polished section of hessite, microscopic quantities of Ag were identified in cracks and along the contact with other minerals. Bromargyrite is the main supergene Ag mineral. Other supergene Ag minerals are embolite, cerargyrite, argentite, stromeyerite, native Ag, and argentojarosite. The main hypogene Ag-bearing minerals are hessite, tetrahedrite, and galena.

Base metal mineralization, often oxidized, occurs in fault and fracture zones in Early Laramide volcanics and the Uncle Sam Tuff. The most common minerals are sphalerite, galena, and chalcopyrite. Sphalerite is fairly common in the Tombstone district, and most commonly was found associated with chalcopyrite, galena, and pyrite. The average sphalerite content in samples from various mines in the eastern part of the district and the Charleston Lead mine was about 15 volume percent (Newell, 1974). Galena also is a common mineral in ore specimens of the district, and was commonly associated with pyrite, sphalerite, chalcopyrite, and less frequently with tetrahedrite. When present, the galena content of individual polished specimens ranged between about 2 and 95 volume percent (Newell, 1974). The average content was about 30 volume percent. Newell proposed that the high Au and Ag assays reported for galena ore from the Empire mine at least partially was explained by the presence of Au-bearing hessite grains in the galena. Galena with spotty Cu and Zn minerals is found along fissure zones and anticlinal rolls cut by mineralized fissures in Paleozoic and Mesozoic sedimentary formations. Ore bodies are often closely associated with cross-cutting Laramide intrusive dikes and fissures.

Chalcopyrite is widespread in the Tombstone ores. The most commonly identified occurrence of chalcopyrite was as exsolution blebs in sphalerite (Newell, 1974). This occurrence is typical of porphyry copper deposits. Less commonly, chalcopyrite was found as anhedral grains that occasionally enclosed and replaced pyrite, sphalerite, and tetrahedrite.

9.1.1 Magma-Metal Series Zoning of Ag Deposits

Typical alkali-calcic oxidized districts are Ag-Pb-rich districts with by-product Zn and Cu, such as Tintic, Tombstone, and Park City. Ag grades in these types of deposits generally range from 0.04 to 0.06%, Pb grades from 0.8 to 9%, Zn grades from 0.01 to 5%, Cu grades from 0.1 to 0.7%, and Au grades from 0.0002 to 0.0005%. Metal ratios show a heavy Ag bias (244:1 to 100:1 Ag:Au), a strong Pb-Zn bias over Cu (Cu/[Pb+Zn] from 0.03 to 0.2), and a base:precious metal ratio from 30:1 to 250:1 (Wilt, 1993). The various subtypes of the alkali-calcic, oxidized magma-metal-series class are described in Table 9-2.

The central or main zone at Tombstone was assigned by Keith (2002) to the Tintic type in the magma-metal-series classification (Keith, 2002). This deposit type consists of Pb-Zn-Ag-Te veins and replacements with subordinate amounts of Au, Te, Cu, antimony (Sb), bismuth (Bi), and arsenic (As). The main Cu mineral in the Cu zone is usually enargite-famatinite, rather than tetrahedrite or chalcopyrite. If present, Bi, Pb, Cu, and Ag tellurides are present as cosalite, altaite, rickardite, hessite, native bismuth, and enargite. Argentite and argentiferous galena are not as common. Mn appears as manganosiderite with subordinate rhodochrosite that may oxidize to Mn oxides in more distal portions. Wulfenite is present, but less common as museum-quality specimens. Supergene Te minerals, such as emmonsite, are present. Zn distribution is more distal.

The State of Maine mine was assigned to the La Colorada type in the magma-metal-series classification (Keith, 2002). This zone consists of Au-enriched, polymetallic, hematitic gossans developed above the main mineralization.

The Reservoir Hill area was assigned to the Bergin zone of the Tintic type in the magma-metal-series classification (Keith, 2002). This zone consists of Ag-Pb (Zn) veins, replacement and manto deposits formed at intermediate depths. These are deep to intermediate depth deposits of Ag-Pb(>Zn), Te in chimneys, veins, replacements, and mantos. Hessite and altaite are locally important ore/indicator minerals, and Sulfosalts are generally lacking.

The Oregon-Prompter mine was assigned to the Prompter zone of the Tintic type in the magma-metal-series classification (Keith, 2002). This type consists of distal Ag-Mn vein and replacements marginal to the main Ag-Pb mineralization.

The Robbers' Roost area was assigned to the Robbers' Roost type in the magma-metal-series classification (Keith, 2002). These are deep to shallow, quartz-sericite-Mo (fluorine (F)) veinlets and breccias associated with stage 4 (latest) quartz-feldspar porphyry intrusions.

The Contention mine was assigned to the Chanarcillo type in the magma-metal-series classification (Keith, 2002). These are supergene chlorargyrite enriched zones. They are bonanza deposits resulting from the oxidation of hypogene Ag-rich ores. They contain Ag (Cl>Br, I) as chlorargyrite, iodargyrite, and bromargyrite.

The general pattern of the Ag mineralized areas is that deeper zones are in the southwest and more oxidized, shallower zones are in the northeast. Deeper mineralized zones, such as the Robbers' Roost area, are in the southwestern part of the Tombstone district and the oxidized portions are in the northeast. This pattern suggests that the upper portions of the Ag mineralization were oxidized after extrusion of the Uncle Sam Tuff. This is consistent with the northeast tilting of the district after mineralization.

9.1.2 Favorable Rocks

Several formations were consistently the most favorable beds for replacement by ore that were mined for the historic Ag production. Substantial mineralization is associated with dikes or fissures and with three productive sedimentary zones: the upper and lower parts of the Bisbee Group and the upper part of the Naco Group limestones. In the Bisbee Group, favorable horizons included the Blue limestone near the base, beds of limestone above the Blue limestone, and the "Novaculite" or metamorphosed Glance Conglomerate at the base of the Bisbee Group. In the Paleozoic section, the upper portion of the Naco Group limestones, beds lower in the Naco Group, and beds in the lower Paleozoic were favorable horizons.

9.1.3 Favorable Structures

Mineralization is directly associated with favorable structures in the Tombstone mining district. North-south fissures, faults, anticlines and rolls, and northeast-striking fissures are favorable structures. Frost (1996) noted that mineralization in the western area follows pre-mineralization faults that themselves postdate the dikes. The following descriptions of northeast-striking faults or fault sets in the western area are from Force (1996).

A set of steep faults occurs between the Charleston highway and the Prompter fault. Mineralization includes amethystine quartz and postdates both the Uncle Sam Tuff and the younger porphyry dikes. Mines on this structure include the Mamie and Sailor mines. Production was a few hundred tons of Ag ore.

Both branches of a fault located northwest of the above structures, offset the limestone-conglomerate marker horizons, but are in turn cut by Schieffelin Granodiorite. Black hornfels are oxidized along the faults. Many of the workings are part of the Soltice claim block.

Another fault set dips northwest and cuts the Uncle Sam Tuff - Bisbee Group contact east of the State of Maine mine. One segment contains a porphyry dike. Workings along this fault set include the Bonanza Group mines and the remainder of the Soltice workings. Production (including all Soltice production) was about 4,500 tons of Pb-Ag ore.

About a half mile northwest of the above fault set is a northwest-dipping fault that locally forms the boundary between the upper and lower units of the Bisbee Group and offsets the Uncle Sam Tuff - Bisbee Group contacts. Force (1996) observed little mineralization, but postulated that the structure extends to the State of Maine mine where parallel structures are mineralized. The Merrimac and Free Coinage workings are in a parallel structure about 650 ft to the east, in the Uncle Sam Tuff.

The western extension of the Prompter fault is mineralized, especially in a northeast-striking segment. A few hundred tons of Ag ore were produced from workings at the Randolph mine.

Mineralization at the western Tombstone district occurs in two styles: fracture-fill (structurally controlled) and limited stratabound structures, both genetically associated. The fracture-fill structures are deep-seated fracture/fault zones trending northeast that are considered the conduits for the pod-type deposits and represent the upper zone of mineralization.

At the portal of the Soltice mine, local stratabound mineralization is developed. Such structures may have been formed at the intersections of fracture zones and/or along highly receptive rock units such as carbonate rocks, limestones, and limey siltstones, which are common units in the Bisbee Group. Quartzite is the predominant outcropping rock type in the western Tombstone district and is found in the upper units of the Bisbee Group. The best example in the district is the historical Goodenough mine located at the southwestern edge of the town. Stopes are located at the top of an anticline, forming an arcuate cavity of several feet high. The anticline axis plunges northeasterly. The stope is quite shallow and is less than 70 ft below the surface.

At the structures, mineralization takes place as Ag-bearing Mn oxides. Mn minerals are predominantly psilomelane, pyrolusite, and manganite, with some rare alabandite, while the Ag minerals are acanthite, proustite, and pyrargyrite. Commonly, horn Ag (chlorargyrite/cerargyrite), in the form of small crystals found in mine dumps, occurs as a secondary mineral after acanthite.

9.1.4 Age of Ag-Pb-Zn Mineralization

Newell (1974) constrained the age of Ag mineralization in the Tombstone district with structural evidence and age determinations on the Schieffelin Granodiorite and the Uncle Sam Tuff. He confirmed the age of mineralization near Charleston where the K-Ar age of a sericite sample from the Charleston Lead mine was 74.5 ± 3 Ma.

9.2 Porphyry Copper Mineralization

Guilbert (1993) concluded that multiple lines of evidence indicate the presence of porphyry copper centers in the Tombstone district. This evidence for several porphyry centers within and around the Tombstone caldera complex included characteristic alteration zoning, mineralization zoning, and geochemical halos. Evidence for such porphyry centers is the regional geochemical pattern derived from the district-wide sampling conducted by Newell (1974). That data, re-compiled by Briscoe and Waldrip (1982), show characteristic porphyry copper metal zoning of Cu-Mo 'high' areas surrounded by Pb-Zn-Ag halos. When the geochemical data from Newell are combined with data from geologic mapping, aeromagnetic surveys, drill information, metal production, observations of surface characteristics, and color air photo interpretation, Guilbert (1993) deduced that porphyry centers are present.

Newell (1974) noted that the Emerald mine was located about 1,300 ft south of the Prompter fault and contained important Mn mineralization. He noted that the Emerald mine workings bottomed in ore at a depth of about 880 ft where the water table was reached. According to Butler and others (1938), a carload of chalcocite ore was shipped from the bottom level of the mine. Newell suggested that the Cu in the Emerald mine could be related to the rhyolite porphyry. The Emerald mine reportedly contained the largest Cu deposit in the district (Butler and others, 1938).

Metal distribution patterns in porphyry copper deposits were summarized by Jerome (1966) and by Lowell and Guilbert (1970). In porphyry copper deposits, Mo is generally concentrated near the core of the intrusive, and Pb, Ag, and Zn are typically found in peripheral zones (Figure 8-1). Highest Cu values occur at intermediate positions between the core and peripheral zones.

Characteristics of porphyry copper-molybdenum deposits of the metaluminous, calc-alkalic magma-metal series classification are described in Table 9-3.

9.2.1 Age of Porphyry Copper Mineralization

Newell (1974) constrained the age of the rhyolite porphyry at 63 Ma. This unit crops out in the Hay Mountain area. The rhyolite porphyry associated with Mn mineralization in the southern part of the district was dated at about 63 Ma (Creasey and others, 1962). Mineralization was associated with this rhyolite, as shown by the emplacement of the Extension/Comstock quartz monzonite porphyry in the eastern part of the district. K-Ar dating of a hornblende in this rock yielded a date of 62.8 ± 2.6 Ma (Drewes, 1985). These ages are consistent with the age of porphyry copper mineralization in porphyry copper deposits south of Tucson and provide favorable evidence for the potential for porphyry copper mineralization in the Hay Mountain project area.

9.3 Other Mineralized Zones in the Tombstone Area

Mn mineralization is widespread throughout the Tombstone district and has occurred in various amounts with most of the oxidized Ag-Pb ore. The manganiferous ores are replacements in limestones. Sometimes argentiferous Mn oxides occur in irregular, lenticular or pipelike replacement bodies along steeply dipping fractures and fault zones, usually in Naco Group limestones. Most of the ore bodies are extremely irregular, ranging from 1 to 20 ft in width and from a few feet to 150 ft in length. The chief Mn minerals are pyrolusite, wad, and psilomelane. Small amounts of the rarer Zn-bearing Mn minerals are present in some of the ore, and the rare alabandite (a Mn sulfide) was reported from Tombstone. Only a few deposits have been mined chiefly for their Mn content. A control on the ore deposition seems to have been the northeast-striking fissures, except in the vicinity of the Oregon-Prompter mine where the deposits appear to be controlled by the east-west Prompter fault. The deposits are mainly in the south-central part of the district, south of the richer Ag mines.

Although the Au mineralization in the Zebra and Redrock Canyon areas adjacent to the Hay Mountain project were originally thought to be Carlin-type, disseminated Au deposits, further work indicated it was more likely related to a Au halo around a porphyry copper center associated with a buried intrusive rock.

9.4 Rock Types and Relevant Geological Controls

The most productive horizons for the Ag production in the Tombstone district were the limestones of the Naco Group, the lower part of the Bisbee Group, and dikes. In most porphyry copper deposits in Arizona, the first limestone horizon that the ascending hydrothermal solutions reached was usually the richest, such that the lower Paleozoic limestones frequently host the best primary Cu sulfide ore.

Wherever the structural events have prepared the host rocks to have abundant permeability, via fractures and fissures such as those at the tops of folds and rolls or at intersections of structures, these permeable zones frequently contain mineralization in the mines of the Tombstone district. It is to be expected that any potential mineralization in the Hay Mountain project would have similar characteristics.

9.5 Length, Width, Depth, and Continuity

The Hay Mountain project is an exploration project currently at the conceptual stage. Therefore, the length, width, depth, and continuity of the potential buried porphyry copper mineralization are not known at this early stage.

9.6 Type, Character, and Distribution of Zoning

The Hay Mountain project is an exploration project currently at the conceptual stage. Therefore, the , type, character, and distribution of zoning of the porphyry copper mineralization are not known.

The Tombstone district zoning shows the presence of several mineralization centers. The preliminary analysis suggests that the Cu mineralization is focused on the east and south sides of the district and is related to intrusions that are deeper than, but related to, the 63 Ma rhyolite. The significance of the Mn mineralization is difficult to assess, as Mn is common in the outer zones of both Ag-Pb-Zn deposits and porphyry copper deposits.

9.7 Summary

The Tombstone district has produced a large quantity of Ag ore, in addition to Au, Pb, Zn, Cu, and Mn, primarily as a result of the 74 Ma alkali-calcic magmatism and mineralization. The 63 Ma calc-alkalic Cu magmatism and mineralization appears to have been deposited into the nearby area, though slightly to the east and south of the main Tombstone district. The chalcocite ore produced from the Emerald mine south of the Prompter fault, and possibly the Mn mineralization in the southern part of the Tombstone district, may belong to the later mineralization.

The characteristic metal zoning and geochemical halos in the Tombstone district indicate the presence of several mineralization centers. The nature of sub-surface mineralization within the Hay Mountain area has yet to be drill tested and confirmed. Newell (1974) suggested the Government Butte area would be a primary target for deeper drilling to intersect a possible porphyry copper mineralization center. Numerous exploration companies have drilled in some of the other areas suggested by Newell, but none has drilled in the Hay Mountain project area for Cu.

Table 9-1 Principal minerals of the Tombstone mining district

Native elements	Sulfides	Haloids	Oxides	Carbonates	Sulfates
sulfur	galena	cerargyrite	quartz	calcite	barite
tellurium	argentite	bromargyrite	cuprite	rhodochrosite	anglesite
gold	chalcocite	embolite	tenorite	cerussite	jarosite
silver	sphalerite	fluorite	hematite		plumbojarosite
copper	alabandite		magnetite		
	covellite		hetaerolite		
	bornite		polianite & pyrolusite		
	chalcopyrite		manganite		
	pyrite		psilomelane		

Source: www.mindat.org (accessed June 2011)

Table 9-2 Magma-Metal series subtypes of Metaluminous Alkali-calcic at Tombstone

Model No.	Model Description (Emplacement Level/Tectonic Setting)	DEPOSIT TYPE/ZONE - MAGMA METAL SERIES MODEL
24CA	Au-enriched, polymetallic, hematitic gossans developed mainly above 24A, 24E, and 29B models.	LA COLORADA TYPE - ALKALI-CALCIC SUPERGENE GOLD-ENRICHED OXIDE ZONES Tombstone (State of Maine), AZ;
24J	Mesothermal, Te-bearing Pb-Zn-Ag (Au, Te, Cu, Sb, Bi, As), typically zoned veins and replacements, in or lateral to magnetite-sphene biotite quartz monzonite plutons. Enargite-famatinite is main copper mineral in Cu-rich zone (versus tetrahedrite in 24D and 24F models and chalcopyrite in 25 and 25A models). If present, Bi, Pb, Cu, and Ag tellurides (cosalite, altaite, rickardite, hessite), native bismuth, and enargite strongly indicate 24J model compared to 24, 24A, 24D, 24F, 25, and 25A models. Argentite and argentiferous galena are more frequent in MAC25 compared to MAC24D and 24 models. Mesothermal equivalent of MAC20 epithermal model. Mn appears mainly as manganosiderite with subordinate rhodochrosite, which may oxidize to Mn oxides in more distal settings. Wulfenite is present, but less common, compared to wulfenite in supergene zones of model 25. Supergene tellurium minerals (emmonsite, etc.) distinguish model from other Pb-Zn-Ag mesothermal models (e.g. 14H, 24, 24D, and 25 models). Zinc distribution is more distal compared to 24D and 25 models where it is more proximal. Magnetite-sphene-bearing.	TINTIC TYPE - ALKALI-CALCIC SILVER-LEAD-ZINC (TELLURIUM) REPLACEMENTS and/or VEINS* Tombstone, AZ.
24JD	Meso-leptothermal, Ag-Pb>Zn, Te chimneys, veins, replacements, and mantos, marginal to MAC24JB model. Hessite and altaite are locally important ore/indicator minerals. May show an increase to more zinc-rich material in distal portions (e.g. main Tintic). Lacks sulfosalts compared to 24B and 24G models. Contains Pb-Ag tellurides compared to 25D model.	BERGIN ZONE of the TINTIC TYPE - SILVER-LEAD (ZINC) VEINS, REPLACEMENT, and MANTO MESO-LEPTOTHERMAL INTERMEDIATE PORTION of the TINTIC TYPE Tombstone (Reservoir Hill)
24JE	Leptothermal, Mn (Zn-Ag) veins and replacements marginal to 24JB and 24JC models	PROMPTER ZONE of the TINTIC TYPE - DISTAL SILVER-MANGANESE VEIN/ REPLACEMENT PORTION of the TINTIC TYPE Tombstone (Prompter and Bunker Hill), AZ
24JF	Mesothermal-epithermal, quartz-sericite-Mo (F) veinlets and breccias associated with stage 4 quartz-feldspar porphyry intrusions of metaluminous alkali-calcic oxidized serial sequences.	ROBBERS' ROOST TYPE – ALKALI-CALCIC MOLYBDENUM VEINLSTS AND BRECCIAS Tombstone (Robbers' Roost breccia pipes) in stage 4 Uncle Sam Tuff), AZ
25F	Leptothermal, peripheral jasperoid Zn, Pb, Ag (Mn, Ba) of 24J and 25 models. In part coincides with MAC23 model.	Tombstone, AZ
25H	Supergene, bonanza Ag (Cl>Br,I) chlorargyrite-iodargyrite-bromargyrite oxidation products of hypogene Ag-rich ores in MAC17, 22, 24, 24D, 24A, 24H, 24JC, 24JD, and 25 models.	CHANARCILLO TYPE - SUPERGENE CHLORARGYRITE ENRICHED ZONES Tombstone (Contention), AZ (MAC24J)

Source: Keith, 2002, MagmaChem model book

Table 9-3 Magma-Metal series subtypes of Metaluminous Calc-alkalic at Tombstone

Model No.	Model Description (Emplacement Level/Tectonic Setting)	DEPOSIT TYPE/ZONE - MAGMA METAL SERIES MODEL
14C	Mesothermal, high-sulfur, porphyry Cu/Ag/Mo(Rh) with fringing mesothermal Pb-Zn-Ag-Au(Sb-Hg-As-W-Mo-Ti) veins, skarns, and replacements associated with epizonal, biotite granodiorite porphyries (3rd stage in mesozonal/hypabyssal MCAho sequence). Potassic zones lack magnetite and contain molybdenite. Red rutile formed from breakdown of original hornblende, biotite, and magnetite is characteristic of potassic zone alteration. Boron (as tourmaline) locally occurs in distal phyllic zones). Early Stage 3 is characterized by biotite-chalcopyrite (trace magnetite-chalcopyrite). Molybdenites are more rhenium-rich compared to alkali-calcic. Giant size deposits are associated with granodiorite porphyry intrusions where hornblende crystallizes early and before biotite and where the ground mass component commonly exceeds 50% of the rock volume.	MORENCI or CHUQUICAMATA TYPE - CALC-ALKALIC PORPHYRY COPPER (MOLYBDENUM-SILVER) DEPOSITS* Cu (Mo, Ag) Porphyries: Ray, AZ; Chino, NM; Tyrone and Tyrone (Copper Leach), NM; Resolution (Magma East), Superior East, Sierrita-Esperanza, Twin Buttes-Mission-Pima, San Manuel-Kalamazoo, Silver Bell, Globe-Miami, Lakeshore, Mineral Park, Rosemont, Copper Creek, and Christmas, San Juan, Lone Star, Schultze (Pinto Valley, Miami-Inspiration, and Copper Cities, Poston-Butte), Red Mountain and Thunder Mountain, Chilito, Casa Grande (Sacaton), Bagdad and Copper Basin, Morenci, AZ;
14F	Mesothermal Cu-Mo central zone (may form a concave downward ore shell at potassic/phyllic zone interface). Includes stockwork, breccia pipe, and, more rarely, manto physical formats.	SAN MANUEL COPPER-MOLYBDENUM ZONE of the MORENCI or CHUQUICAMATA TYPE – PORPHYRY COPPER-MOLYBDENUM CENTRAL PORTION of the MORENCI or CHUQUICAMATA TYPE* **Stockworks hosted in Stage 3 biotite granodiorite porphyries:** Mineral Park pit, Sierrita-Esperanza, New Years Eve, Bagdad pit, Morenci pit, Metcalf pit, and San Manuel-Kalamazoo mine, Silver Bell (El Tiro and Oxide Pits), AZ; Tyrone and Santa Rita pits, SW NM; Butte (EDM portion), MT; Chuquicamata pit, Chile; etc. **Breccia Pipes**: Copper Creek, Copper Basin, and Morenci, AZ; **In rocks lateral to Stage 3 biotite granodiorite porphyries**: Ray and Chilito (in 1.2 Ga diabase sills), SE AZ; Sierrita (in early diorite stock), AZ.

Source: Keith, 2002, MagmaChem model book

10 Exploration (Item 12)

During the 1960s through the 1970s, major mineral exploration companies (ASARCO, Inc., Placer Amex, Inc., Newmont Mining Corporation, the Anaconda Company, and Phelps Dodge Corporation) are known to have worked in the eastern and southern parts of the Tombstone district. Some of these companies were reportedly in search of porphyry copper mineralization at depth, but their records were not available for this report. During the 1980s, there was limited open-pit mining and heap leaching of low-grade Ag ores in the main Tombstone district. Total historical expenditures on the property are not known. Historical "reserve" estimates are not known to exist.

Sporadic geologic mapping, geochemical sampling, and a few geophysical surveys were conducted across the district through the 1950s to 1990s by major exploration companies in pursuit of Ag and porphyry copper mineralization and by the USGS. Follow-up drilling of porphyry copper targets in the southwestern part of the district proved the existence of porphyry copper mineralization and related quartz monzonite porphyry intrusions. However, the options were dropped and further exploration activities were not undertaken, possibly as a result of the low Cu prices at the time. Specific information on the Cu exploration activities of the major exploration companies and the subsequent results are generally not available, although a few reports were located. These major exploration programs are known chiefly from newspaper clippings and anecdotal evidence. Somewhat more information is available on the activities of smaller exploration companies in the records of ADMMR.

10.1 Tombstone District Exploration

Historical exploration in the Tombstone mining district is poorly documented in the public records. The earliest prospects were located from surface outcrops of altered or mineralized ground. As early mining commenced in the district, local structures and styles of mineralization were recognized and pursued as mineral targets. Little exploration was necessary in the boom years of the late 1880s and 1890s. Sporadic exploration has been carried out since those days, but little is documented. A few reports were found and are summarized below. The geologic units described in the Bisbee quadrangle by Ransome (1904) also crop out in the Tombstone Hills.

10.1.1 1921-1965

In 1928, a report on the Mellgren properties in the Tombstone district was prepared by C.J. Sarle (with contributions by V.C. Mellgren). The property, which reportedly covered the greater part of the western portion of the district, consisted of 56 contiguous lode claims and fractional claims covering an area of about 1,050 acres. The report mainly summarized the known geology of the western part of the Tombstone district, estimated potential resources, and recommended alternative exploration programs for the area.

Since the late 1920s, exploration activities in the district by the Federal government, major exploration companies, and smaller mining companies are known from anecdotal evidence and a few reports. While the old records and reports generally are not available, those that were found are described below. SRK observed old drill collars in the western part of the district during a site visit in 2008.

The U.S. Bureau of Mines (USBM) investigated and reported on the Mn ores in Arizona as part of a federal investigation for strategic minerals. The work was performed during 1940 and 1941 and three reports were published (Romslo and Ravitz, 1947; Needham and Storms, 1956; Farnham and others, 1961). These reports are some of the earliest known on exploration activities in the Tombstone district. Six abandoned mines were sampled, including the Randolph mine in the western part of the district, and the samples were shipped to the USBM laboratory in Salt Lake City. A sample from the surface dump at the Randolph mine assayed 17.12 percent Mn and 17.3 oz/ton Ag.

The 1941 exploration activities included mapping of the areas; exploration of various mines and deposits by sampling old drifts, crosscuts, and stopes; and diamond drilling from underground stations (Needham and Storms, 1956). Early results indicated that no great Mn tonnage could be expected from any individual mine or deposit. As the Mn occurred with the Ag, most of it was mined out years ago. After subsequent testing at a semi-pilot plant, the USBM determined that 90 percent or more of the Mn could be recovered by the dithionate process and 80 to 90 percent of the Ag could be recovered by flotation or cyanidation (Farnham and others, 1961).

The USBM explored for barite deposits in Arizona in the late 1950s, describing only one deposit in the Tombstone district, at the Ground Hog mine (Stewart and Pfister, 1960). The caved condition of the old workings made it impossible to determine the downward extent of the barite mineralization, which reportedly extended below the 200-ft level. Rasor (1937) indicated that barite is sparse or lacking in most ore deposits of the district. Newmont Exploration, Ltd. held claims leased from Tombstone Development Co. until the early 1950s. The Newmont exploration was conducted in the late 1950s and early 1960s in underground drifts in the north end of the Contention workings (Briscoe, personal communication).

10.1.2 1966-1990

ASARCO

The American Smelting, Refining & Mining Co. (ASARCO) was reported to have performed considerable exploratory work during the 1960s and 1970s on claims leased from Tombstone Development Co. (Farnham and others, 1961). The ASARCO work was conducted on the Seth Horne claims around 1973.

A comment in a field trip guidebook (Briscoe, 1988) confirmed that ASARCO conducted deep drilling in 1973–1974 in the Tombstone district. The purpose of the ASARCO drilling was to target porphyry copper deposits thought to be associated with Laramide granodioritic and quartz monzonitic plutons within a caldera complex. One such target was the Robbers' Roost site southwest of Tombstone, where intense phyllic alteration and breccia pipe emplacement are exposed by erosion.

Alanco

Information concerning work at the Ground Hog mine (SW¼ Sec. 22, T20S, R22E) by Alanco Ltd. was obtained from the files of the ADMMR. A report prepared by the ADMMR dated November 14, 1984, indicated that mapping and drilling by air-track on the surface and underground cleaning, mapping and sampling had been performed at the mine and that "… approximately $200,000 was spent in 1984." Other notes described some of the work performed. Another note dated June 7, 1985, also stated that Alanco reported the company had been mapping and sampling at the mine.

The second ADMMR note, dated April 15, 1988, stated Alanco reported that the Ground Hog mine contains 200,000 tons of low grade Ag and a little Au that could be economic with a slight rise in Ag prices. New financing would allow them to reopen the mine and reopen the Charleston Road Mill. Regarding the Ground Hog mine, Southwest PAY DIRT for May 1988 announced that (1) Precious Metals Mines, Inc. of Chicago will provide the funding to reopen the Cochise County mill and mine, and (2) the mine will be open pit and is expected to produce 1,000 tons of ore daily that will be crushed at the mill.

Interstrat Resources Inc.

A report prepared in 1985 for Interstrat Resources Inc. (also spelled Intrastrat) was obtained from the files of the ADMMR. The Interstrat property consisted of 101.2 acres (Arizona State Prospecting Permit #08-80356-00) plus about 10 acres of patented fee lands. The property, located in the N½ Sec. 16, T20S, R22E, reportedly contained "…the extension of the north-striking, west-dipping, State of Maine vein." Geologic mapping, surface sampling, and a drilling program appear to have been conducted during 1983 and 1984. Accompanying the brief report were a table of analytical results and hand-drawn maps and cross sections.

The table, "Spectrographic Analysis Results, 1984," reported Au and Ag values for samples collected in 1983 and apparently in 1984 from back-hoe and dozer cuts, prospect pits, trenches, mineralized and un-mineralized porphyry, and surface soils. Ag values ranged from zero to 220.07 oz Ag/ton. The five greatest Ag values were 29.2, 33.29, 44.64, 75.00, and 220.07 oz Ag/ton. Au values ranged from zero to 0.980 oz Au/ton. The five greatest Au values were 0.020, 0.040, 0.300, 0.800, 0.980 oz Au/ton.

The maps showed the following features: outcrops of bleached Uncle Sam Tuff, structures [fissures] with dips and the location of two andesite dikes, patented and unpatented claims, historical mines (without names), roads and surface elevations, and trench, sample, and drill locations with Au and Ag values. Three cross sections based on four drill holes indicated Au and Ag values at depth from the assay results and related the values to projected vein outcrops and old mine workings. The report recommended the following steps to bring the company's state holdings into production: define drilling to finalize open pit layout, calculate tonnage-grade and waste associated with a specific pit outline, determine production parameters, and decide upon a plan of operation.

An application for a mineral lease on state lands covered under Interstrat Prospecting Permit #08-80356-00 was made to the Arizona State Land Department (ASLD) on November 13, 1985. The application covered six claims (Fox No. 1 through No. 6) and asked that the claims be consolidated. In response, ASLD prepared an Evaluation Report dated July 11, 1986. The Mineral Lease Application No. 11-92569 was noted to be "partial conversion of 08-80356." ASLD report noted the following: W.W. Grace assigned Exploration Permit No. 08-80356 to Interstrat on March 6, 1981. Work done on the permit consisted of trenching, drilling, sampling and assaying, and geology. Fox No. 1 through Fox No. 3 claims cover Ag-Au mineralization associated with the northern extension of the State of Maine fissure system. The Fox No. 4 claim contains mineralization that is related to the Clipper and May northward extensions. Fox No. 5 and Fox No. 6 claims cover the southward extension of the Clipper system.

During the 4.5 years that Interstrat held the Exploration Permit, enough work was done to indicate that some 50,000 tons of rock averaging +1.5 oz Ag/ton was present on the northern extension of the State of Maine system, which is amenable to open pit mining to a depth of 100 ft. Interstrat demonstrated that the Fox claim group is "a borderline 'prudent man' discovery." The term borderline was used because of the then low price for Ag and the relatively small tonnages thus far indicated. ASLD recommended approval of the lease application; however it is not known whether the mining lease was completed.

10.1.3 1990-2010

BHP Minerals

Newspaper clipping from late 1993 (The Northern Miner, December 13, 1993, and December 20, 1993) reported that BHP Minerals International Exploration had optioned 13 state mining leases and four federal claims from Excellon Resources (EXN) and MVP Capital for their joint property in Arizona—the Robbers' Roost area (Sec. 30, T20S, R22E). This project was promoted by James Briscoe, although his drilling recommendations were not followed. The newspaper clippings state, "Having examined old core from drilling in 1973–74, the companies believe the project has the potential to host an open-pit, heap-leachable chalcocite blanket about 150 ft. below surface." A subsequent clipping (Southwestern PAY DIRT for November 1994) quoted EXN and MVP as stating BHP had spent more than the required $150,000 during the first year of the agreement. BHP completed geological studies and geophysical surveys that identified a favorable setting and several anomalies, and subsequently drilled three reverse circulation (RC) holes. The holes defined a large pyritic halo and provided a vector toward Cu enrichment zones. One drill hole was completed out of a three-hole diamond drill program. Business Wire reported on June 19, 1995, that BHP had commenced drilling on the Robbers' Roost property as part of a three-hole drill program designed to test biogeochemical and geophysical anomalies to a depth of about 1,500 feet.

A quarterly report filed by Excellon Resources on SEDAR (www.sedar.com) for the quarter ended January 31, 1997 stated that the company decided to discontinue further work on the Robbers' Roost project near Tombstone and that the properties were in the process of being returned to the original vendors.

JABA, Inc. Properties

James A. Briscoe was (and remains) Chief Executive Officer (CEO) of JABA, Inc. and is the current CEO of Liberty Star. JABA previously explored the Contention mine area and other areas in the Tombstone district through various joint ventures and partnerships. InfoMine.com (website accessed April 1, 2008) provided a property summary of the "200-ha Contention option and a further 1,600 ha in five properties in and around the Contention area" for historical research purposes. The website indicated the property records had been archived. "Abandoned property" was listed for company owner. A note with reference date of July 15, 1999, stated "Excellon dropped its interest in the property in 1996."

Thirty-five documents, dating from January 6, 1992, to July 15, 1999, are listed as available from InfoMine.com. The following items were reported on the website. In 1989, drilling returned 3.02 g/t Au equivalent from surface to 110 ft in one drill hole. Other holes also contained mineralization. The mineralization was reportedly hosted by Bisbee metasedimentary rocks that are totally oxidized near the surface. A possible fault-offset continuation of the zone was recognized and Au-Ag grades were encountered on at least three targets. In June 1994, a 10-hole drill program commenced on the Contention property. Indicated resources, with a reference date of December 13, 1993, were presented as follows: Au - tonnage of 262,000, grade of 3.36 g ("Grade is Au equivalent. Deeper reserve in the pit area."); Au - tonnage 1,047,000, grade 2.16 g ("Grade is Au equivalent. Shallow reserve in the pit area.").

These tonnage and grade estimates are historical reported resources for which no back up information is available. The methods used to estimate the indicated resources are not known, and the data have not been reviewed by a Qualified Person. Therefore, the resource should not be relied upon, and these historical resources or any other resources are not reported as current and CIM compliant resources.

A JABA news release dated April 14, 1997, reported, "The Downey Project is adjacent to JABA's Robbers' Roost porphyry copper project, southwest of Tombstone, Arizona. The Downey has potential for Ag-Pb-Zn mineralization arranged in zones, on the east side of Robbers' Roost. One hole drilled to a depth of 1,515 feet intercepted short zones of sub-economic Ag mineralization, and the property was returned to its owners." This same information was contained in a staff note in the ADMMR file on JABA.

A news article in The Mining Record dated September 3, 1997, reported that JABA had acquired two "large scale projects in southwestern Arizona." One was the Downey property (adjacent to the Robbers' Roost property) acquired from Tombstone South Minerals, Inc. under a ten year exploration lease with option to purchase. The second project was Robbers' Roost (Sec. 30, T20S, R22E), in the area of a "deep seated porphyry copper target…confirmed by drilling done by ASARCO in the early 1970s." The JABA announcement stated, "Extensive exploration work has been completed on both projects and Phase 1 drilling commenced on the Downey project on May 27, 1997."

Tombstone Exploration Corporation

Exploration by Tombstone Exploration Corporation (TEC) at their Tombstone property began prior to 2006 with sampling that included the underground workings at the Soltice, Greenwich, and Ace-in-the-Hole historical mines.

Exploration activities conducted in 2008 by TEC included geologic mapping; RC drilling; and collection and assaying of samples from mine dumps, trenches, and surface and underground rock exposures. All exploration work is being conducted by the company, other than drilling, and laboratory assays, which were performed by subcontractors to TEC.

Exploratory drilling was conducted by TEC in early 2007 to intersect the fissure veins at depth, to locate and confirm mineralized zones, and to test fissures-vein thickness and continuity. Drill samples were analyzed with a Niton X-ray fluorescence (XRF) analyzer and the samples that appeared to be mineralized were assayed. The six holes drilled in the Red Top claim intercepted Cretaceous Bisbee Group quartzite and/or limestone, Tertiary Uncle Sam Tuff, and occasionally an andesite dike. These units were overlain in the uppermost 10 to 30 feet by alluvium. At varying depths the holes intercepted infrequent stringers of calcite along fractures, zones of strong iron and Mn oxides, and occasional faults. The three holes drilled into the Black Horse/Ace-in-the Hole mine area intercepted Cretaceous Bisbee Group quartzite and/or limestone, hornfels, chert, and occasional interbeds in TEM3 of an unknown rock type, logged as a possible basalt. These units were overlain in the uppermost 15 to 40 feet by alluvium. At varying depths, the holes intercepted infrequent stringers of calcite along fractures, zones of strong iron and Mn oxide, and occasional faults.

Geologic mapping was conducted by TEC in Secs. 9, 10, 15, and 16, T20S, R22E, at scales of 1:10,000, mainly for surface mapping and 1:5,000, mainly for underground mapping and also where more detail was desired. Some limited mapping was initiated in Secs. 17 and 22, T20S, R22E. The mapping focused on strike, dip, and mineralization of the fissures and veins that strike northeast across the area of the principal historic mines in the western part of the district: State of Maine, Bonanza Group mines, Soldier, Soltice, and Ace-in-the-Hole/Black Horse. The mapping activities also included the location and orientation of historic shafts, pits, and dumps. Where accessible, the underground workings of these mines were mapped or earlier maps were verified. Mineralized trends that are the TEC's exploration targets were shown on their Canadian NI 43-101 report (SRK, 2008).

Samples were collected by TEC at their Tombstone property between late 2005 and early 2008. Thirteen surface samples collected on the property in October 2005 were assayed for Au and Ag by Jacobs Assay Office of Tucson, but the sampling locations were not documented. Au values for the 13 samples ranged from non-detect to 0.021 oz/t Au; Ag values ranged from non-detect to 2.20 oz/t Ag. Samples from the nine drill holes were collected in 2007. In early 2008, samples were collected from elsewhere on the TEC property: mine dumps, underground works, trenches, and surface locations (collectively referred to as surface samples). The assay results are indicative of mineralization, particularly where high grade samples were purposely collected. Samples from the Santa Ana mine, which is east of drill holes RT 2 and RT 3, show the highest values within the ranges reported. The highest values in the drill hole samples occurred in RT 1 within the 410–450 ft interval. Some representative samples also returned high grade assays, in particular the Merrimac FW S. pit, Merrimac N. pit main zone, Merrimac main zone (rock chip), Merrimac main zone (channel), Black Horse dump (grab), Soltice Area (grab), and Sec. 15 shaft dump (grab).

A news release on November 21, 2008, indicated that Phase I drilling on the Tombstone project completed five holes for a total of 2,230 metres and tested prospective stratigraphy and mineralized structures through the northern and central part of the property. The company continues to develop targets for the 2009 exploration program through detailed evaluation of the 2008 drill results with respect to the structural and stratigraphic controls on the mineralization. The TEC website (www.tombstonemining.com, accessed June 2011) indicated that additional claims were staked based on the results of the ZTEM survey, which indicated a deep copper system close to their State of Maine claims.

10.2 Exploration In and Near the Hay Mountain Project

The Hay Mountain project is an early stage, conceptual, district-scale, exploration project. At this stage of the project, exploration drilling for Cu has not been done on the Hay Mountain project. However, considerable exploration for Au was done in 1978 through 2005 in the Redrock Canyon, Zebra, and Hay Mountain projects (Figure 10-1). These areas overlap with the Hay Mountain area of interest. However, samples collected during that exploration were analyzed for Au and/or Ag, but were not analyzed for Cu.

Exploration geochemistry, geophysics, and drilling at the Redrock Canyon project in the northwest part of the Hay Mountain project suggested that the Au of the Redrock Canyon project is part of the Au halo surrounding the buried Hay Mountain porphyry copper system (DuHamel and Briscoe, 2003). This exploration was done on state mineral exploration permits in the early 2000s by JABA, based on exploration done by companies (Primo Gold, JABA, and Phelps Dodge Corporation) in the late 1970s and early 1980s.

The Zebra prospect was located in Sec. 27, 28, 29, 33, and 34, T20 S, R23E, which overlaps with the Hay Mountain project area. The area was prospected for Au by Energy Reserves Group, Consolidated Paymaster, and JABA starting in 1981 on state mineral exploration permits. The exploration concept at that time was for Carlin model, hot spring, disseminated Au targets. The Au mineralization is associated with silica jasperoid development and fluorite and barite mineralization. Alteration includes the argillization of thin-bedded shales and massive limestones that are poorly exposed in a small basin related to faulting. Au values from jasperoid samples assayed as high as 4.5 ppm Au (0.138 oz/ton) (Renn, 1981). Several drill holes were drilled in 1982-85 to shallow depths and some intersected Au mineralization. These indicated that the Au mineralization is related to feeder structures rather than to the rhyolite intrusive. The soil sampling conducted in 1986 also indicated that the Au mineralization occurs in association with feeder structures. Modern interpretation suggests that the Au mineralization is related to the outer Au halo that is common around porphyry copper deposits.

10.3 Geologic Mapping

The geologic map of the Tombstone area (Gilluly, 1956) includes the Hay Mountain project area. More recent geologic maps (Force, 1996; Pearthree and others, 2005, and Ferguson and others, 2009) have renamed some of the units, especially the Uncle Sam Tuff, which was formerly named the Uncle Sam Porphyry. The geologic map of Moore (1993) is quite generalized and does not accurately delineate the pre-caldera rocks, but shows the caldera margins.

The main outcropping rocks are Late Paleozoic limestones of Permian Colina Limestone and the underlying Pennsylvanian-Permian Earp Formation in the hills. A few hills contain Permian Epitaph Dolomite overlying the Colina Limestone. The Colina Limestone is intruded by Tertiary rhyolitic sills in the western and northern parts of the Hay Mountain project area. A few outcrops of Cretaceous Bisbee Group sediments crop out on the east side of a north-striking fault. The valleys between the hills are composed of Quaternary-Tertiary gravels and weathered and altered limestone and clay.

Additional geologic mapping was done for the Zebra, Redrock Canyon, and Hay Mountain projects in the 1990s and 2000s. The Tempo Resources 1990 exploration and geologic mapping program in Secs. 28 and 34 in the Zebra project located multiple northwest-striking jasperoid vein swarms toward the rhyolite porphyry outcrops. The fracture and fault intersections found in the detailed mapping were related to feeder structures of the Au mineralization (Halterman, 1990). The Zebra property received its name from the red and white striped “zebra” auriferous jasperoid located in the southwest quarter of Sec. 34. The reddish layers contained fine-grained fluorite and hematite and the white layers were composed of chalcedonic quartz and open-spaced quartz (Halterman, 1990).

Mapping and sampling of the Zebra property in 1995 showed the Colina Limestone is a dense, competent limestone with local lenses of jasperoids that are anomalous in Au as fracture fill veins and lenses concordant with bedding. The Colina Limestone consists of dark gray to black, dense limestone with abundant gastropods and crinoids, and echinoid spines in some units. The Colina Limestone on the Zebra property dips about 10 degrees north with minor variations, giving the appearance of a slightly undulating topography.

The lower limit of the Colina is a transition zone to the more clastic sediments of the Earp Formation. The Earp Formation underlies the Colina and is composed of sandstone, shale, and dolomitic limestone. The contact between the Colina and Earp at the type sections of each formation on Colina Ridge and Government Draw contain a porous horizon at the contact, either a fine-grained sandstone or a rubble conglomerate (Vanderwall, 1995).

Tertiary rhyolite porphyry intrudes the Colina Limestone and may be the source of the mineralizing solutions. The rhyolite porphyry is accompanied by local silicification and bleaching of the adjoining limestone. The “flat-topped” appearance suggests that the rhyolite is a sill injected between the upper units of the Colina Limestone, although mapping by Consolidated Paymaster indicates it is a plug. The rhyolite porphyry is buff colored and contains quartz phenocrysts less than 1/8 inch in length. Most of the exposed rhyolite weathers rusty brown, while the fresh rhyolite weathers white.

The jasperoid occurrences appear to be bedding controlled. The jasperoid in the southwest quarter of Sec. 34 and in the northeast quarter of Sec. 33 are between beds of the second unit in the Colina Limestone

A detailed geologic map of the Hay Mountain project was prepared by JABA over an air photo base in 1998 at a scale of 1 in = 1,000 ft. This map shows outcrops of Devonian Martin Formation, Mississippian Escabrosa Limestone, Pennsylvanian Horquilla Limestone and Earp Formation, Permian Colina Limestone, Cretaceous Bisbee Formation, Tertiary porphyritic rhyolite and aplitic intrusive rocks, and Tertiary conglomerate, gravel and sand, with Quaternary Tertiary gravel sand and silt in alluvium of floodplains, terraces, pediments and basins. Areas of alteration and mineralization centers were indicated by hematite staining, argillization, and jasperoids. Faults, drill hole locations and aeromagnetic contours are also shown on the geologic map over an air photo base.

10.4 Geochemical Sample Collection

Geochemical samples in the Redrock Canyon project were collected by Newell in 1974, Primo between 1978 and 1994, Phelps Dodge in 1996 and 1997, and by Minerals Exploration & Environmental Geochemistry (MEG) Labs in Carson City, Nevada for JABA in 2003-2004 (Figure 10-2). The 1986 soil sampling program by Tempo Resources, Ltd. Collected samples in Sec. 28, with several samples containing anomalous Au. Additional sampling program in 1988 analyzed for Au in all samples and for As, Cu, Pb, and Zn in a few samples in Secs. 27 and 28 (Halterman, 1990).

The samples collected on the Zebra property in Secs. 28, 33, and 34 (T20S, R23E) by Phelps Dodge in 1989 were analyzed for Au, Ag, As, Sb, Mo, and Se. Additional spectrographic analysis was done for Mo, Ag, Be, B, Pb, V, Cu, Zn and on 11 samples for by Skyline Labs, Inc. For Au, Ag, As, Sb, Cu, Pb, Zn, Mo Bi, Co, Ni, Cd, Te, Se, Tl, W, with several samples showing greater than 200 ppm Cu (DuHamel, 1989)

In 1990-91, Primo Gold Ltd conducted additional geological mapping and geochemical sampling (323 samples analyzed for Au, As, and Hg), and geophysical surveys. The geophysics consisted of IP, resistivity, TEM, and CSAMT (Halterman, 1991). Additional soil samples were collected in May 1992, but only analyzed for Au.

Rock chip sampling in 1997 of more than 80 locations in the Zebra project were collected by Phelps Dodge. Most of these samples were analyzed for Au, Ag, As, Sb, Mo, Se, Cu, Pb, and Zn by ICP by Skyline Labs, Inc. A few samples were also analyzed for Bi, Co, Ni, Cd, Te, Tl, and W, but these were near background or below detection limits. A few samples in Secs. 17 and 29 returned values greater than 200 ppm Cu (Liberty Star data files).

The 2004 samples (Figure 10-3) included rock chip, soil, and mesquite biogeochemical samples that were assayed for Au, As, Hg, and Sb, with no analyses of Ag, Cu, Pb, Zn, Mo, Se, and numerous other elements. A map of the JABA Redrock Canyon geochemical sampling for Au shows several areas with values higher than 4 ppb. The Surfer plot for Cu from the 2003 geochemical survey of soil in the Redrock Canyon area is shown in Figure 10-4. The mesquite samples were assayed for Au and other elements, as well as Mo, Pb, Zn, Ag, and Cu by ICP. The geochemical sampling in 2004 included 87 vegetation samples from white thorn acacia, 87 soil samples, 85 lag samples and 26 rock chip samples.

A geochemical sampling program was conducted by Liberty Star in 2005 in the Hay Mountain project (Smith, 2005). A total of 162 vegetation samples of creosote, acacia, and some mesquite were collected, along with 162 soil samples collected at the same time. Liberty Star conducted a geochemical survey of vegetation and soil in the Hay Mountain area in 2005. Smith (2005) summarized the results and plotted the results from soils samples in Surfer plots of Ag (Figure 10-5), As, Au, B, Ba, Bi, Ca, Cd, Co, Cr, Cu (Figure 10-6), Fe, Ga, Hg, K, La, Mn, Mg, Mo, Na, Ni, P, Pb, S, Sb, Sc, Se, Sr, Te, Th, Th, U, V, W and Zn. He also plotted the results from the vegetation samples in Surfer plots of Ag, As, Au, B, Ba, Co, Cr, Cu (Figure 10-7), Fe, Hg, K (Figure 10-8), La, Mn, Mo, Na, P, Pb, S, Sb, Se, Sr, and Zn (Smith, 2005).

The vegetation was prepared for analysis at MEG Labs in Carson City, Nevada. The sample preparation included washing, leaf removal, milling of twig matter and sizing to -1 mm, and analysis of the dry pulp by *aqua regia* digestion and inductively coupled plasma/mass spectroscopy (ICP/MS) for 37 elements. Au was analyzed from the dry pulp (ACME Labs 1VE-MS package). Soil data was derived from the phyllosilicate fraction (-325 mesh) and analyzed by aqua regia digestion and ICP/MS from a 15 gram aliquot for 37 elements. Soil geochemical data for Ag (Figure 10-5) and Cu (Figure 10-6) and vegetation data for Cu (Figure 10-7) and K (Figure 10-8) were plotted using Surfer and interpretations of each were made from proportional dot plots (Smith, 2005).

Mesquite biogeochemistry has been shown to be suitable for mineral exploration purposes in southern Arizona (Chafee, 1975; Brown, 1970; Huff, 1970). The chemical analysis of mesquite twigs from areas with thin soil horizons on pediment surfaces is a particularly valuable application of the method, as mesquite trees have long penetrating roots (Newell, 1974). Samples were collected from mesquite trees along linear features identified on the aerial and satellite photographs. Mesquite ash generally contains higher metal concentrations than do the surrounding media (rocks, soil, dry wash, and water). As considerable variation can be introduced by varying twig diameters, Newell sampled only mesquite twigs with a diameter between 0.25 and 0.5 in, which corresponded to second year growth. Three or more trees were sampled where possible at each site. Newell collected 352 mesquite samples and analyzed them for Cu, Mo, Ag, and Zn.

10.5 Geophysical Surveys In and Near Hay Mountain

MinSearch, Inc. conducted two geophysical surveys in the Zebra project in 1988 – a magnetic survey (Figure 10-9) and a Very Low Frequency (VLF) survey (Figure 10-10) (MinSearch, 1989). The magnetic data indicated the presence of two magnetic highs, one in Sec. 34 and another across the middle of Sec. 27-28. These could indicate the presence of a buried intrusive igneous rock at depth. Some of the VLF highs indicate the presence of faults and represent conductive bodies possibly associated with shear zones (ADMMR file data).

Hauck (1989) discussed the results of the Phelps Dodge aeromagnetic surveys from 1964, as reported by Eisenbeis (1971). He suggested that the aeromagnetic high centered in Sec. 33, T20S, R23E, indicates a possible source intrusive of dioritic composition. Weak IP anomalies also indicated edge of the inferred intrusive rocks, as it is in the vicinity of the strongest magnetic gradient. Another area of very high resistivity zones in Sec. 28 suggested zones of silicification. Hauck indicated that the MinSearch ground magnetic surveys agreed with the results of the 1964 Phelps Dodge aeromagnetic survey.

Geophysical surveys of parts of the Redrock Canyon project were conducted in 1989 and 1990 by Phelps Dodge and MinSearch Inc. (Figure 10-11). These surveys included dipole-dipole apparent resistivity (Figure 10-12) and induced polarization (IP) data (Figure 10-13), which was reprocessed and inversion modeled by Zonge Engineering & Research of Tucson, Arizona in 2003 (Van Reed, 2003).

Additional Controlled Source Audio-Frequency Magneto Tellurics (CSAMT) geophysical surveys were conducted in seven lines oriented along northeast-trending lines (Figure 10-11). CSAMT makes use of electromagnetic waves in the audio or hearing range of frequencies. Measurements of the electric and magnetic field along the survey line are made and are related to resistivity, which results from geologic and mineralogic features. JABA collected 869 geochemical samples along the geophysical lines. Geochemical samples were collected along these lines.

A recent Z-Axis Tipper Electromagnetic (ZTEM) and aeromagnetic geophysical survey was conducted by Geotech (2010a, 2010b) for TEC. The area covered is west and south of the town of Tombstone, but parts of the survey overlap or are adjacent to the Hay Mountain area.

10.6 Interpretation of Tombstone District

Guilbert's (1993) interpretation of the geochemical, geophysical, and geological data in the Tombstone district is summarized below. The Hay Mountain project has some bedrock outcrop, the area interpreted to overlie the intrusive rock and delineating a potential porphyry copper center occurs in a valley area with alluvium at the surface (Figure 8-1).

A zoning pattern is apparent in the Tombstone district production and alteration-mineralization studies. High Mn-Ag mineralization characterized the outer arcuate rim of mines from northwest to southeast, including the Lucky Cuss, Prompter-Oregon, Emerald, and Bunker Hill. Zoning from the outer Mn zone toward the southeast corner of the townsite shows that Mn decreases to the southeast while Zn, Cu, silica, Au, F, and Mo increase.

The potential porphyry copper center at Hay Mountain is not visible on the surface. The bedrock into which the mineral system is presumed to have been emplaced is composed of a thick section of Paleozoic carbonates. Before its erosion, a blanket of unknown thickness of extra caldera Uncle Sam Tuff capped the Laramide erosion surface on the Bisbee Group sediments. It would be expected that such a porphyry mineral system would consist of skarn alteration of the carbonates proximal to the mineral center along with carbonate replacement bodies of massive sulfides of Zn, Pb, and perhaps at some depth Cu and Mo. The discovery of such mineralization is an exploration objective, but there is circumstantial evidence for this Cu mineralization. Exploration by Eagle Picher Mining Co. in the 1930s discovered massive sphalerite galena-Ag bodies (Burton De low threshold values considered < 400 ppm ere, personal communication to Briscoe, 1982), and production of this type of material from the Jeanes Roll was documented by Butler and Wilson (1937). Ransome's unpublished notes from his first investigations in the district in 1914 contain comments about pervasive calc-silicate alteration of the Naco Group limestone on the 600 ft level of the Contention mine. Although the suspected Hay Mountain porphyry center is under cover, zonation of precious metals in exposed rocks around the projected porphyry center is similar to recognized haloes around better exposed porphyries.

Excellon Resources, as part of its exploration campaign in the Tombstone area, contracted for new orthophotography at 1" = 2,000'. On this photography, the Prompter fault is not straight as it has been mapped previously, but rather is concave to the north. It lines up with the north- to northeast-concave Lucky Cuss fault system. The combination of the two faults describes an arcuate structure, the centroid of which is the projected Hay Mountain porphyry center. These faults localize Mn-Ag mineralization that can reasonably be interpreted as the outer part of a porphyry alteration zonation (Guilbert, 1993).

10.6.1 Interpretation of Geophysical Surveys

In the general Tombstone district, the aeromagnetic surveys (Figure 7-18) and gravity surveys (Figure 7-19) are regional surveys and do not give sufficient detail to interpret exploration targets. Both indicate the general outline of the bedrock of the Tombstone Hills, but there is not sufficient detail to make detailed interpretations. Background values at Tombstone were about 300 to 400 gammas, but the granodiorite was found to have values between 700 and 1000 gammas. Brant (1966) found the Schieffelin Granodiorite had a magnetic susceptibility of 1800 x 102 c.g.s. units (centimeter-gram-second units).

Interpretation of the IP geophysical data for the Redrock Canyon and Hay Mountain areas suggests a deep-seated porphyry surrounded by skarn type alteration in the Paleozoic sediments (DuHamel and Briscoe, 2003). The Hay Mountain system is defined by an aeromagnetic high (Figure 10-14) that corresponds to Cu, Mo, Zn, and outer Au halo zoning identified by geochemical sampling (Smith, 2005). The CSAMT and IP data from Zonge are shown in Figure 10-15. The ZTEM survey of the area southwest of Tombstone fringes the Hay Mountain area and shows a zone of high IP in the Hay Mountain area (Geotech, 2010) (Figure 10-16).

10.6.2 Interpretation of Geochemical Surveys at Tombstone

Anomalous values for base metals (Cu, Mo, Zn) were noted by Newell (1974) in several areas around Tombstone in the following general locations:

- Government Draw-Walnut Gulch structural intersection, where anomalous Cu values (200-275 ppm) and low to high threshold values of Zn occurred in Secs. 1, 2 and 3, T21S, R23E (this is the Hay Mountain project area);
- Walnut Gulch north of Tombstone as it changes directions from northwest to west, where background and low threshold Cu values were found, but only background Zn values (<400 ppm) occurred;
- San Pedro-Government Draw structural intersection (Sec. 17, 18, T21S, R22E) north of Lewis Springs, where Cu tended to increase from low threshold concentrations (101-150 ppm) to high threshold values (150-200 ppm), and where Zn had low to high threshold concentrations, and where Mo was anomalous;
- Intersection of the Ajax fault with the Prompter fault in Secs. 15 and 16, T20S, R22 E, where background to low threshold Cu values and low threshold concentrations of Zn were also found, and mine dump samples showed high ratio values for Cu, Ag, and Zn;
- Intersection of the Horquilla fault with the Ajax fault (Sec. 27, T20S, R22E), where low threshold to anomalous Cu values and high threshold and anomalous Zn values were found;
- Northeast-striking fractures in the Uncle Sam Tuff (Secs. 19, 20, 29, and 30, T20S, R22E) contain background and low threshold concentrations of Cu, and background concentrations of Zn;
- Near the State of Maine and San Pedro mines, anomalous values of Zn from Sec. 9 and 17, 3 mi west-southwest of Tombstone, and the center of the high Mo ratios in mine dump samples between the Charleston Lead mine and the State of Maine mine in Sec. 29;

Eastern edge of the main Tombstone district (Sec. 12, T20W, R22E), where and low to high threshold Zn and Mo in mesquite twigs and high Pb and Mo mine dump ratios; and

- Near the Emerald mine (Sec. 14, T20S, R22E), where high threshold Zn and Cu in mesquite twigs and high Cu and Zn ratios in mine dump samples exist.

Newell suggested that the Government Draw anomaly was the most promising. This is near the Hay Mountain project area. This potential drilling target is where anomalous Cu values (200-275 ppm) and low to high threshold values of Zn occurred in Secs. 1, 2 and 3, T21S, R23E.

The interpretation of the 2004 JABA sampling program indicated that the location of large disseminations of Au in the Redrock Canyon project are dependent on intersecting feeder veins where they transition from the impermeable Colina Limestone to the porous underlying Earp Formation, with other possibly favorable porous formations deeper in the Paleozoic section. The higher grades of the submicron Au mineralization are located in subtle surface expression of veins characterized by silica, minor iron staining, decalcification of limestone, and subtle marbleisation and bleaching. The most obvious Au indicator is limonite-stained jasperoid in bodies up to 100 ft wide and 400 ft long that frequently assay more than 1 ppm Au, with values up to 1.6 oz/ton Au where the veins are heavily limonite- and hematite-bearing (DuHamel and Briscoe, 2003).

10.6.3 Interpretation of Geochemical Surveys at Hay Mountain

Smith (2005) indicated that economic metals on the Hay Mountain property include Cu-Mo and Au-Ag. He stated that a porphyry system is indicated by spatially coherent B, Ba, Co, Cu, Fe, La, K, Mn, Mo, Na, P, S, Sb, Se, Sr, and Zn. A potassic core is suggested by enrichment of K, P, and Sr, and overlapping Cu. Associated hydrothermal activity is indicated by a very broad halo of boron. Circular features with depleted centers are found in the patterns of Fe, La, Mo, and Se. Elevated Sb and Mn concentrations are outbound of the core. This porphyry feature at Hay Mountain is 800 m east-west by 600 m north-south. A second and much smaller system is indicated by a tight cluster of Mo-Au enrichment in the northwest corner of the survey block (Smith, 2005).

Au and Ag are weakly enriched in the center of the porphyry system. Smith also stated that three more areas indicate coincident Au-Ag mineralization. These areas generally trace a discontinuous southeast-northwest trend across the Hay Mountain property that is loosely coincident with associated pathfinder elements Cu, Hg, and depletions of Zn.

Anomalous soil concentrations of Ag, As, B, Cu, Ga, Fe, K, La, Mn, P, Pb, Sc, Tl, and Zn are concentrated in the southeast corner of the Hay Mountain block. These form a large circular area of elevated trace metal concentrations that are believed to be caused by a mineralized porphyry intrusive. Several linear features in the soil data indicate various northwest, north-northwest, and northeast orientations that may be related to radiating dikes nearer the surface than the intrusive rock (Smith, 2005).

The primary drill target recommended by Smith (2005) is the porphyry system in the southeast corner of the Hay Mountain project, with particular attention to the high-Cu areas that might indicate secondary enrichment blankets. A second porphyry target is defined by the Mo-Au cluster in the northwest corner of the survey block. Smith also recommends four additional areas for drilling that lie on a northwest trend.

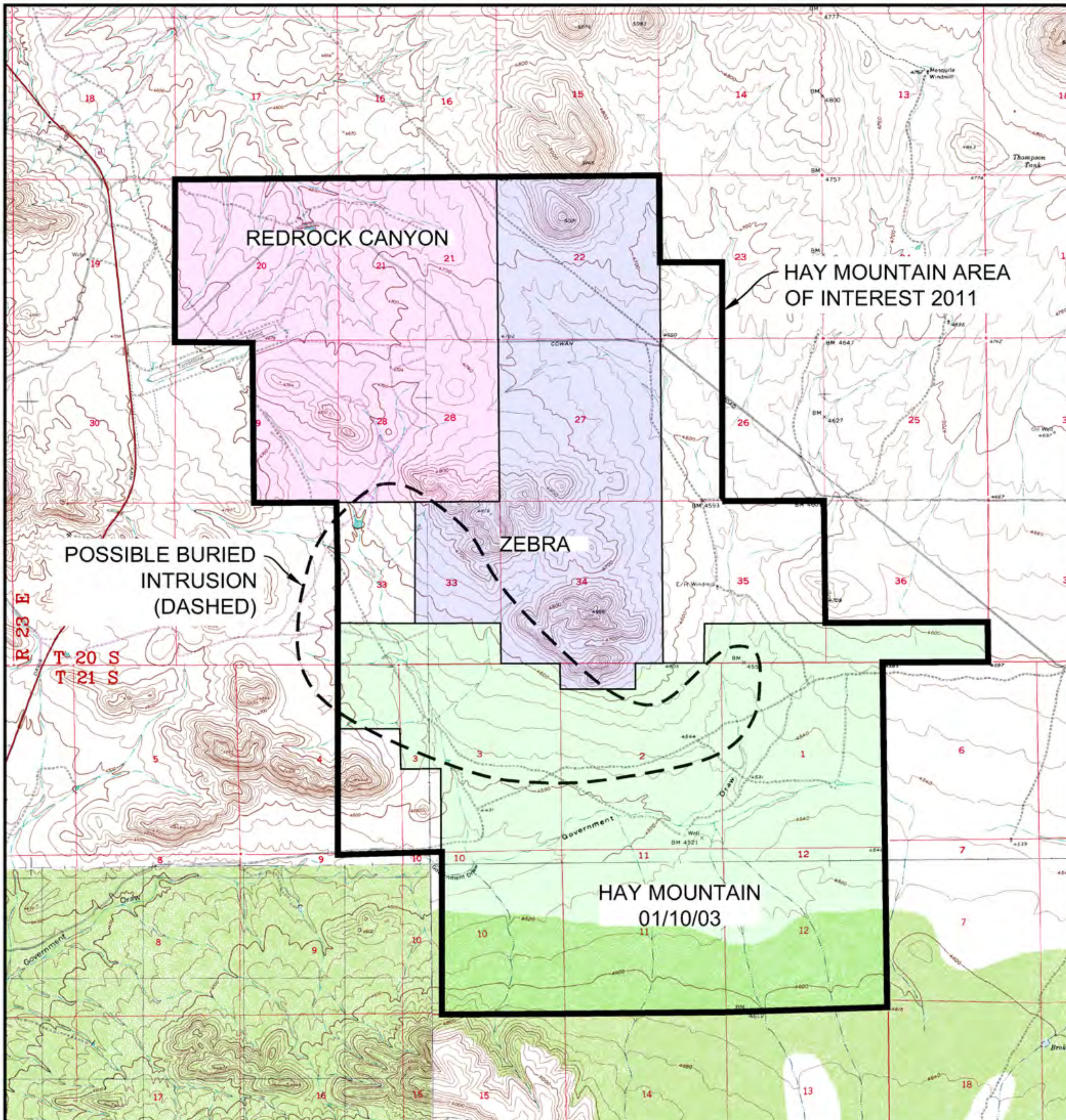
10.7 Conclusions

SRK concludes that Liberty Star's early stage exploration concept is appropriate for the property. The concept for a potential buried copper porphyry deposit south of Tombstone has been developed based on an interpretation of the available local and district-scale surface geology, structure, and geochemistry data, the compilation of mineralization and zonation observations made by Briscoe and others from historic mining operations, and the geophysical surveys. The compilation of available data has been conducted in accordance with acceptable industry procedures. The direct association of copper porphyry deposits with an extensive caldera complex has been demonstrated at the Silver Bell mine and elsewhere in the region and has the potential to be applicable in the Tombstone district.

10.8 Recommendations

SRK makes the following recommendations:

- Use industry-standard mapping software such as ArcInfo for preparing maps. Such software would permit preparation of maps and data in a conventional format for presentation or sharing on an as-needed basis;
- Conduct a comprehensive soil geochemical and geobotanical sampling program on the Hay Mountain property to confirm and supplement the earlier analyses by Newell. Record the results in an Access or similar database and link to the ArcInfo base map. The database should contain the following information for each sample: sample number, laboratory sample number, sample location by latitude/longitude and/or UTM, sample location by description, sample collection date, sampler's name, sample type, analytical laboratory, sample analysis date, assay/analytical results by element, units of measure for each assay/analysis, analytical method(s) for each element. Assays and analytical results, and QA/QC analytical check assays should be recorded in the units used by the laboratory.
- Conduct ZTEM geophysical surveys specifically over the Hay Mountain project area. ZTEM is a helicopter-borne survey method that measures electromagnetic activity. Geotech's technology and sensitive measuring equipment enables detection and modeling of the shape of metallic mineral bodies at more than two kilometers (3,300 feet) below the surface.
- Assess the most favorable areas the project area, confirm land access requirements, and apply for exploration permits as required.
- Conduct exploration drilling in the locations determined by results of the above recommended work.



GENERAL NOTES

1. THIS DRAWING IS FOR ILLUSTRATIVE PURPOSES ONLY. ALL DIMENSIONS AND LOCATIONS ARE APPROXIMATE BASED ON AVAILABLE INFORMATION.
2. THE DRAWING IS IN UTM NAD 27 COORDINATES, ARIZONA ZONE 12N, FEET.

REFERENCES

1. LIBERTY STAR DATA FILES.
2. USGS

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0 2500 5000 7500 10000

SCALE IN FEET

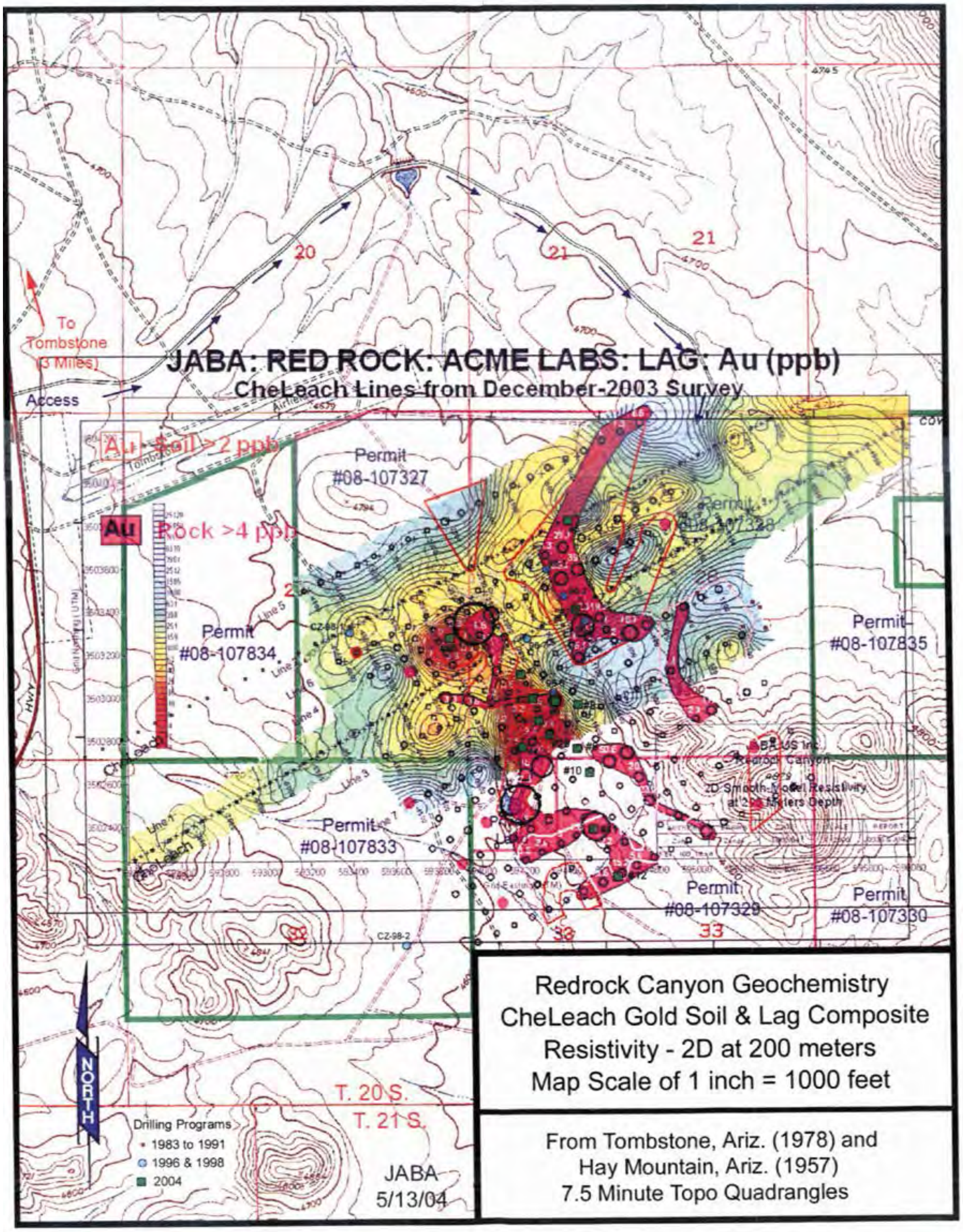
srk consulting

LIBERTY STAR URANIUM & METALS CORP.

Tombstone, Arizona

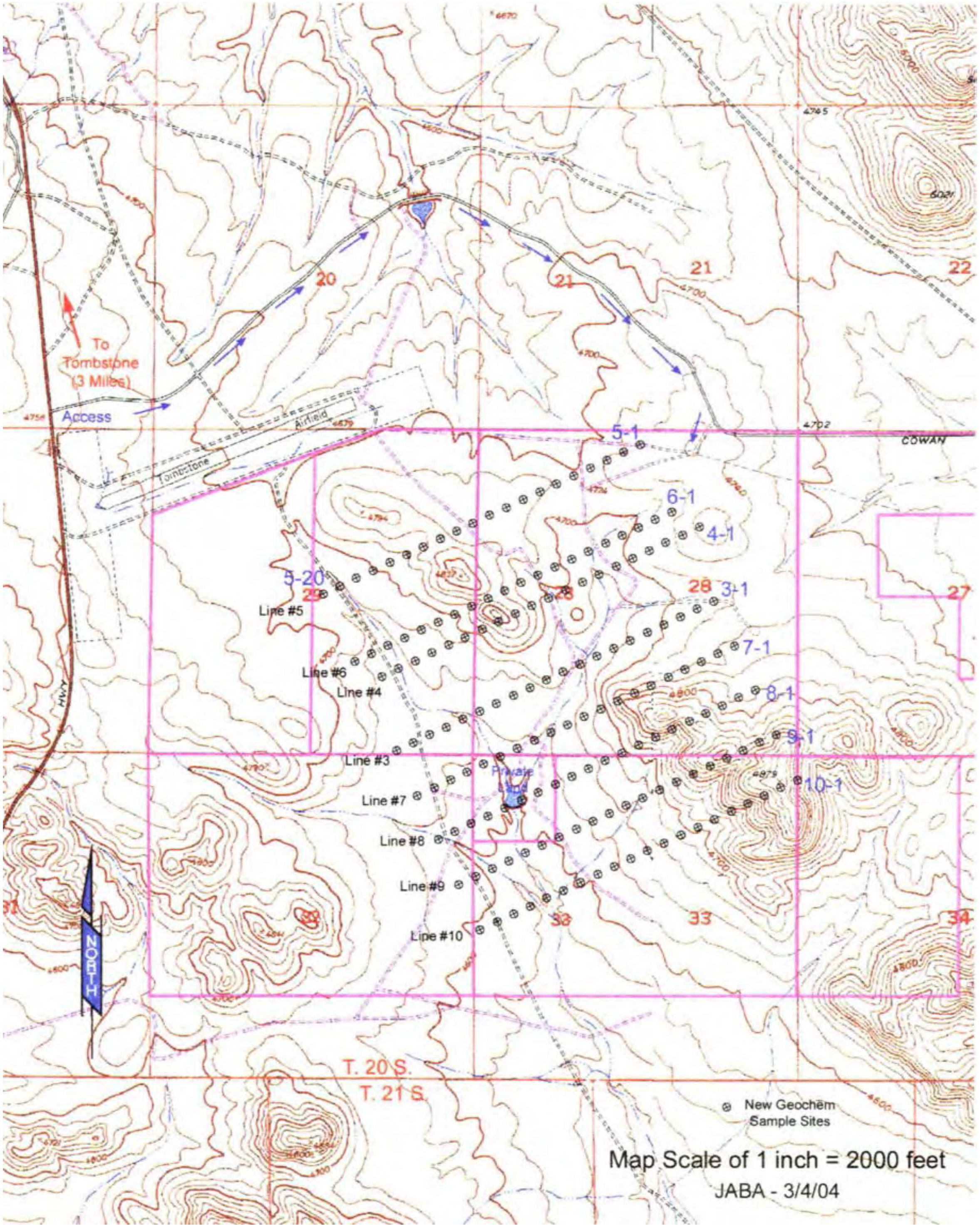
Hay Mountain and surrounding areas

SRK JOB NO.: 173300.03 Task 600	Internal Control Number 3	Hay Mountain Exploration Report	DATE: June 2011	APPROVED: JR	FIGURE: 10-1	REVISION NO. 1
FILE NAME: 10-1 HAY MOUNTAIN AND SURROUNDING AREAS						



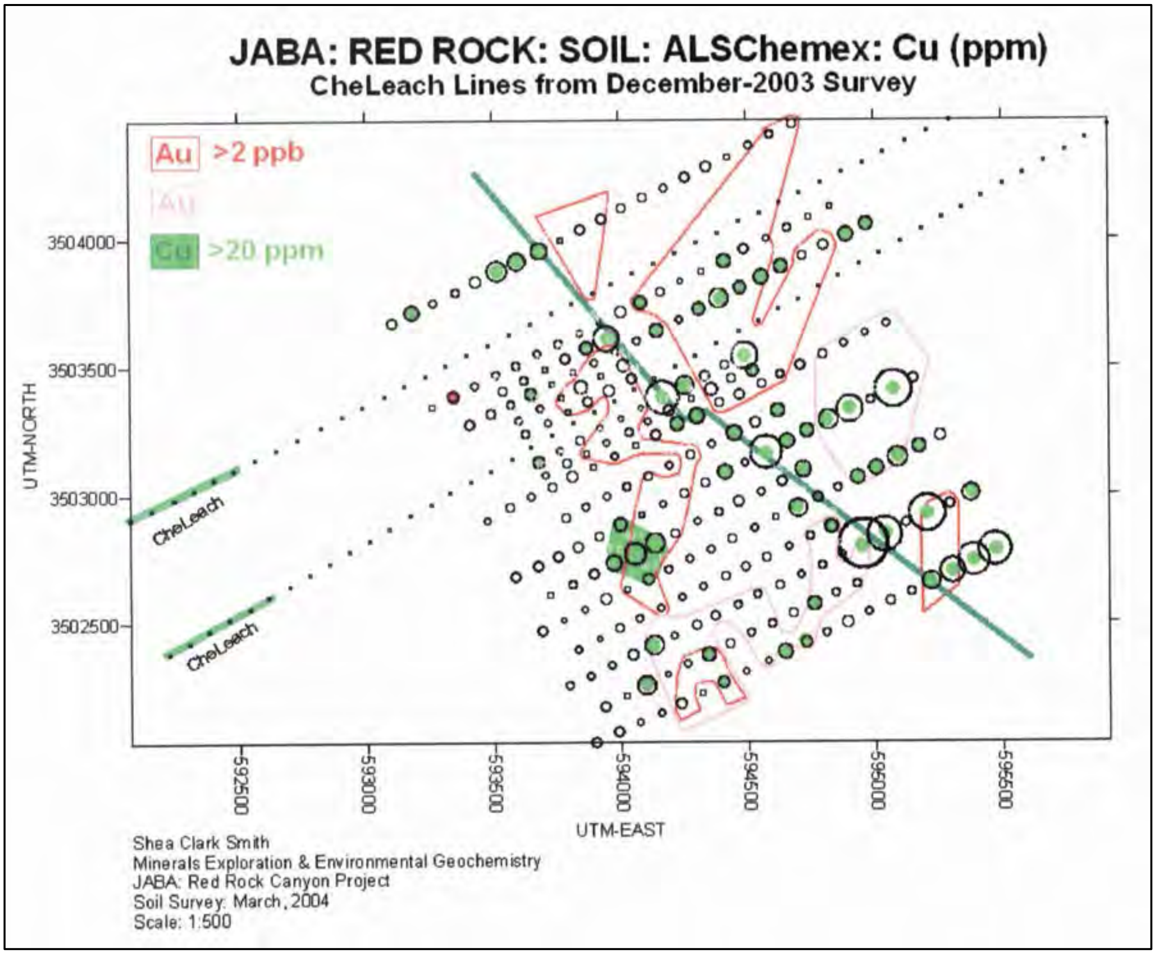
Source: Liberty Star historic data

Figure 10-2 Map of Redrock Canyon soil geochemical samples



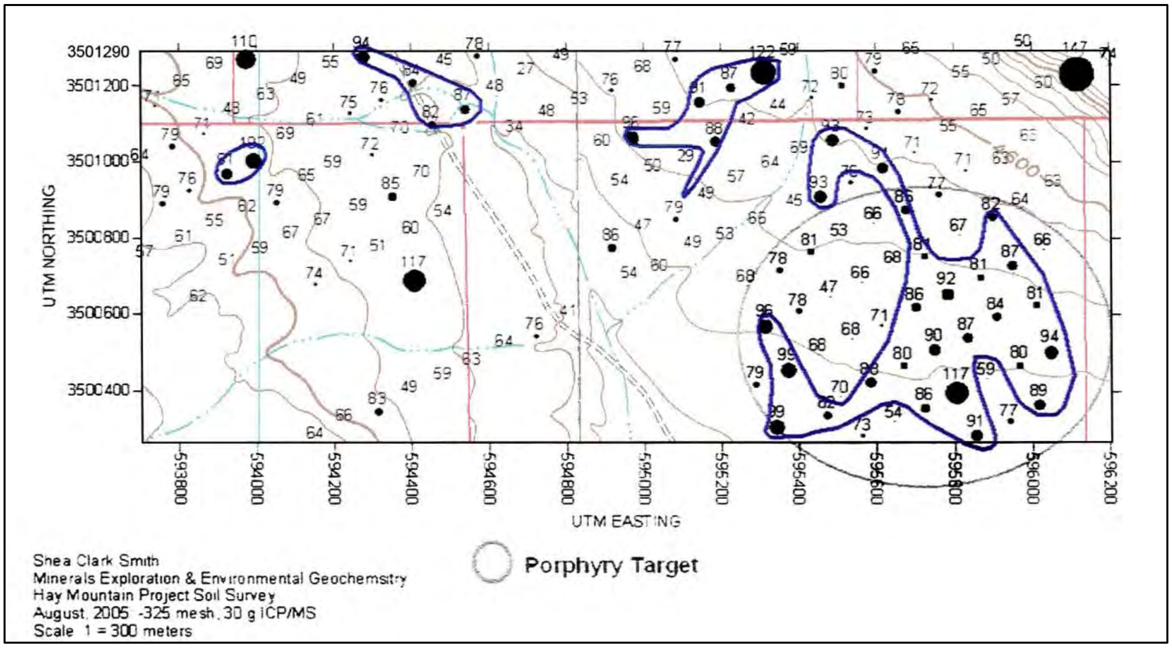
Source: Liberty Star file data (2004)

Figure 10-3 Hay Mountain geochemical sampling lines 2004



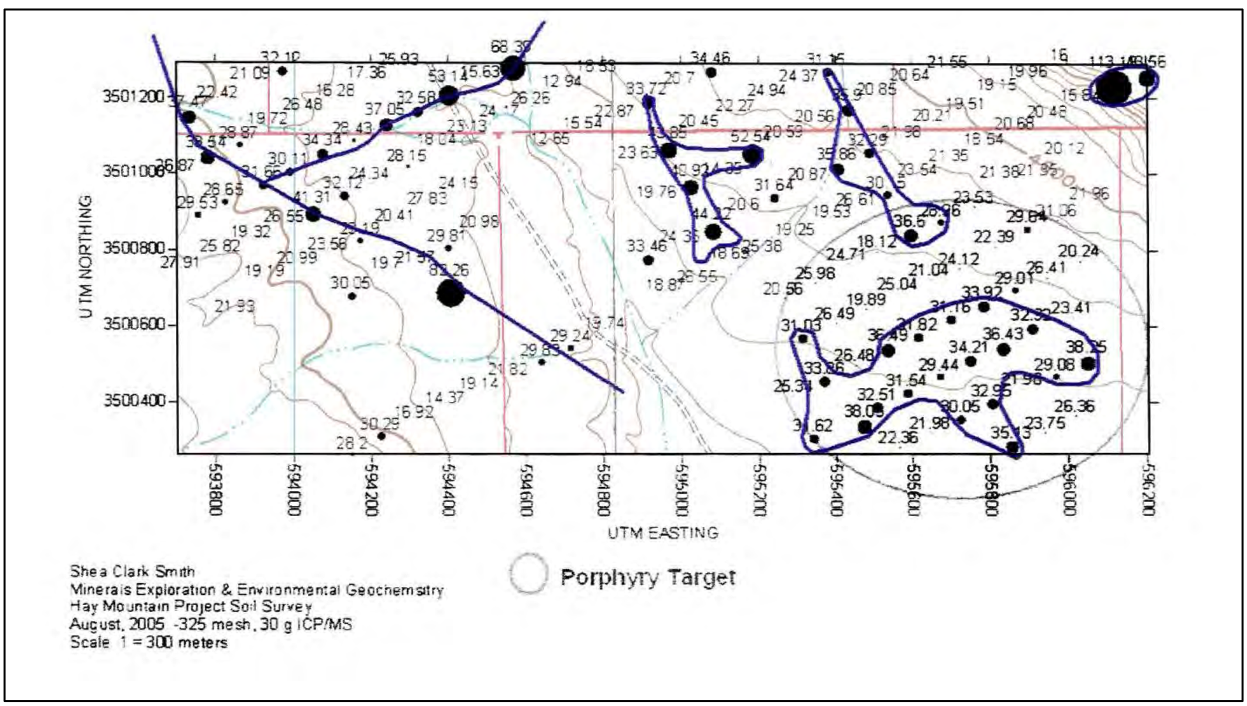
Source: Liberty Star historic data

Figure 10-4 Cu in soil geochemistry Redrock Canyon



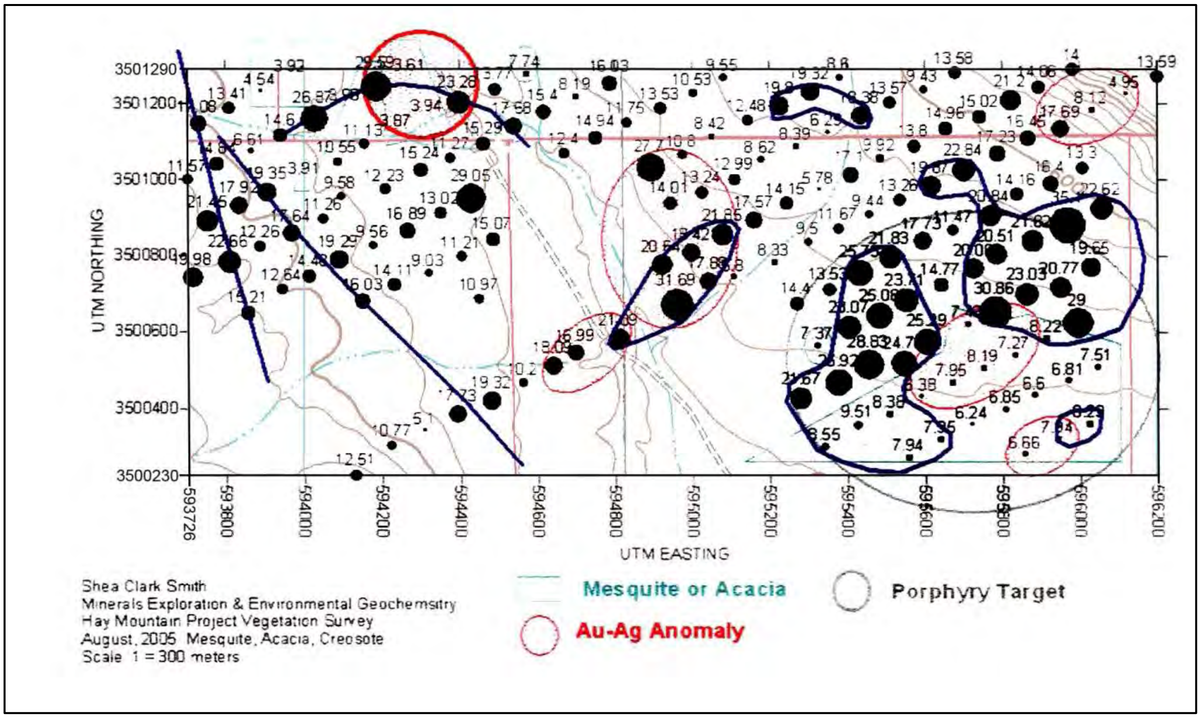
Source: Smith (2005)

Figure 10-5 Anomalous Ag in ppm in Hay Mountain soil samples



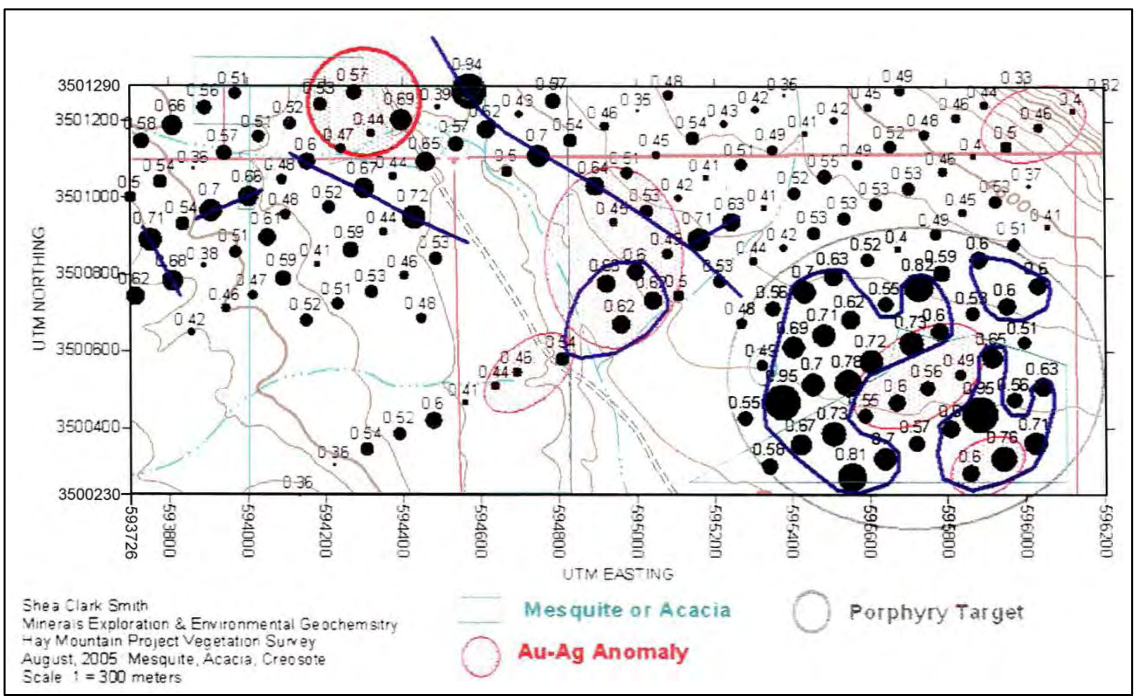
Source: Smith (2005)

Figure 10-6 Anomalous Cu in ppm in Hay Mountain soil samples



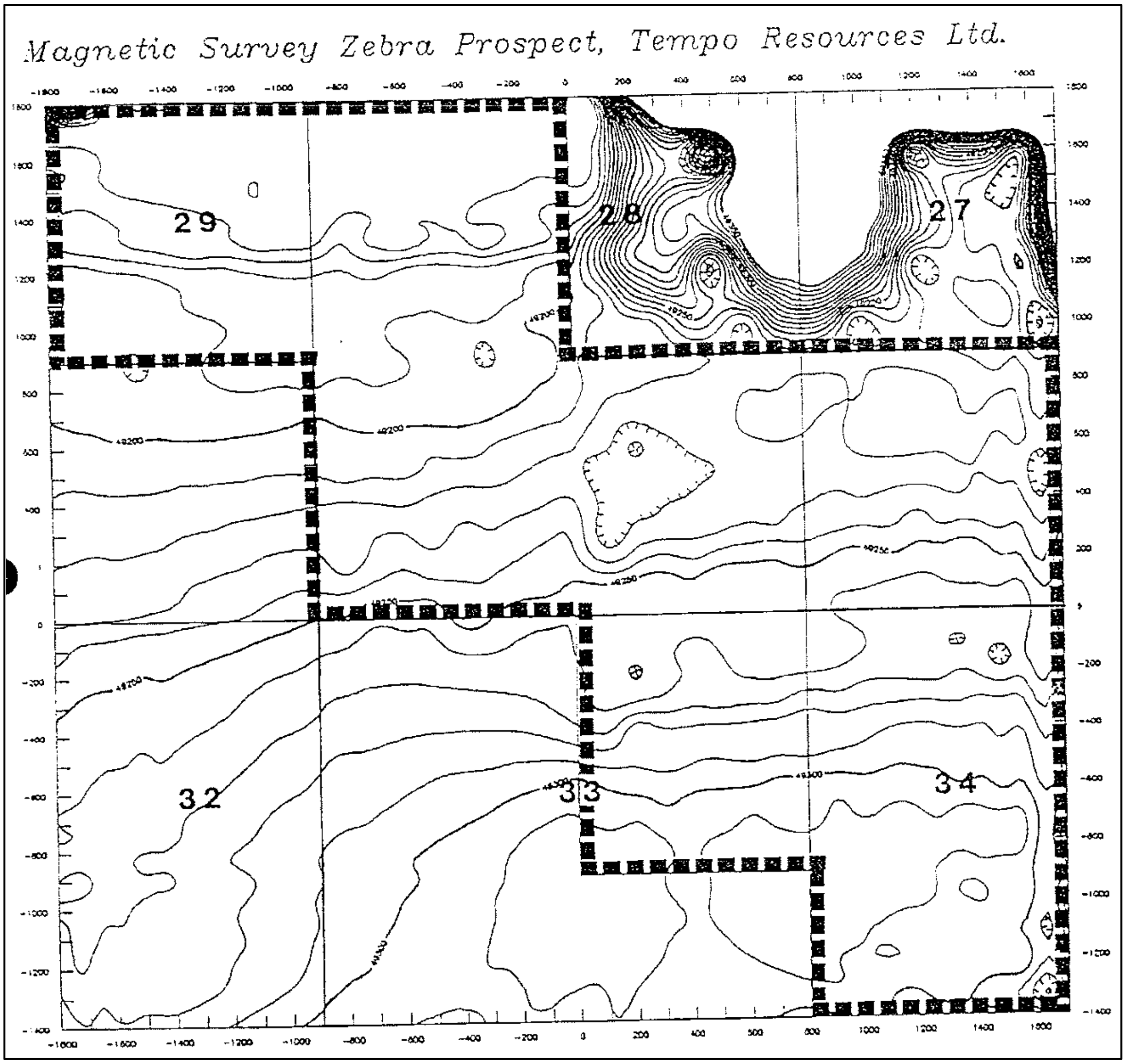
Source: Smith (2005)

Figure 10-7 Anomalous Cu in ppm from Hay Mountain vegetation samples



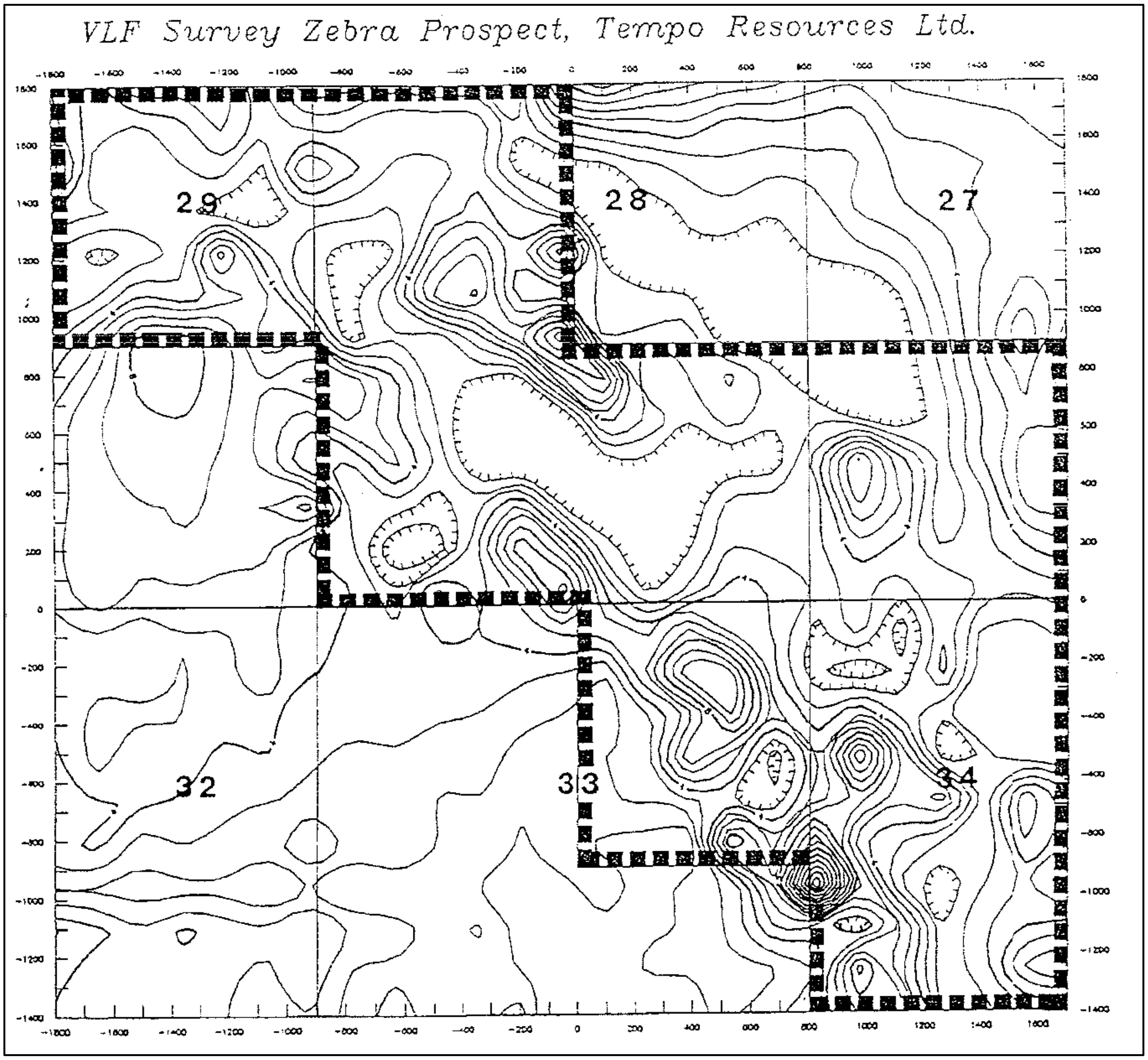
Source: Smith (2005)

Figure 10-8 Anomalous potassium (K) in ppm from Hay Mountain vegetation samples



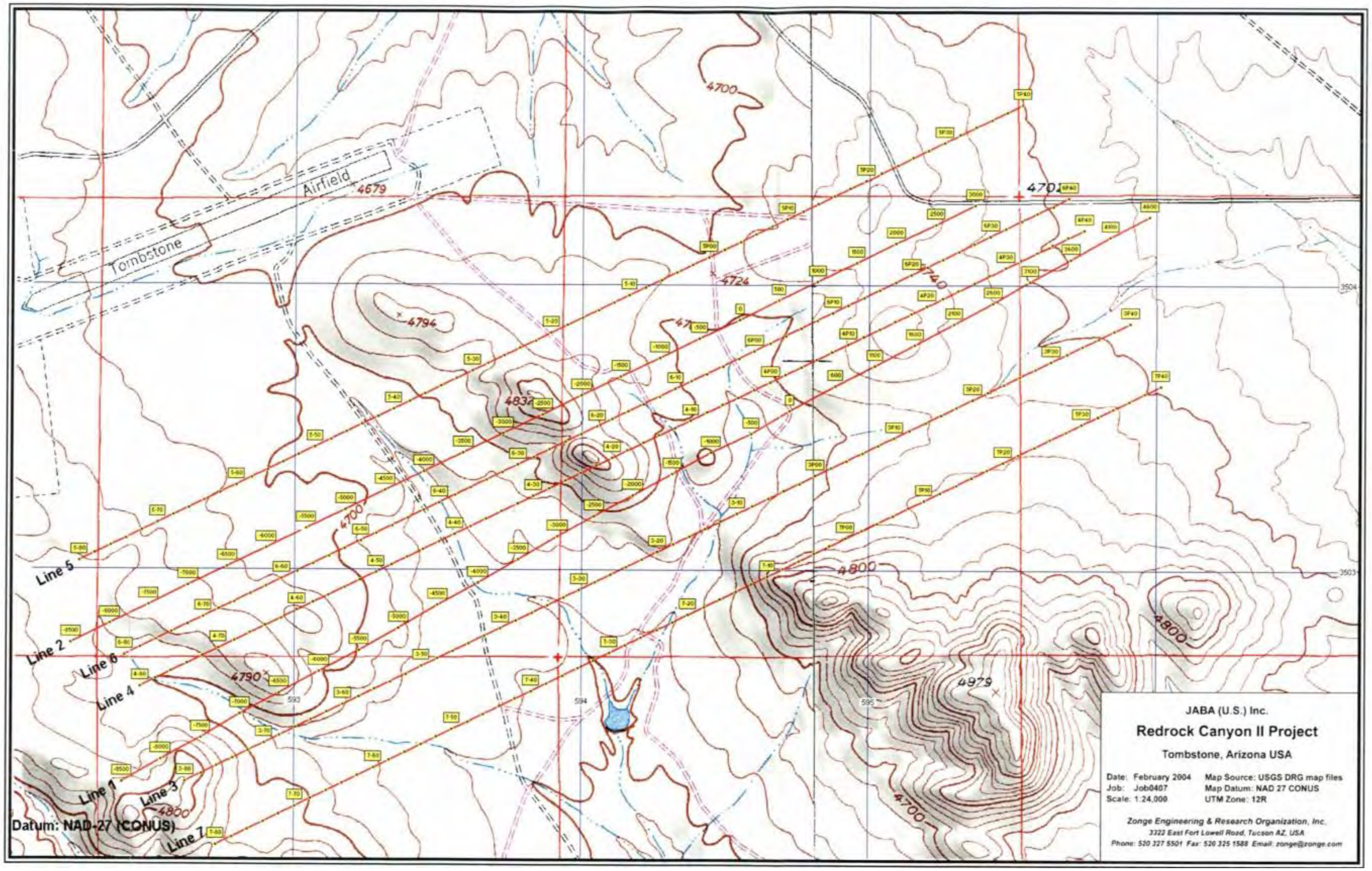
Source: Renn (1989)

Figure 10-9 Magnetic survey of Zebra prospect



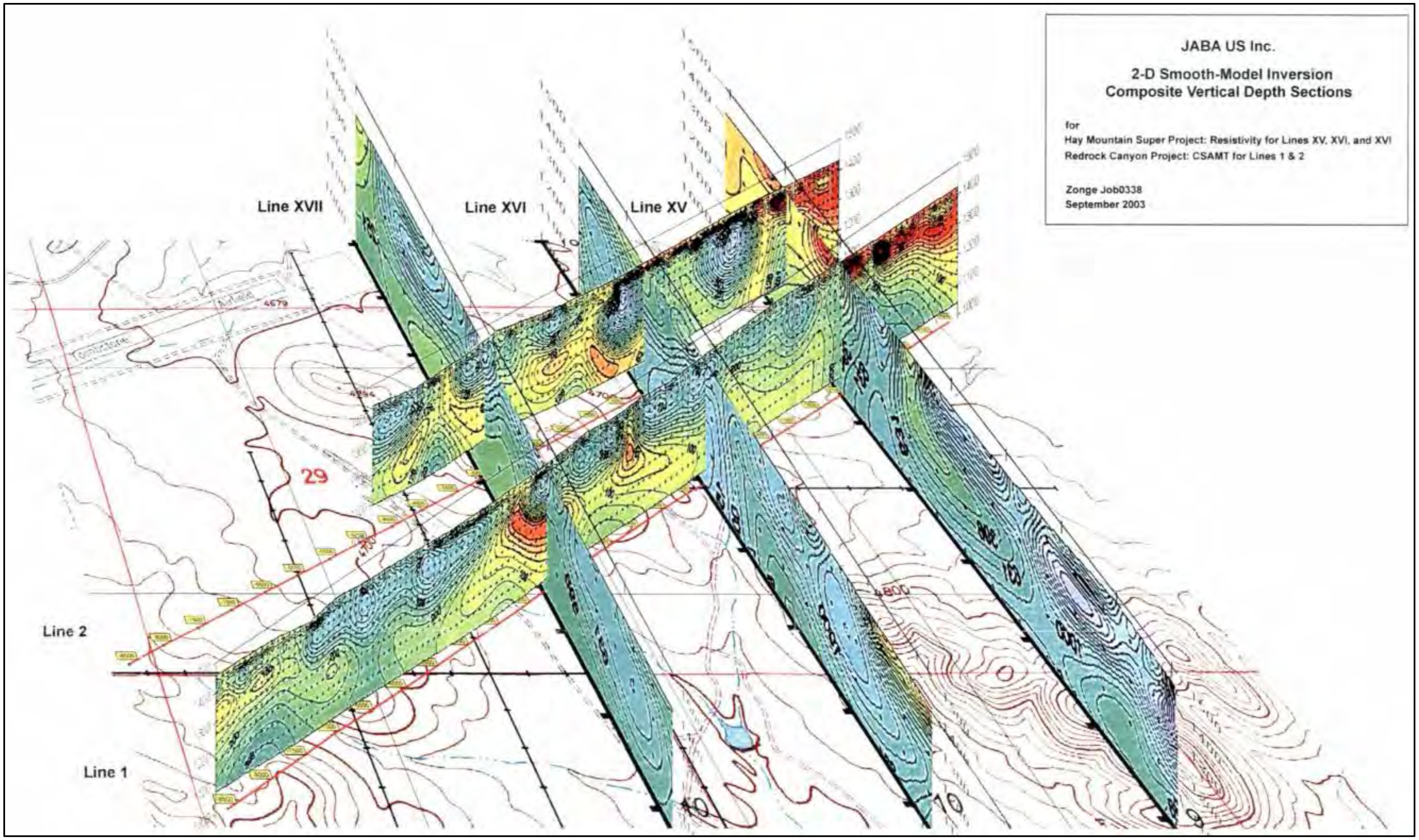
Source: Renn (1989)

Figure 10-10 VLF survey of Zebra prospect



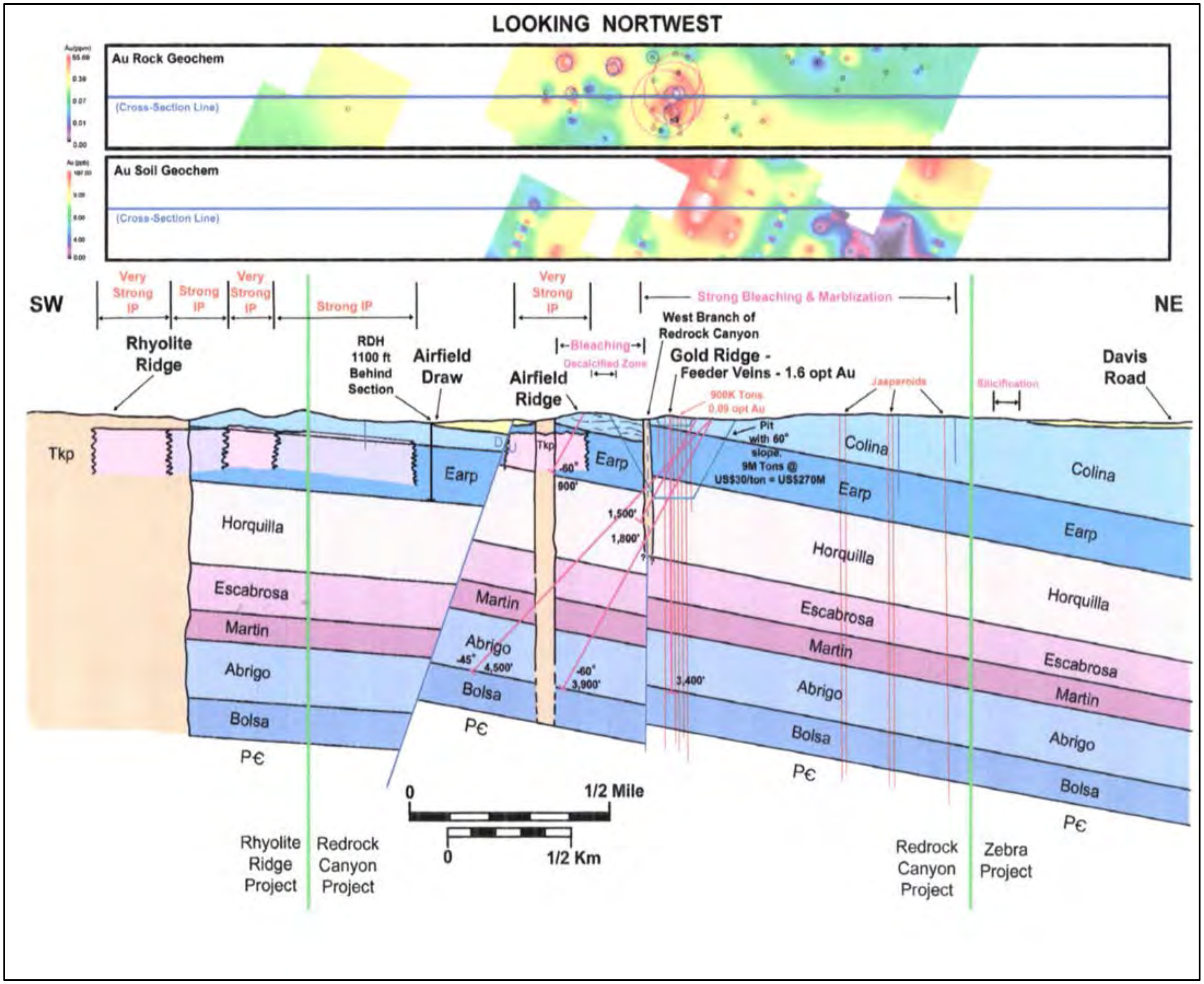
Source: Zonge (2004)

Figure 10-11 CSAMT survey lines, Redrock Canyon project



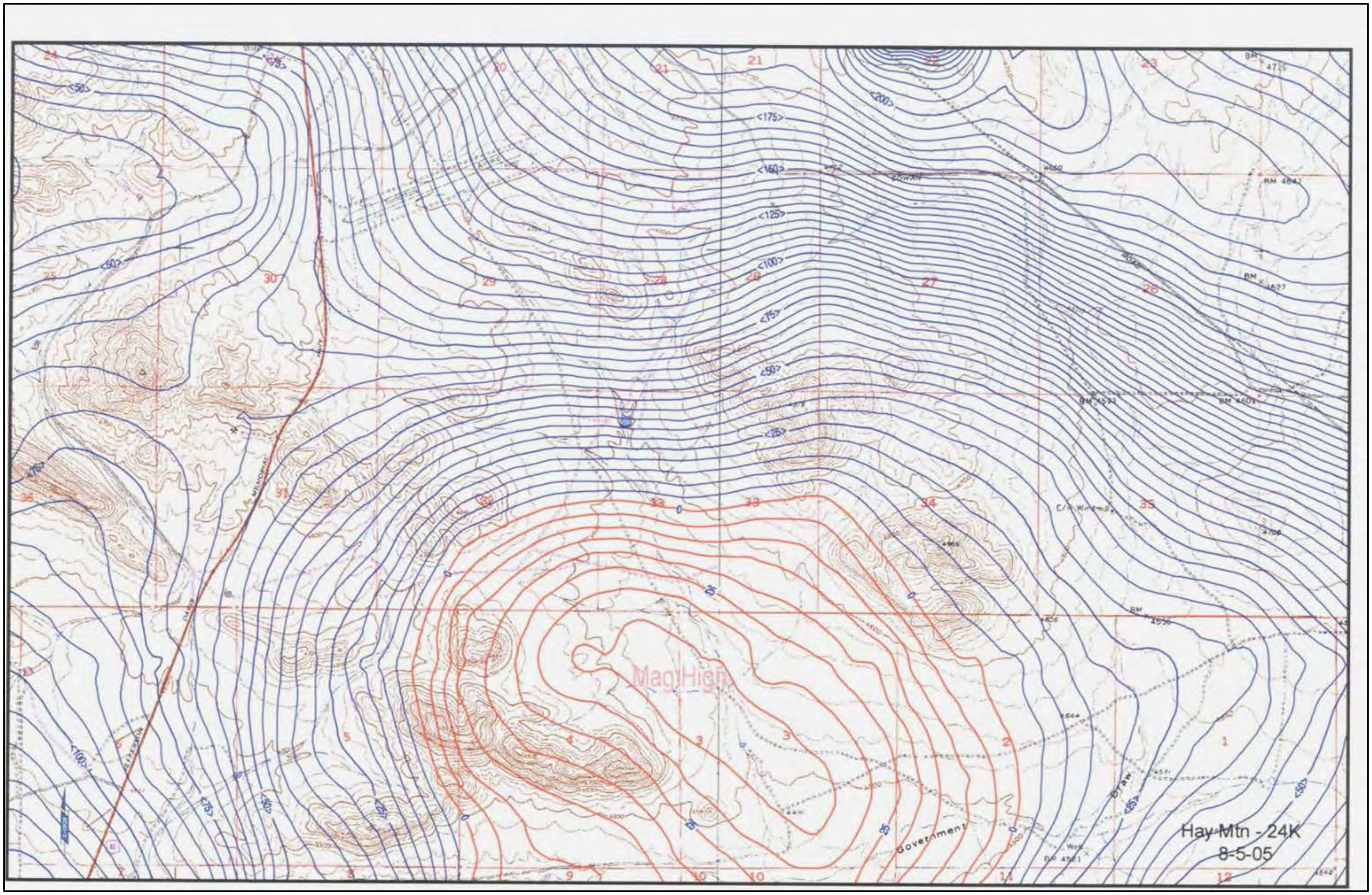
Source: Zonge (2004)

Figure 10-12 2D resistivity for Hay Mountain project and CSAMT for Redrock Canyon project



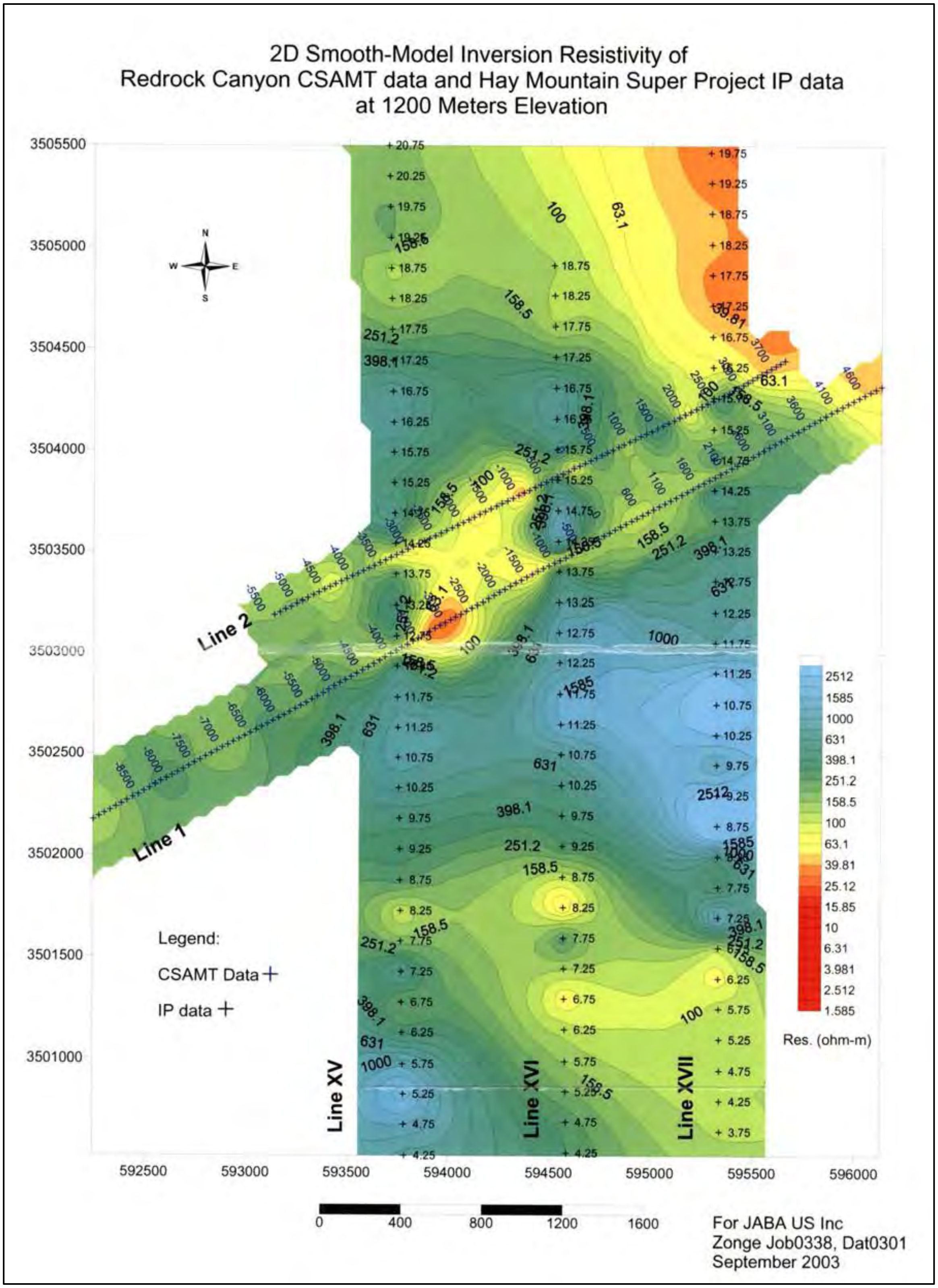
Source: Liberty Star file data

Figure 10-13 Induced Polarization and stratigraphy of Redrock Canyon and Zebra projects



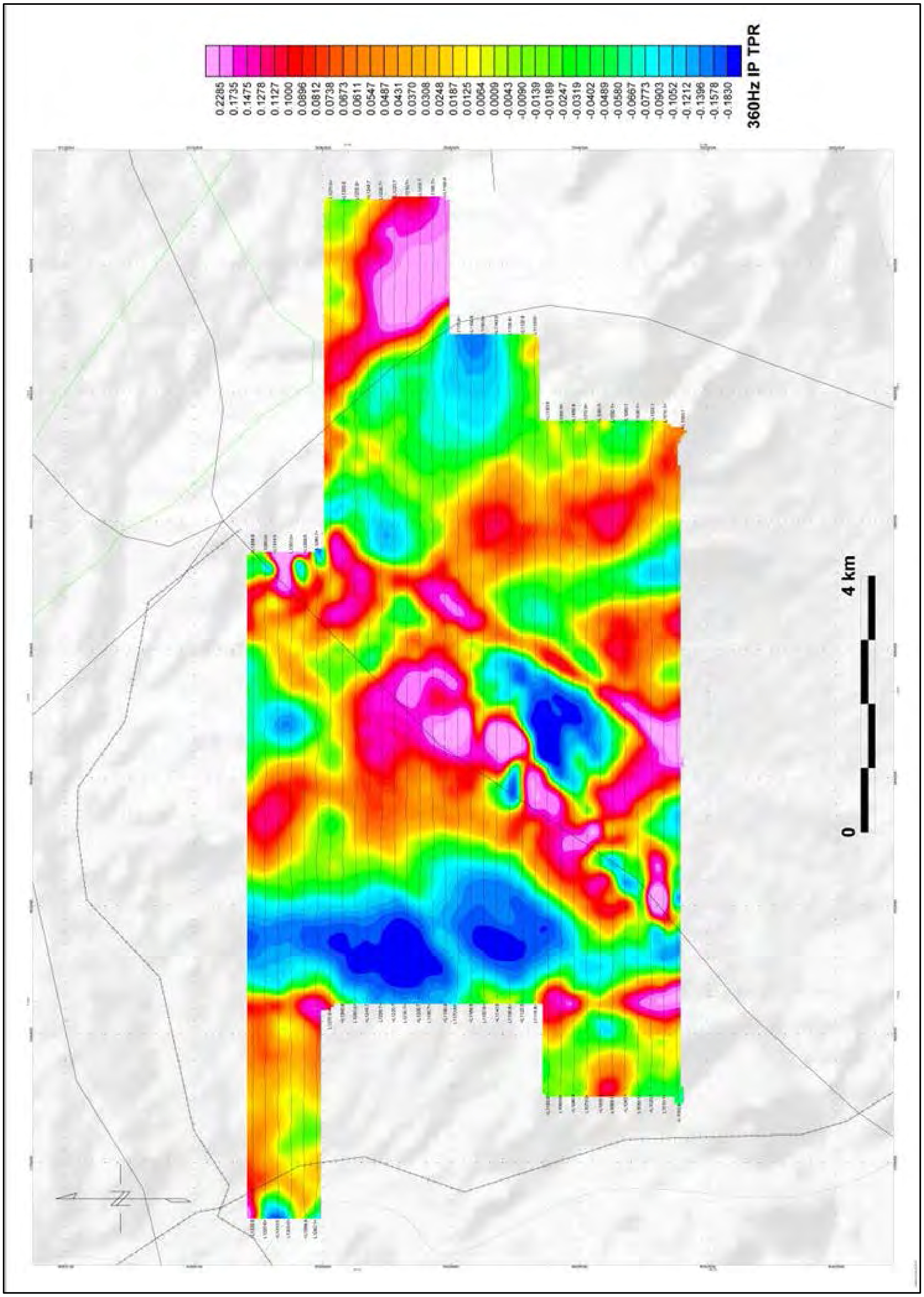
Source: Liberty Star file data

Figure 10-14 Aeromagnetic survey of Hay Mountain area



Source: Liberty Star file data

Figure 10-15 Redrock Canyon and Hay Mountain IP and CSAMT data



Source: Geotech (2010)

Figure 10-16 High Frequency (360 Hz) in-phase total phase rotated (TPR) ZTEM survey

11 Drilling (Item 13)

The Hay Mountain project is an early stage exploration concept and no exploration drilling has been done by Liberty Star for Cu. Several drill holes were drilled for Au in the Zebra and Redrock Canyon project areas (included in the Hay Mountain area), but samples were not assayed for Cu.

11.1 Type and Extent of Drilling

Reverse circulation drill holes were drilled in the Zebra project in 1989 in Sec. 28 and 33 (Figure 11-1). These holes intersected anomalous Au mineralization with a maximum value of 0.45 oz/ton over a 20 ft interval (Halterman, 1989, 1990). The drill program by Consolidated Paymaster consisted of 10 reverse circulation drill holes totaling 2,465 ft in Secs. 34 and 28. These holes intersected minor Au mineralization near the surface. The Wellington Financial drill program in 1985 consisted of one drill hole, 28-4 and intersected argillically altered, hematite-stained limestone with minor amounts of Au (0.037 oz/ton near the surface. The 1989 drill program by Tempo Resources on the Zebra property consisted of 7 drill holes (28-3, 28-4, 89-1, 89-2, 89-3, 89-4, 89-5, 89-6 totaling 1,311 ft. These drill holes intersected Au mineralization, iron oxide alteration, or jasperoids (Halterman, 1990). The 1983, 1985, and 1989 drill programs located an area of shallow Au mineralization in Sec. 28. The Au mineralization is disseminated through several receptive limestone intervals.

In 1990, 9 reverse circulation angle holes (90-1, 90-2, 90-3, 90-4, 90-5, 90-6, 90-7, 90-8, and 90-9) were drilled in Sec. 28 on the Zebra project, with an average depth of 140 ft (Halterman, 1990). All but one drill hole contained anomalous Au (Halterman, 1990). However, the samples were only analyzed for Au (by Atomic Absorption [AA]/Fire Assay finish), so no conclusions can be interpreted concerning the Cu potential.

Seven exploration drill holes were drilled by rotary, reverse circulation equipment in Secs. 28 and 34 in November 1995-January 1996 for a total footage drilled of 3,145 ft. The drill holes targeted the stratigraphic contact between the Permian Colina Limestone and Earp Formation at a depth of 200 to 400 ft in a permeable zone, although no significant Au intercepts were found and the project was not recommended for further work by Sunshine Mining & Refining Co. (Vanderwall, 1996).

Exploration drilling for Au was conducted at the Redrock Canyon, Zebra, and Hay Mountain projects during 2004 (Figure 11-2). Drill logs, chain of custody, analytical results, and laboratory certificates were found in the Liberty Star files from four core drill holes in the Redrock Canyon area. RRC-ddH-1 was in Permian Colina Limestone and had a total depth of 487.5 ft; RRC-ddH-2 was in Permian Colina Limestone and Pennsylvanian Earp Formation an had a total depth of 1013 ft; RRC-ddH-3 was also in Colina and Earp formations and had a total depth of 1064 ft; and RRC-ddH-4 was in Cretaceous Bisbee Group sediments and had a total depth of 321.5 ft.

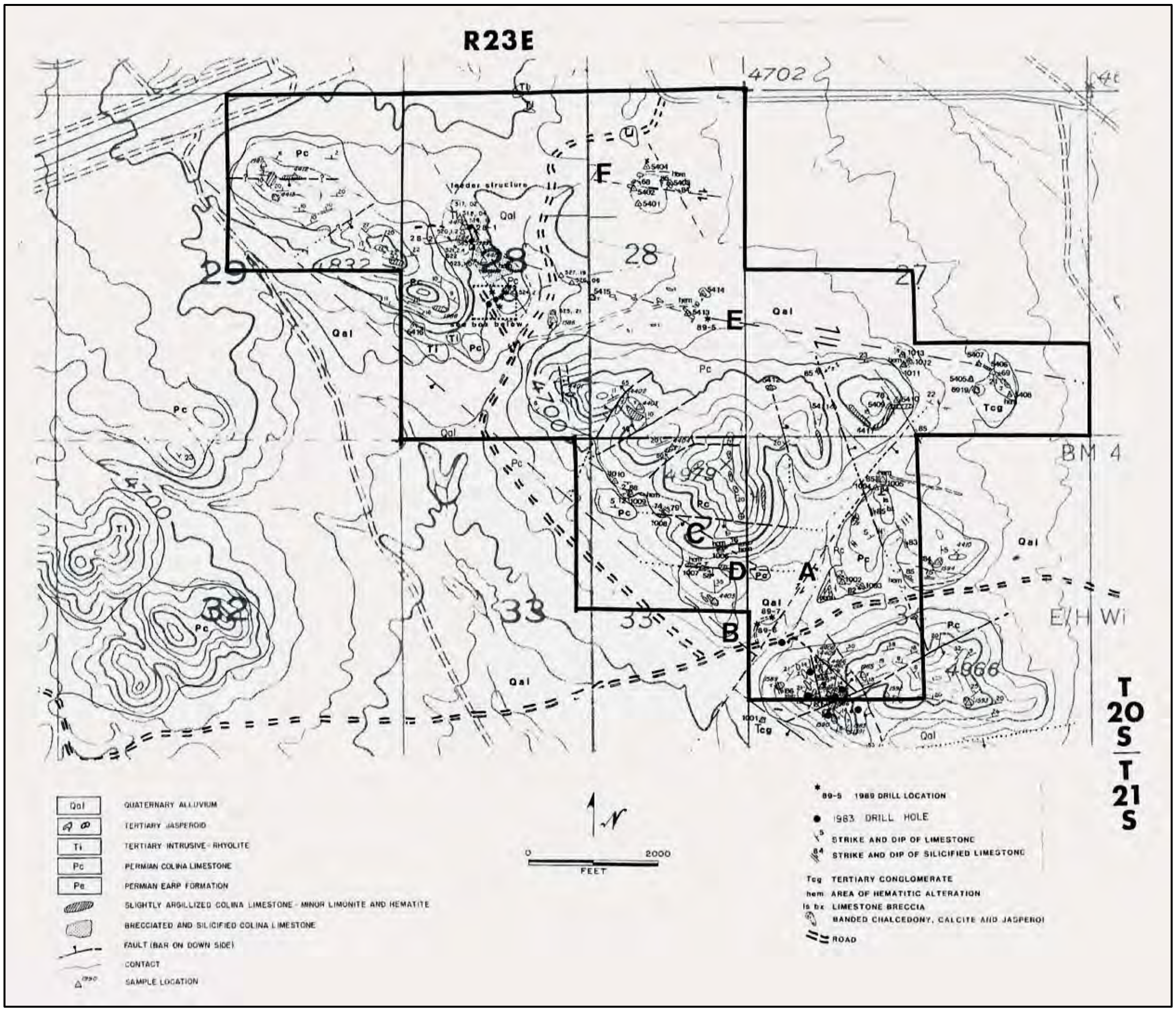
An oil test well, Bedrock Oil 1 State (also called Bedrock Oil Co. – Winnie No. 1), was drilled in 1982 in the Se ¼ of the SE ¼, Sec. 4, T21S, R23E. The Arizona Oil & Gas Commission permit number was 0833 and the total depth was 2,932 ft. Drill logs indicate the top of the Mississippian Escabrosa Limestone was at approximately 1,860 to 1870 ft depth and the top of the Devonian Martin was at approximately 2,710 ft. Slight gas or oil shows were recorded at about 860 ft, 1,140 ft, 2,310 ft, 2350 ft, 1,700ft, and 2,860 ft. The well lost mud circulation at 2,880 ft and the well was properly plugged according to Arizona Oil & Gas Commission rules.

11.2 Drilling Recommendations

SRK Consulting makes the following recommendations:

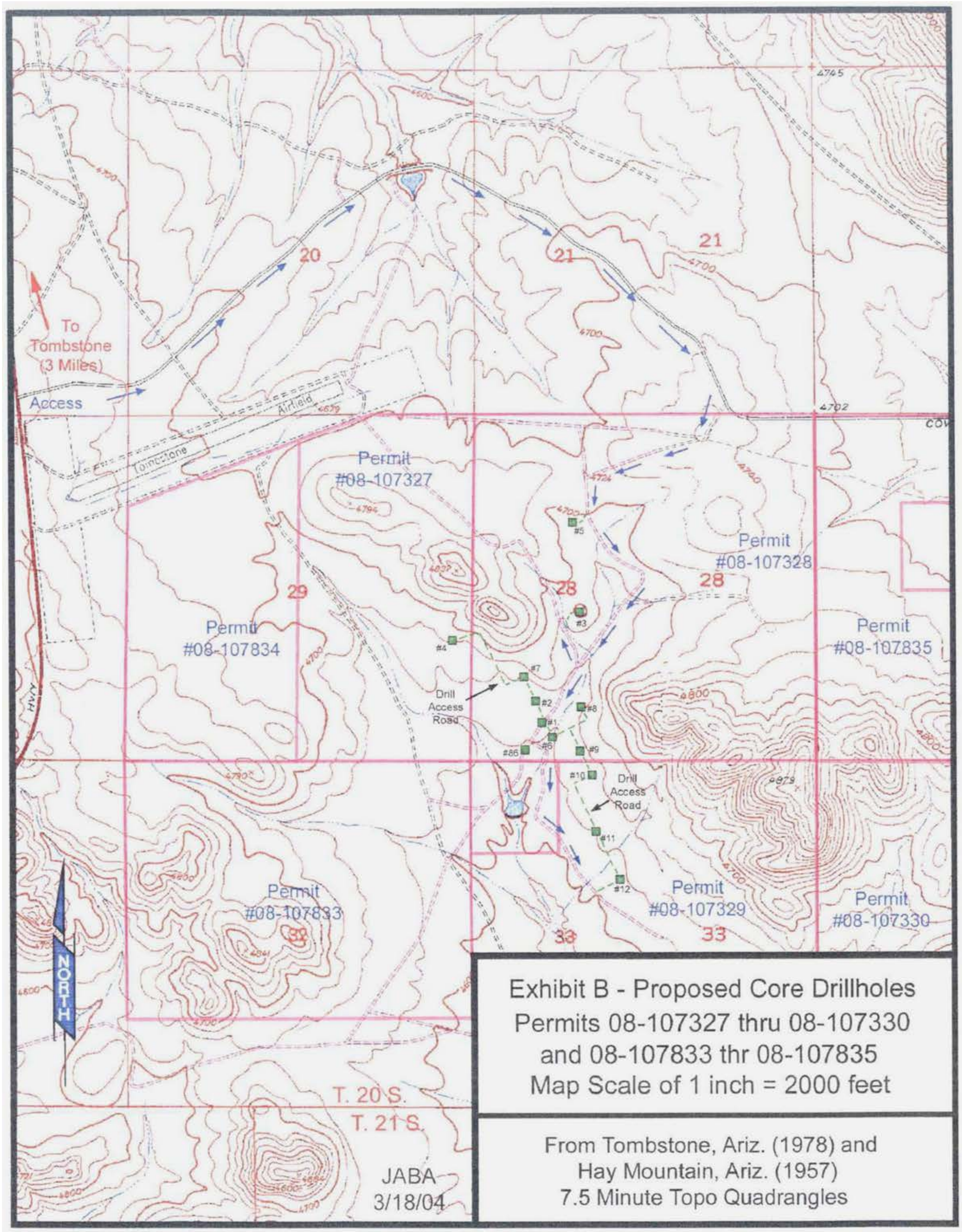
- Select the most prospective drilling location and assess land access and permitting requirements;
- Conduct core drilling for the following purposes:

    - Discover mineralization or favorable indication of potential mineralization to confirm and refine the exploration concept;
    - Provide samples for assaying and mineralogical and metallurgical testing; and
    - Conduct additional in-fill and/or extension drilling if preliminary drilling results are positive;
        - Additional drilling should be by the core drilling methods with HQ size core to provide good quality material to examine the host rocks, alteration, mineralization, and structure in greater detail.
- Conduct down-hole surveys to measure drill-hole deviation, particularly for drill holes in excess of 100 m.
- Devise a suitable drill log format and data entry codes that will allow inclusion of detailed lithology, alteration and mineralization information, in numeric form, in addition to assay data, to allow for digital drill logs.



Source: Halterman, 1989, Tempo Resources

Figure 11-1 Zebra project geologic map and drill hole locations



Source: Liberty Star file data; only #1, #2, and #3 were drilled of the 12 proposed drill holes.

Figure 11-2 Drill hole locations, Hay Mountain, 2004

12 Sampling Method and Approach (Item 14)

No sampling for Cu has been done in the Hay Mountain project area by Liberty Star, as this is an early stage exploration concept. A summary of previous sampling and recommendations for future sampling are provided below.

12.1 Sample Collection and Conclusions

No sampling has been done in the Hay Mountain project area by Liberty Star, so sampling conclusions based on recent work cannot be drawn. The sample collection procedures used by Newell for the geochemical sampling of mesquite twigs and of the mine dump samples are described in his dissertation (Newell, 1974). The location of Newell's samples are shown in Figure 7-12. The drilling samples collected by exploration companies in the Zebra and Redrock Canyon areas were presumably collected using industry standard procedures, but SRK has not reviewed this information.

12.2 Sampling Recommendations

SRK Consulting makes the following recommendations:

- Mesquite twig sampling should be performed on a representative number of samples in the project area to confirm by independent analysis the concentrations and metal zoning and associations reported by Newell. The analysis package should include multi-element analysis to assess metal concentrations, zoning, and ratios.
- Initial drilling, as defined in Section 11.0, should be by RC methods or core drilling methods if more reasonable, with samples taken on 10-foot intervals. Samples taken in the basin-fill formations would be logged for characterization purposes, but would not be assayed unless mineralization, such as exotic copper, is identified.
- If the preliminary drilling results are positive, additional HQ diamond drill core would be planned. Sample intervals in core should be no more than 10 feet. Samples in diamond drill core should honor natural lithologic breaks to enable statistical analysis of grade by rock type.

13 Sample Preparation, Analyses, and Security (Item 15)

There is no description of sampling preparation, sampling procedures, or sample assaying procedures, as no sampling has been done in the Hay Mountain project area by Liberty Star. No factors impacting accuracy of results can be assessed and no QA/QC procedures were defined. QA/QC procedures will be defined and sample security descriptions will be produced when sampling procedures are conducted. Liberty Star uses industry standard protocols to prepare samples and uses certified analytical laboratories to ensure good quality, repeatable results.

13.1 Recommendations

SRK Consulting makes the following recommendations:

- Standard Operating Procedures should be developed for all sampling programs to ensure that collection, handling, storage, and record-keeping methods are uniform, repeatable, and documentable. Establish procedures to ensure that sample bias and contamination do not occur.
- If initial drilling is performed by RC methods, due care should be taken to collect representative samples above and below the water table. Chip samples should be preserved in chip trays.
- Core should be digitally photographed, split or sawn, and the half-core not sampled should be archived. Pulps should be retained indefinitely in a dry storage location. Rejects should be retained for a period of time until all analyses have been evaluated. Rejects can be used for additional QA/QC checks by outside laboratories or for possible metallurgical and mineralogical investigations.
- Samples should be given an ambiguous sample identification number to disguise the sample location or depth. Samples should be analyzed by a certified laboratory for a minimum of total copper by atomic absorption method. Multi-element scans are also recommended by ICP-MS analytical methods to enable Liberty Star to assess other metal concentrations, associations, and ratios.
- Field blanks and pulp standards (if available) should accompany each 10 samples, at a minimum. Field blanks should be prepared using inert, non-mineralized rock collected outside the area of mineralization.
- Duplicate pulp samples should be sent to an independent, certified assay laboratory at the rate of one per 20 samples for quality assurance/quality control purposes.
- For several drill holes, the half-core samples from several intervals should be analyzed to assess homogeneity of the mineralization.
- Compare assay results of duplicate samples from two laboratories to determine analytical precision.

14 Data Verification (Item 16)

Liberty Star made available historic records including geologic and sample location maps, drilling results of previous work in the Tombstone district, reports, AutoCAD files, assay reports and other data. SRK did review this historic data but an extensive verification of historic data against original data or assay reports was not performed.

As no new analytical data on the Hay Mountain project are currently available, no data verification, in the field or office was performed. No project quality controls or quality assurance was performed and no check assay sample preparation or results are described. Verification of land status is in progress by Environmental Support Services, of Oracle.

The lack of data of analytical data of Liberty Star is expected for the early exploration conceptual phase of the project.

15 Adjacent Properties (Item 17)

Adjacent properties include the claim block owned by TEC, and various patented claims that are owned by the successors of Tombstone Consolidated. Liberty Star has contracted with Environmental Field Services to investigate the mineral exploration rights to the Hay Mountain project area of Liberty Star.

SRK (2008) reported that one exploration company had filed claims in the Tombstone mining district adjacent to the Tombstone Exploration property. Southern Silver, a Canadian-based company (TSX.V: SSV), reported in December 2007 that its Tombstone project consists of a claim block of approximately 1,800 hectares, and described the project as a "multi-target porphyry/skarn precious and base metals exploration property." The property is located south of the west parcel held by TEC. Southern Silver reported that "up to 2,000 meters of Phase 1 core drilling is planned to test prospective stratigraphy, structures and a series of mineralized, east-northeast-trending fracture zones." Their current website does not list their Tombstone project (accessed June 2011).

16 Mineral Processing and Metallurgical Testing (Item 18)

No mineral processing and or metallurgical testing have been done at the Hay Mountain project, as the project is currently in the exploration phase. Any porphyry copper discovery should be amenable to well-known metallurgical recovery methods that are used in porphyry copper deposits throughout the world. Until a mineral deposit of potentially economic interest in located, metallurgical testing is not necessary.

17 Mineral Resources and Mineral Reserve Estimates (Item 19)

The Hay Mountain project is an early stage, conceptual exploration project.

There is no current NI 43-101 compliant mineral resource or mineral reserve estimate for the Hay Mountain project. The historical production stated in Section 6.0 (History) should not be relied upon as it has not been verified or classified according to CIM or SME resource/reserve categories by a Qualified Person.

While Liberty Star considers the historical information in this Technical Report significant and relevant information, Liberty Star is not reporting a current mineral resource or mineral reserve for the Hay Mountain property.

18 Other Relevant Data and Information (Item 20)

SRK is not aware of any other relevant data or information that affects the potential to pursue continued exploration on the Hay Mountain project land holdings.

While the Hay Mountain project is currently an early stage exploration property, SRK recommends that the following areas be considered for proactive involvement by Liberty Star, should there be exploration successes in the planned programs in 2011/2012:

- Community and public relations with respect to Liberty Star's activities to keep the local population or land owners informed in the event that the level of exploration should dramatically escalate;
- Development of relationships with the local surface land owners with respect to surface use and access, as part of the overall Public and Community Relations; and
- Collect basic environmental data such as measuring the water levels in any open exploration drill holes prior to abandoning the hole. Assess whether groundwater data can be collected from any existing monitor well or stock water well.

The Hay Mountain project is well situated for potential future development from an infrastructure perspective. It is located 25.5 mi south of the divided 4-lane Interstate Highway (I-10) at an off-ramp, near a major natural gas pipeline and high voltage transmission lines. The Hay Mountain project location is such that a potential underground mine and other facilities at this location would be south of the town of Tombstone, which is a National Historic Monument.

Arizona has an active mining industry, such that both state agencies and local communities in southeastern Arizona are familiar with mining activities. In the case of the local community, residents might welcome a renewal of their past mining history.

While there have been no current socio-economic assessments of the project or any potential development of the project. There are no known or previously identified issues that would materially affect the ability to proceed with further exploration and development work at the project.

19 Interpretation and Conclusions (Item 21)

SRK's preliminary examination of the evidence indicates that Liberty Star's approach to exploration at the Hay Mountain project is valid. The Hay Mountain project is a beginning-stage exploration property in an area that generally has been inactive for the past 25 years due to low Ag commodity prices. Potential may exist to establish the existence of a copper porphyry target emplaced as a result of deep fractures associated with an earlier caldera complex.

The Tombstone district had undergone exploration and extensive development during the period 1878 through the 1910s, but activity declined after that. During the 1960s through the 1970s, major minerals exploration companies are known to have worked in the area. ASARCO, Inc., Placer Amex, Inc., Newmont Mining Corporation, the Anaconda Company, and Phelps Dodge Corporation were active in the Tombstone district. Some of these companies were reportedly in search of porphyry copper mineralization at depth, but their records are not available. During the 1980s, there was limited open-pit mining and heap leaching of low grade Ag ores in the Tombstone district at the Contention pit. Total historical expenditures on the property are not known. Historical "reserve" estimates are not known to exist.

While neither historical, nor current, NI 43-101 compliant resources and/or reserves have been established on either the district or for the Hay Mountain project area, Liberty Star considers the existing project data to be important, substantial, and relevant to developing the exploration concept for the project area.

The subsurface geology and mineralization in the Hay Mountain project is not well documented. However, the property represents an opportunity to develop and pursue exploration concepts and targets for drilling, using the existing historical data for background. The Hay Mountain property will have the inherent opportunity and risk of a beginning-stage exploration property as defined in the sections below.

19.1 Opportunity

The major opportunity at the Hay Mountain project is to drill define mineralization likely to occur along several structural zones, and pursue exploratory drilling, geophysical surveying, geochemical sampling, and detailed geological mapping. Hay Mountain would be explored and evaluated as a potential deep underground porphyry copper target.

Basic historical information is available that indicates past production in the Tombstone district, but information is not available to confirm mineralization at the Hay Mountain exploration target.

Public awareness is increasing about potential underground mining operations in Arizona. Feasibility studies are currently on-going at other proposed underground mines including the very large tonnage Resolution Copper project (Cu, Mo) near Superior, the Copper Creek project (Cu, Mo) near San Manuel, and the Copperstone Mine (Au) near Parker.

19.2 Project Risks

A Cu mineralized deposit has not yet been drill-defined by Liberty Star for the Hay Mountain project.

The primary risk at the exploration stage is that drill targets and the depth of the proposed drill holes will not hit the target mineralization. Exploration targets of interest at this point in time are Cu-bearing skarns and veins found in structural zones and in the contact metamorphic zone adjacent to dikes and porphyry deposits. It is not known to what extent Cu mineralization of economic interest might be present. A mineral resource estimation for the Hay Mountain project is premature, pending exploration drilling that defines such a mineralized deposit. There are many variables in the resource estimation process that are risks in achieving a desirable resource estimate, and include the variability of assay grades and continuity of mineralization across a deposit large enough to operate. There is no guarantee that a resource of sufficient size to be of economic interest to Liberty Star can be identified.

The current price for Cu is at a record high for the last 50 years. Currently the price is over US$4.13 per lb, nearly four times the commodity price of earlier years. Stability of commodity price and the availability of supplies to meet demand are risk factors for the Hay Mountain project.

20 Recommendations (Item 22)

Recommendations for future work programs, the approximate timeline, and estimated costs to advance the Hay Mountain project are provided below.

SRK recommends the geological concepts and exploration targets can be pursued by a program of mapping, sampling and confirmation analyses, geophysical surveys, and drilling, for a minimum estimated cost of approximately $1,275,000, as shown in Table 20-1.

20.1 Recommended Exploration Programs and Cost Estimates

The next step to further explore the project will require additional data analysis by combining geological, geophysical and geochemical data into ArcGIS maps or other computerized systems, ZTEM geophysical surveys, additional geochemical sampling, and core drilling and assaying. If favorable mineralization is discovered, additional Phase II drilling would focus on extending the known limits of the potential deposit or drilling to greater depths. A resource estimate would not be completed until sufficient drilling was completed to characterize the resources to an inferred classification.

The following exploration programs are recommended:

- Geochemical sampling, including biogeochemical, soil and rock chip in areas of outcrop and relative abundances and metal ratios of Cu, Mo, Pb, Zn, Ag, Au, and others;
- Data plotting and contouring in GIS systems;
- ZTEM electromagnetic geophysical survey across the area; and
- Drilling 10 diamond drill holes to approximately 1,000 ft depth.

20.2 Geological Mapping and Sampling

A program of continued mapping and sampling is recommended. All data should be incorporated into a GIS database using ArcGIS or similar software. Geological, geochemical, structural, alteration, remote sensing, and geophysical data should be compiled to define drill targets.

20.3 Geochemical Soil and Geobotanical Sampling

Additional soil and botanical geochemical sampling is recommended in the Hay Mountain project area. Recent studies suggest that metal ions migrate through bedrock into post-mineral soil cover and are detectable by geochemical sampling techniques analyzed with very low detection limits. Geochemical evidence of mineralized deposits can be detected through more than 2,000 to 4,000 ft of cover.

Geobotanical sampling would include deep-rooted phreatophyte desert plants, including mesquite, cat's claw (acacia), and creosote bush (greasewood). Biogeochemical plant twig samples should be taken at closer than 1/4 mile intervals or 16 samples per square mile. Collection of samples at an interval of 200 m along 500 to 1,500 m sample lines proved effective in exploration efforts at both the Silver Bell caldera and the Big Chunk caldera, Alaska. Samples would be analyzed for 64 elements by certified analytical laboratories. Soil samples should also be taken at the same sites as the geobotanical samples and analyzed for 64 elements to enable calculating and mapping metal ratios.

All samples, including drill cuttings or core, should be analyzed by methods with extremely low detection levels. These techniques include inductively-coupled plasma (ICP) and Graphite Furnace Atomic Absorption (GFAA). These methodologies should give the following or better detection limits:

- For plant ash (30 gm aliquots): Au 0.05 ppb, Ag 1 ppb, Cu 5 ppb, Mo 5 ppb; and
- For soil (15 gm aliquots): Au 0.2 ppb, Ag 3 ppb, Cu 10 ppb, Mo 20 ppb.

Twelve additional elements or more (64 elements are preferred) should be run on all samples and include a minimum of As, Bi, Cd, gallium (Ga), Hg, Pb, Sb, selenium (Se), Sn, Te, Tl, and Zn. At least 160 samples are planned to be collected, with estimated costs of $67/sample, including labor costs for field sampling, for an approximate cost of $11,000.

20.4 Geophysical Surveying

ZTEM electro-magnetic geophysical surveys across the project area, combined with the results of the geochemical sampling, should indicate specific drill targets. ZTEM is an innovative airborne electromagnetic system that uses the natural or passive fields of the Earth as the source of transmitted energy and that measures vertical fields caused by conductivity contrasts in the Earth, such as a massive sulfide body.

Two-dimension inversions of the ZTEM results can be performed over selected lines using the Geotech Zvert2d software developed by Phil Wannamaker, University of Utah, for Geotech Ltd. 2D inversion modeling converts the airborne ZTEM data to equivalent resistivity-depth sections, extending from surface to 2 km depths. An analysis of the 3-D ZTEM data, in combination with soil and vegetation geochemical data, will indicate the most favorable locations for the diamond drill holes.

The approximate cost of the ZTEM survey of assumed adequate detail (200 m spacing of lines) in the Tombstone area is about US $159.00 per line km, plus mobilization/de-mobilization, fuel, etc. The Hay Mountain project area would be especially appropriate for a ZTEM survey for an approximate cost of $147,000.

20.5 Exploration Drilling

SRK recommends a scout drilling program be conducted on the Hay Mountain geochemical and geophysical anomalies. After the most favorable targets are determined, definition drilling as Phase II can proceed on those targets to define a potential ore body. Core drilling would be aimed at determining depths and grades of mineralization, rock types, and alteration zoning. It would also provide geotechnical information, samples for bulk density measurements, and samples for preliminary metallurgical testing. An initial scout drilling program is suggested that would include a minimum of ten 1,000-foot core holes in the most promising areas. Drilling should be conducted after all available geological, geochemical, and geophysical information is compiled and evaluated to define drill targets.

The Hay Mountain project scout drill holes will be designed to penetrate an expected average of 200 to 400 ft of post-mineral cover and drill 600 feet into bedrock to sample for rock and alteration type and obtain geochemical samples. The all-in drilling cost is estimated to be about $100 per foot, for a total drilling cost of $1,000,000, plus approximately $60,000 for labor of a geologist to log core and a technician to enter data into computer programs. After the best target is determined by scout drilling, future drilling efforts can be focused on defining grades and amounts of mineralization to the inferred, measured, and indicated ranges.

20.6 Other Geological and Metallurgical Work

Data should be entered into computer programs, such as a GIS model of the district. These data can be transferred where appropriate to MineSight or other appropriate mine planning and reserve estimating software.

Initial rock mechanics data should be obtained on drill core samples (RQD data, compressive strength, along with representative specific gravities) as an integral part of the drilling program. Initial metallurgical testing can be done on new drill core as well. The aim of the metallurgical testing is to evaluate minimum preliminary indications of possible metal recoveries.

20.7 Proposed Budget

In the following cost estimates, where cost per sample is quoted, these are "all in" costs and include all sample collection costs including mobilization and demobilization, travel, food and lodging, field crew and supervision, base maps, sample bags, shipping, sample preparation and assay costs. The "all in" cost per biogeochemical and soil samples at the designated spacing is $67 per sample.

The recommended Phase I programs for geology-geophysics, drilling, and geotechnical studies can be completed in a 6-month time period for a minimum expenditure of approximately $ 1,275,000, as itemized in Table 20-1. This is a minimum budget for direct expenses on the property, and does not include personnel or the owner’s costs for land, fencing, and other similar expenditures.

Table 20-1 Estimated Exploration Budget

Work	Time to Complete	Amount
Geological mapping, sampling, compilation	4 months	$ 10,000
Geochemical sampling & analysis	3 months	$ 11,000
Geophysical surveys (ZTEM)	1 month	$ 147,000
Core Drilling (10 holes for 1,000 ft @ $100/ft)	3 months	$ 1,000,000
Assays (600 samples @ ~$67 each)	4 months	$ 40,000
Labor logging core, data entry	5 months	$ 60,000
Geotechnical studies	concurrent	$ 2,000
Project management, travel, misc.	6 months	$ 5,000
TOTAL	**6 months**	**$ 1,275,000**

21 Date

The date of this report is August 31, 2011. The effective date is August 31, 2011.

The undersigned prepared the report entitled "Hay Mountain Exploration Report, Tombstone, Arizona". The format and content of the report is intended to conform to Form 43-101F1 of the National Instrument of the Canadian Securities Administrators.

Signed and sealed

QP1 Jan C. Rasmussen, RG, Ph.D., Registered Member SME

Signed and sealed

QP2 Corolla K Hoag, Reg. Registered Member CPG

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23 Glossary

American versions of Imperial English units of measure (U.S. Customary Units) are used in this report, as these are the commonly used units of measure in the United States. Analytical results are generally reported as ounces per short ton (oz/Ton) or parts per million (ppm) for silver (Ag) and gold (Au); percent for lead (Pb), zinc (Zn), copper (Cu), and manganese (Mn); and ppm for other trace elements (1,000 ppm = 0.1%; 10,000 ppm = 1.0%).

23.1 Units of Measure

The following list of conversions is provided for the convenience of readers more familiar with the metric system. All dollar amounts used in this report are US$.

LINEAR MEASURE

1 foot (ft) = 0.3048 meters

1 mile (mi) = 5,280 ft = 1.6093 kilometers

AREA MEASURE

1 acre = 0.4047 hectares

1 square mile = 640 acres = 259 hectares

WEIGHT

1 short ton (T) = 2000 pounds (lb) = 0.9072 metric tons (tonnes (t))

1 pound (lb) = 16 ounces (oz) = 0.4536 kilograms (kg) = 14.583 troy ounces

ANALYTICAL VALUES

gram/tonne = 1.0 ppm = 0.02917 oz

Troy/short ton = 0.03215 oz Troy/tonne

oz Troy/tonne (oz/t) = 31.1035 grams/tonne (g/t)

oz Troy/short ton (oz/T) = 34.2857 grams/tonne (g/t)

23.2 Acronyms and Technical Terms

Table 23-1 Frequently used acronyms and technical terms

Acronyms /Technical	Definitions
AA	Atomic absorption
Acanthite	An ore of silver Ag2S
Ag	Silver
Alabandite	The mineral MnS, usually occurring as iron-black massive or granular form
Altaite	A tin-white mineral PbTe
Amethyst	A transparent to translucent, purple to pale violet variety of crystalline quartz
Andesite	Fine-grained volcanic rock of intermediate composition, mostly plagioclase feldspar with ferromagnesian minerals
Anglesite	A white orthorhombic mineral PbSO4, a common secondary mineral formed by the oxidation of galena and an ore of lead

Acronyms /Technical	Definitions
Anhydrite	A mineral consisting of anhydrous calcium sulfate CaSO4
Anticline	An upfold shaped like an arch in which the rock layers dip away from the axis of the fold
Argentiferous	Silver-bearing mineral
Argentite	A dark lead-gray cubic dimorph of acanthite Ag2S, an ore of silver
Argentojarosite	A yellow or brownish mineral of the alunite group $AgFe_3(SO_4)_2(OH)_6$
Argillite	A compact fine-grained sedimentary rock (mudstone, claystone, siltstone, or shale) that has undergone a somewhat higher degree of induration, but is not slate
Arsenopyrite	A tin-white or silver-white to steel-gray orthorhombic mineral FeAsS
Assay	Arsenic
Assay	The chemical analysis of mineral samples to determine the metal content.
Au	Gold
Barite	A white, yellow, or colorless orthorhombic mineral $BaSO_4$
Basalt	A fine-grained, mafic (dark colored), igneous rock composed mainly of ferromagnesian minerals and calcium-rich plagioclase
Bismuthinite	A lead-gray to tin-white orthorhombic mineral Bi_2S_3
Bornite	A brittle, metallic-looking mineral Cu_5FeS_4
Bromargyrite	A yellow isometric mineral, AgBr (synonym of discredited brymyrite)
Calcite	Calcium carbonate, $CaCO_3$
Caldera	A large, basin-shaped volcanic depression, mostly circular
Caldera complex	The diverse rock assemblage underlying a caldera, comprising dikes, sills, stocks, and vent breccias, crater fills, talus beds of tuff, cinder and agglomerate, fault breccias, cinder cones, and talus fans along fault escarpments
Cd	Cadmium
Cerargyrite	A group name for isomorphous, isometric silver halide minerals, mainly chlorargyrite, bromargyrite, and embolite
Cerussite	A colorless, white, yellowish, or grayish orthorhombic mineral of the aragonite group PbCO3
Chalcocite	A copper- and sulfur-bearing mineral (Cu2S) a common secondary copper ore mineral.
Chalcopyrite	A brassy mineral (CuFeS2) the primary ore of copper.
Chlorargyrite	A white, pale yellow, or gray isometric wax-like mineral that darkens on exposure to light AgCl
Co	Cobalt
Cosalite	A lead-gray or steel-gray mineral $Pb_2Bi_2S_5$
Covellite	An indigo-blue hexagonal mineral CuS
Cryptomelane	A mineral $K(Mn^{+2},Mn^{+4})_8O_{16}$
Cu	Copper
Cuprite	A red (crimson, scarlet, vermilion, brownish-red) isometric mineral Cu_2O
Dacite	A fine-grained extrusive rock with the same general composition as andesite, but with a less calcic plagioclase and more quartz

Acronyms /Technical	Definitions
Dip	Angle of inclination of a geological feature/rock from the horizontal.
Diopside	A mineral of the clinopyroxene group $CaMg(SiO_3)_2$
Disconformity	A surface that represents missing rock strata, but beds above and below that surface are parallel to one another
Dolomite	A common rock-forming rhombohedral mineral $CaMg(CO_3)_2$
Embolite	A yellow-green isometric mineral Ag(Cl,Br)
Emmonsite	A yellowish-green mineral $Fe_2Te_3O_9.2H_2O$
Enargite	A grayish-black or iron-black orthorhombic mineral Cu_3AsS_4
Epidote	A yellowish-green, pistachio-green, or blackish-green mineral $Ca_2(Al,Fe)_3Si_3O_{12}(OH)$, occurring in low-grade metamorphic rocks derived from limestones
Epithermal	A mineral deposit formed within about 1 kilometer of the surface and in the temperature range of 50-200 degrees C, occurring mainly as veins
Fault	The surface of a fracture along which movement has occurred.
F	Fluorine
ft	feet
Galena	A bluish-gray to lead-gray mineral PbS, generally with cubic crystals and cleavage
Garnet	A group of minerals of the formula $A_3B(SiO_4)_3$, where A = Ca, Mg, Fe+2, and Mn+2, and B=Al, Fe+3, Mn+3, V+3, and Cr.
GIS	Geographic Information System
Gossan	An iron-bearing weathered product overlying a sulfide deposit, formed by the oxidation of sulfides and the leaching out of the sulfur and most metals, leaving hydrated iron oxides
Grade	The measure of concentration of copper within mineralized rock
Granite	A felsic (light colored), coarse grained, intrusive igneous rock containing quartz and composed mostly of potassium- and sodium-rich feldspars
Granodiorite	A coarse-grained igneous rock intermediate in composition between granite and diorite, containing quartz and some alkali feldspar (orthoclase) and plagioclase
Granophyre	An irregular microscopic intergrown of quartz and alkali feldspar in a porphyritic extrusive igneous rock
Hausmannite	A brownish black, opaque mineral Mn_3O_4
Hematite	A common iron mineral, Fe_2O_3
Hessite	A lead-gray cubic mineral, Ag_2Te
Hetaerolite	A black mineral $ZnMn_2O_4$
Hg	Mercury
Hollandite	A silvery-gray to black mineral $Ba(Mn^{+2},Mn^{+4})_8O_{16}$
Hornblende	A common mineral of the amphibole group, $(Ca,Na)_{2-3}(Mg,Fe,Al)_5Si_6(Si,Al)_2O_{22}(OH)_2$
Hornfels	A fine-grained rock composed of a mosaic of equidimensional grains without preferred orientation and typically formed by contact metamorphism
Hypogene	Mineral deposit formed by ascending solutions
ICP	Inductively-coupled plasma spectroscopy, an analytical procedure
IP	Induced Polarization, a geophysical survey method

Acronyms /Technical	Definitions
Igneous	Primary crystalline rock formed by the solidification of magma
Iodaryrite	A yellowish or greenish hexagonal mineral AgI (former name iodyrite)
Isoclinal	A fold whose limbs are parallel, like hairpins
Jarosite	An ocher-yellow or brown mineral of the alunite group $KFe_3(SO_4)_2(OH)_6$
Laccolith	A concordant igneous intrusion with a known or assumed flat floor and a postulated dike-like feeder commonly thought to be beneath its thickest point
Latite	A porphyritic extrusive rock having phenocrysts of plagioclase and potassium feldspar (orthoclase) in nearly equal amounts, little or no quartz, and a finely crystalline to glassy groundmass
Leptothermal	Formed at temperature and depth conditions intermediate between mesothermal and epithermal
Limestone	A sedimentary rock composed mostly of calcite ($CaCO_3$)
Limonite	A general field term for a group of brown, amorphous, naturally occurring hydrous ferric oxides, with a mineral formula that varies from $2Fe_2O_3.3H_2O$
Lithology	Geological description pertaining to different rock types.
Ma	Million years ago or Mega-annum
Magmatism	The development and movement of magma (liquid rock) and its solidification to igneous rock
Magnetite	A black, isometric, strongly magnetic, opaque mineral of the spinel group $(Fe,Mg)Fe_2O_4$
Manganite	A brilliant steel-gray or iron-black mineral MnO(OH) that is an ore mineral of manganese
Manganosiderite	A variety of siderite containing manganese
Manto	A flat-lying, bedded deposit, either a sedimentary bed or a replacement strata-bound orebody
Mesothermal	A hydrothermal mineral deposit formed at considerable depth and in the temperature range of 200-300 degrees C
Miogeoclinal	Relating to a prograding wedge of shallow-water sediment at the continental margin or seaway with no associated volcanism
Mn	Manganese
Mo	Molybdenum
Molybdenite	A lead-gray hexagonal mineral MoS_2
NI 43-101	Canadian National Instrument 43-101
Ni	Nickel
Novaculite	A dense hard even-textured light-colored cryptocrystalline siliceous sedimentary rock, similar to chert, caused by thermal metamorphism of silica-rich rock
Oxide	Minerals and mineral zone produced during the oxidation of the primary copper and iron mineralization. The term includes copper, iron, and manganese hydroxide, oxide, and silicate minerals
Oz/Ton	ounces per short ton
opt	ounces per short ton
Orogeny	An episode of mountain building and intense deformation of the rocks in a region, generally accompanied by metamorphism and igneous activity

Acronyms /Technical	Definitions
Pb	Lead
Pd	Palladium
Phonolite	An fine-grained volcanic rock composed of alkali feldspar, mafic minerals, and any feldspathoid, such as nepheline, leucite, or sodalite
Phyllite	A metamorphic rock in which clay minerals have recrystallized into microscopic micas, giving the rock a silky sheen
Plumbojarosite	A mineral of the alunite group $PbFe_6(SO_4)_4(OH)_{12}$
Porphyritic	A texture in igneous rocks in which large crystals are enclosed in a matrix (or ground mass) of much finer-grained minerals
Porphyry Copper	Disseminated copper minerals in a large body of porphyry (igneous rock containing large crystals in a fine-grained ground mass)
ppb	parts per billion
ppm	parts per million
Polianite	A synonym of pyrolusite
Propylitic	Hydrothermal alteration of rocks containing calcite, chlorite, epidote, serpentine, quartz, pyrite, and iron oxides
Proustite	A red rhombohedral mineral Ag_3AsS_3
Psilomelane	Manganese oxides, a general field term for mixtures of manganese minerals, or for a botryoidal, colloform manganese oxide whose mineral composition is not specifically determined (wad)
Pyroclastic	Texture containing rock fragments produced by volcanic explosion
Pyrolusite	A soft iron-black or dark steel-gray tetragonal mineral MnO_2
QA/QC	Quality Assurance/Quality Control; procedures used to assure accuracy and consistency of analytical results
Quartzite	A rock composed of sand-sized grains of quartz that have been welded together during metamorphism
Quartz Monzonite	Granitic rock with abundant quartz and equal amounts of orthoclase feldspar and plagioclase feldspar
Potassic	Alteration zone in the core of deposits, contains K-feldspars, biotite, phlogopite, chlorite, vermiculite, anhydrite, gypsum
Pyrite	A common, pale-bronze or brass-yellow, isometric mineral FeS_2, (fools gold)
Phreatic explosions	A volcanic eruption or explosion of steam, mud, or other material that is not incandescent, caused by the heating and expansion of groundwater due to an underlying igneous heat source
Re	Rhenium
Rhodochrosite	A rose-red or pink to gray rhombohedral mineral of the calcite group $MnCO_3$
Rhyodacite	Extrusive porphyritic igneous rocks intermediate in composition between dacite and rhyolite, with quartz, plagioclase, and biotite (or hornblende) as the main phenocryst minerals and a fine-grained to glassy groundmass composed of alkali feldspar and silica minerals
Rhyolite	A fine-grained, felsic (light colored), volcanic rock made up mostly of feldspar and quartz
Rickardite	A deep purple mineral Cu_7Te_5
Rutile	A usually reddish-brown tetragonal mineral TiO_2

Acronyms /Technical	Definitions
Sb	Antimony
Schist	A metamorphic rock characterized by coarse-grained minerals oriented approximately parallel
Sedimentary	Pertaining to rocks formed by the accumulation of sediments, formed by the erosion of other rocks.
Sericite	A white, fine-grained potassium mica occurring in small scales and flakes as an alteration product of various aluminosilicate minerals, having a silky luster, close to muscovite in composition
Sialic	Composed of rocks that are rich in silica and alumina
Sill	A tabular intrusive structure concordant with the country rock
Skarn	Rocks composed nearly entirely of lime-bearing silicates and derived from contact metamorphosed limestones and dolomites into which large amounts of Si, Al, Fe, and Mg have been introduced
Slickenside	A polished and smoothly striated surface that results from friction along a fault plane
Sn	Tin
Sphalerite	A yellow, brown, or black isometric mineral ZnS
Stratigraphy	The study of stratified rocks in terms of time and space.
Strike	Direction of line formed by the intersection of strata surfaces with the horizontal plane, always perpendicular to the dip direction.
Strike-slip	In a fault, the component of the movement or slip that is parallel to the strike of the fault
Stromeyerite	A dark steel-gray orthorhombic mineral with a blue tarnish, CuAgS
Subduction	The process of one lithospheric plate sliding plate beneath a continent or island arc in the plate tectonic process
Sulfide	A sulfur-bearing mineral or a zone of sulfur-bearing mineralization. This includes copper sulfides such as chalcopyrite, bornite, and chalcocite and iron sulfides such as pyrite.
Supergene	Enrichment processes that occur relatively near the surface and include the predominance of meteoric water circulation with concomitant oxidation and chemical weathering. Metals that have been leached from the oxidized ore are carried downward by percolating groundwater, and react with hypogene sulfides at the supergene-hypogene boundary. The reaction produces secondary sulfides with metal contents higher than those of the primary ore.
Tetrahedrite	A steel-gray to iron-black isometric mineral $(Cu,Fe)_{12}Sb_4S_{13}$
Total Expenditure	All expenditures including those of an operating and capital nature.
T	Ton (short ton)
Tetrahedrite	Tellurium
Tenorite	A triclinic mineral CuO that occurs in minute shining steel-gray or iron-gray scales, black powder or black earthy masses, generally in the oxidized (weathered) zones or gossans of copper deposits
Titanium	Ti
Tl	Thallium
Transpressive	An intermediate stage between compression and strike-slip motion in crustal deformation in zones of oblique compression
Unconformity	A surface that represents a break in the geologic record, with the rock unit

Acronyms /Technical	Definitions
	immediately above it being considerably younger than the rock beneath
V	Vanadium
Wollastonite	A mineral of the pyroxenoid group CaSiO2 generally found in contact metamorphosed limestones
Wulfenite	A yellow, orange, or red tetragonal mineral $PbMoO_4$
Zn	Zinc
ZTEM	Helicopter borne AFMAG Z-axis Tipper electromagnetic and aeromagnetics using a cesium magnetometer

Appendix A: Certificate of Authors

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CERTIFICATE OF AUTHOR

I, Jan C. Rasmussen, a Registered Geologist, do hereby certify that:

1. I am employed as a Senior Associate Geologist of:

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2. I graduated with a Bachelors of Science degree in Geology from the University of Arizona in Tucson, Arizona, in May 1965. I graduated with a Master of Science degree in Geosciences from the University of Arizona in December 1969. I graduated with a Doctor of Philosophy degree with a major in Geosciences (Economic Geology specialty) and minor in Engineering Geology from the University of Arizona in December 1993.

3. I am a Registered Member (3526300) with the Society of Mining, Metallurgy, and Exploration Geology and have been since 2006. I am a Registered Geologist in the State of Arizona, USA, (#15,566), and have been since 1983.

4. I have worked as a Geologist in the mining and mineral exploration business or as a geology professor for a total of 37 years since my graduation with an M.S. in Geology from the University of Arizona. I am a Senior Associate Geologist with SRK with experience in exploration, environmental permitting, and mine reclamation. I am a Registered Geologist in Arizona and an SME Registered Professional Member. I am a Qualified Person for this Technical Report, and am responsible for writing all sections of this report.

5. I have read the definition of “qualified person” set out in National Instrument 43-101 (NI 43-101) and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101), and past relevant work experience, I fulfill the requirements to be a “qualified person” for the purposes of NI 43-101.

6. I am responsible for writing all sections of the technical report titled Hay Mountain Exploration Report, Tombstone District, Arizona, effective date August 31, 2011, and dated August 31, 2011 (the “Technical Report”) relating to the Hay Mountain project. I visited the Hay Mountain project on July 1, 2011, for 1 day.

7. I have not had prior involvement with the property that is the subject of the Technical Report.

8. I am independent of the issuer applying all of the tests in section 1.5 of National Instrument 43-101.

9. I have read NI 43-101 and Form 43-101F1, and the Technical Report has been prepared in compliance with that instrument and form..

10. I consent to the filing of the Technical Report with any stock exchange and other regulatory authority and any publication by them for regulatory purposes, including electronic publication in the public company files on their websites accessible by the public, of the Technical Report.

11. As of August 31, 2011, to the best of my knowledge, information and belief, Technical Report contains all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Dated this 19 Day of September 2011

Jan C. Rasmussen

REGISTERED GEOLOGIST
CERTIFICATE NO. 15664
JAN CAROL RASMUSSEN
DATE SIGNED 9/19/11
ARIZONA U.S.A.
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CERTIFICATE OF AUTHOR

I, Corolla K Hoag, a Professional Geologist and Certified Professional Geologist do hereby certify that:

1. I am employed as a Principal Geologist of:

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2. I graduated with a Bachelors of Science degree in Geology from Western Washington University, Bellingham, Washington in 1983. In addition, I have obtained a Master of Science degree in Economic Geology from The University of Arizona, Tucson in 1991.

3. I am a Founding Registered Member (1455400RM) with the Society of Mining, Metallurgy, and Exploration Geology and have been since July 2006. I am a Certified Professional Geologist through the American Institute of Professional Geologists, CPG - 11205, and have been since August 2008. I am a Registered Geologist in the State of Arizona, USA, (#32701), and have been since 1997. I am a Professional Geoscientist in the State of Texas, USA (#10380) and have been since April 2008. I am a Professional Geologist in the State of Alaska (G-614) and have been since September 2008.

4. I have worked as a Geologist for a total of 24 years since my graduation with an M.S. in Geology from the University of Arizona. I am a Principal Geologist with SRK with experience in exploration, mine development, environmental permitting, and mine reclamation including 6 years of direct experience with evaluations and operations of copper projects and operations in Arizona. I am a Registered Geologist in Arizona, an SME Registered Professional Member, and a Certified Professional Geologist. I am a Qualified Person for this Technical Report, and is responsible for review of all sections of this report.

5. I have read the definition of "qualified person" set out in National Instrument 43-101 (NI 43-101) and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101), and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purposes of NI 43-101.

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12. As of August 31, 2011, to the best of my knowledge, information and belief, Technical Report contains all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Dated this 19 Day of September 2011

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