Hay Mountain July 2020 Field Mapping Report

Prepared for: Liberty Star Minerals

By: Daniel Koning, Contract Geologist

August 16th, 2020

Contents

Summary ... 3

Project location and previous work ... 5

Tempo Resources ... 6

Phelps Dodge ... 8

2011 SRK Report ... 8

Biogeochemical Survey ... 8

Airborne ZTEM and Magnetic Survey ... 11

Hay Mountain Project Geology ... 13

Permian Earp Formation ... 16

Permian Colina Limestone ... 16

Permian Epitaph Formation ... 17

Late Jurassic - Early Cretaceous Bisbee Group ... 18

Tertiary intrusive rhyolite ... 19

Quaternary Sediments ... 20

Alteration ... 21

Marbleization ... 21

Polymetallic Replacements ... 22

Type 1 Veins ... 23

Type 2 Veins ... 26

Type 3 Veins ... 29

XRF Zonation ... 34

Cu Zonation ... 35

Mo Zonation ... 36

Pb Zonation 37
Zn Zonation 38
As Zonation 39
S Zonation 40
Ultraviolet Fluorescence (UVF) of Vein-hosted Carbonate 41
Background 41
Methods 42
Results 42
Type 1 and 2 Vein Intensity 44
Structure 46
Folding and Reverse Faulting 46
Possible Pre-mineral Normal Faulting 47
Northwest-southeast Normal Faulting 47
Possible System Tilt 47
Stylolites and carbonate dissolution veining 48
Conclusion 48
References 50

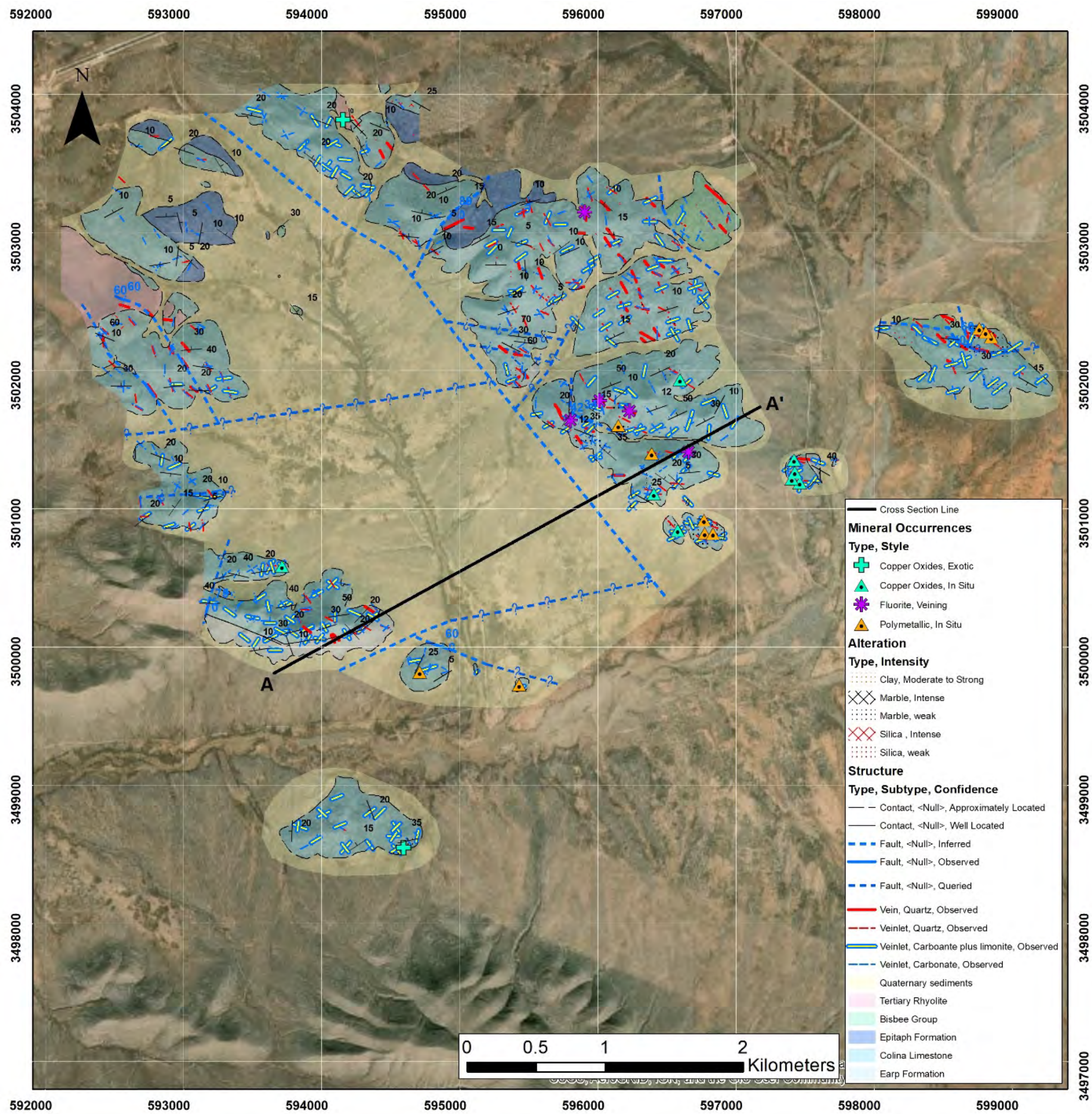

Figure 1: Compiled lithology, structure, veining, and alteration

Summary

From July 14th to August 5th, field mapping was conducted in the Hay Mountain Project area (Fig. 1), located 7 km southeast of Tombstone, in Cochise County, Arizona (Fig. 2). The purpose of mapping was to identify alteration and veining associated with an inferred porphyry copper system at depth, determine the extent of hydrothermal alteration, and comment on the possible the timing of mineralization. Mapping was conducted at 1:10,000 scale and a total of 183 carbonate vein samples were taken for pXRF analysis and UV fluorescence response.

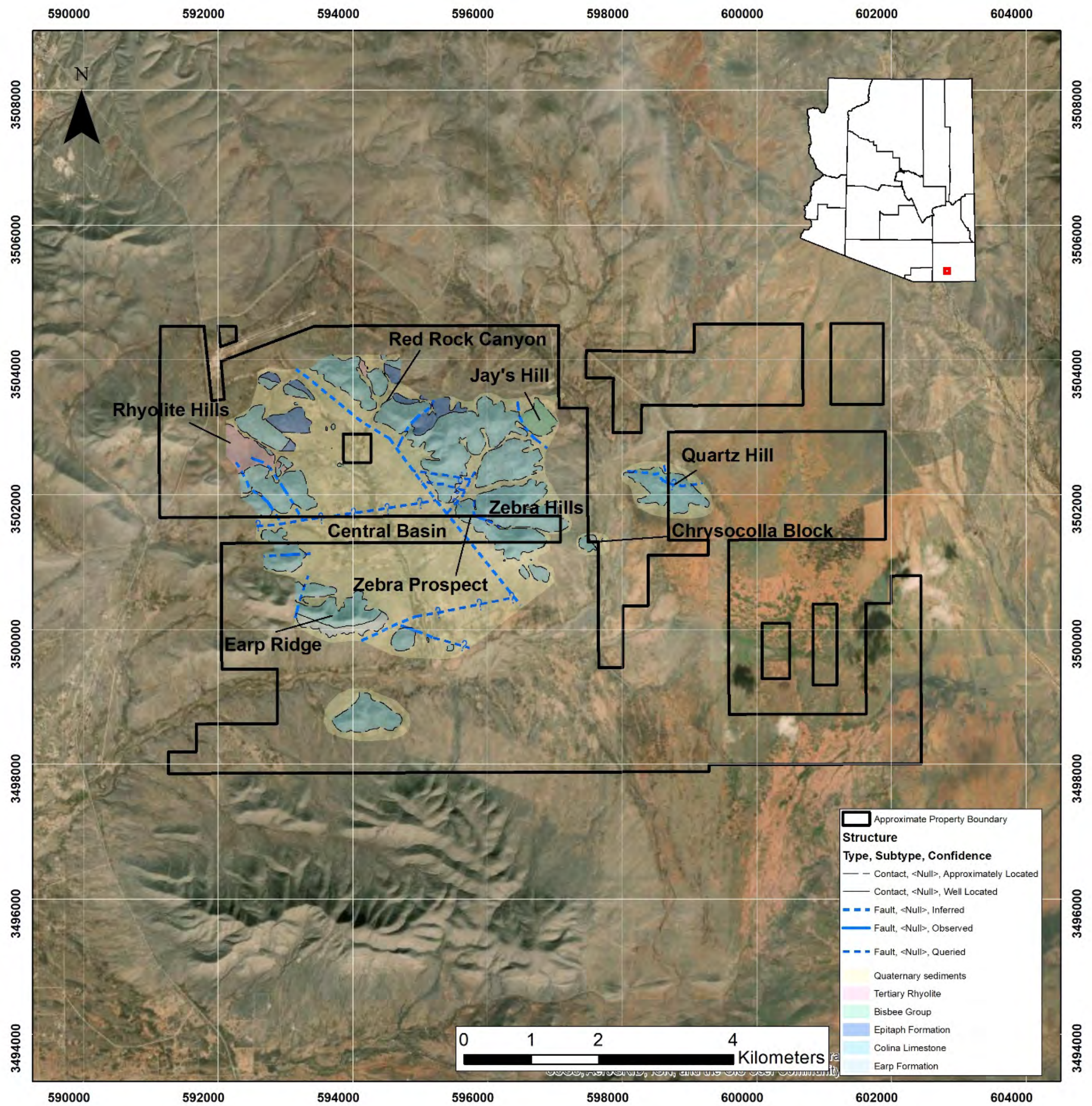

Figure 2: Location of the Hay Mountain Project with geographic names labeled

Previous work on the property includes shallow drilling by Consolidated Paymaster and Tempo Resources in the Zebra Hills and Redrock Canyon, ground IP, and aeromagnetic surveys by Phelps Dodge. In 2011 SRK produced an exploration report detailing previous work in the project area. In 2005 and 2011 a biogeochemical survey was conducted by Liberty Star Minerals. The assay results were examined by Dr. Pim van Geffen of VanGeochem, who identified Mo, Cu, Au anomalies within the central basin. In 2013 an aeromagnetic and ZTEM survey was flown by Geotech for Liberty Start Minerals. The data was reexamined by Geotech and Alan King of Geoscience North in 2019. A magnetic anomaly was identified beneath cover and interpreted as a buried intrusive center. A resistivity low was identified overlapping with the biogeochemical anomaly at surface.

Outcropping lithology consists primarily of the Colina Limestone with lesser amounts of the Earp Formation and the Epitaph Formation. These constitute the middle to upper Permian section of the Naco Group. Sparse outcrops of the lower Bisbee Group are present as the Glance Conglomerate and Morita Formation. Broad open folding of the Paleozoic stratigraphy and some minor small-scale folding is present on the property. No major reverse faulting or tight folding was observed. A set of northwest to southeast striking normal faults are present. These faults may be pre-mineral in origin but have post mineral movement of up to 200 to 300m of apparent offset.

No pervasive wall rock alteration or marble front was identified in the project area. Three vein types were identified consisting of (1) irregular white carbonate plus limonite veins, (2) thin discontinuous orange plus white carbonate veins, and (3) 2 to 3mm sheeted quartz veins. Type 3 veins are associated with structurally controlled hydrothermal breccias and silicification. Type 1 veins (carbonate plus limonite veins) are associated with secondary copper mineralization and local polymetallic replacements reading anomalous Zn +/- Pb +/- Mo. Ultraviolet fluorescence (UVF) responses of this vein set range from white to pale orange, indicating elevated Mn content (Escelante, 2008). Type 2 veins (orange and white carbonate veins) crosscut type 1 veins and were not observed to have a direct correlation to mineralization. This vein set typically shows UVF responses of white to grey to black (non-fluorescent). Type 1 and 2 veins are interpreted as fluid escape structures representing the distal expression of a porphyry copper system. The extent of veining at surface suggests a significant amount of carbonate dissolution at depth, possibly related to skarn or CRD type alteration and mineralization. Type 1 veins cut the Late Jurassic to Early Cretaceous Glance Conglomerate, indicating a possibly Laramide age for the system. Type 3 quartz veins with associated silicification and structurally controlled breccias crosscut both type 1 and 2 veins. These breccias often contain fine goethite after sulfide (likely pyrite), pyrite box works, and fluorite. pXRF readings of sulfide sites as well as previous chip sampling conducted by Phelps Dodge have identified Au anomalies associated with these breccias (DuHamel, 1989). Type 3 veins are tentatively interpreted as a separate, later mineralizing event and may be related to the intrusion of Tertiary (65Ma) rhyolite dikes in the Redrock Canyon area.

Total vein density of type 1 and type 2 veins were plotted and found to be highest in the southern and eastern parts of the property. This is correlated with the previously identified biogeochemical, magnetic and ZTEM, anomalies and interpreted to represent the center of a porphyry copper system beneath post-mineral cover. Type 1 and 2 vein density generally decreases to the north and west. The Rhyolite Hills and Redrock Canyon areas are interpreted to represent the outermost extent of this porphyry system.

Project location and previous work

The Hay Mountain Project is located approximately 7 km southeast of the town of Tombstone, AZ (Fig 2). The property consists of 28 state exploration permits and 84 federal lode mineral claims totaling approximately 5,687 hectares. Previous work in the project area includes but is not limited to shallow drilling by Tempo Resources in 1989, ground IP survey, aeromagnetic survey, and rock chip sampling programs conducted by Phelps Dodge in 1970 and 1989, biogeochemical sampling conducted in 2005 and 2011, and an airborne ZTEM and magnetic survey conducted in 2013. A more detailed account of previous exploration work can be found in SRK's 2011 report on the Hay Mountain Project.

Tempo Resources

Tempo Resources is reported to have drilled 10 RC holes in the project area (DuHamel, 1989) sometime in the late 1980s (possibly 1988 or 1989). The location of these holes is documented in Phelps Dodge's report on the Zebra Prospect. Their total depths are unknown. Two drill pads and one drill hole were discovered during field mapping. These holes are reported to be quite shallow and are likely not more than a few hundred feet (</= 100m) deep. One hole is reported to have been drill to at least 340' (103m). Tempo was targeting "dark red to grey jaspreroid" (DuHamel, 1989) along structures and bedding with associated Au mineralization. This information correlates with quartz veining and silicification mapped in the project area.

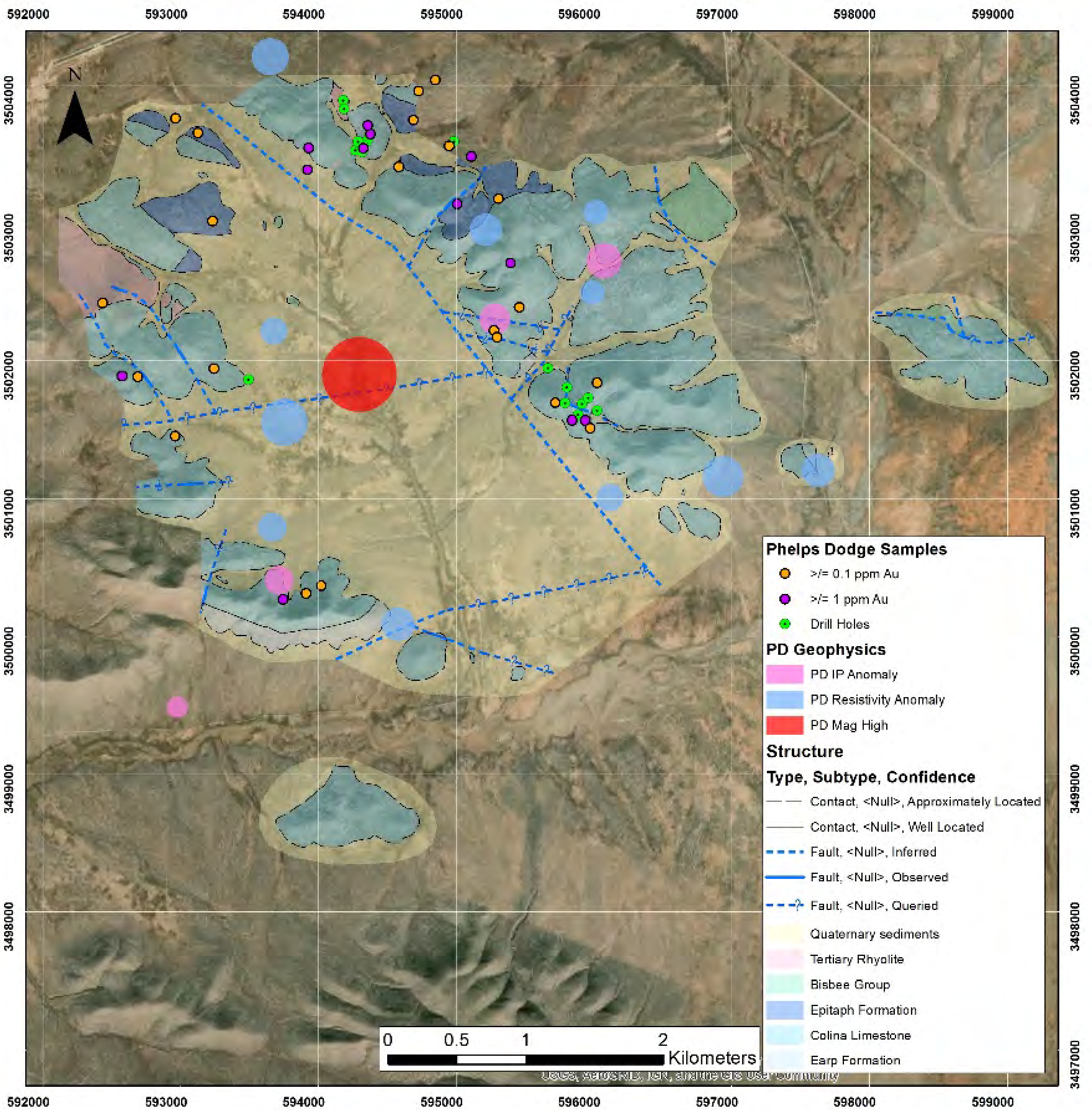

Figure 3: Known drill hole locations from field mapping, PD 1989 report, and SRK 2011 report, PD Au samples, and approximate location of PD geophysical anomalies

Phelps Dodge

In 1970, Phelps Dodge (PD) conducted a ground IP survey and an airborne magnetic survey over most of the project area. The IP survey identified several IP and resistivity anomalies that PD correlated with possible Au mineralization. The airborne magnetic survey identified a mag high near the center of the project area that PD interpreted to represent an intrusive body at depth. In 1989, reconnaissance rock chip sampling of jasperoid was conducted across the property, revealing several Au anomalies, with assays up to 50 ppm. The majority of the gold anomalies were located around the Redrock Canyon and Zebra Hills area (Fig 3).

2011 SRK Report

In 2011 SRK Consulting produced an exploration report covering historic information and previous exploration work on the Tombstone Mining District and the Hay Mountain Project area. The 2011 report covers these in greater detail but a few items from the report are summarized below.

1. "Au prospecting" in the Redrock Canyon area by Energy Reserves Group (geochemical sampling), Consolidated Paymaster (7 shallow RC holes), and JABA beginning in 1981.
2. Extensive geochemical sampling (both rock chip and soil) in the Redrock Canyon and Zebra Hills area from 1974 to 1991.
3. A geochemical sampling program by Liberty Star in 2005 consisting of 162 vegetation samples and 162 soils samples.
4. A magnetic survey and VLF survey were conducted by MinSearch in 1988. These identified two small magnetic highs north of Redrock Canyon and in the Zebra Hills area.
5. A dipole-dipole apparent resistivity and ground IP survey in the Redrock Canyon area by MinSearch and Phelps Dodge in 1989 and 1990. This data was later reprocessed by Zonge Engineering and Research of Tucson, Arizona in 2003.
6. A CSAMT survey was conducted by JABA in the Redrock Canyon area in 2004 and a total of 869 geochemical samples were collected along geophysical survey lines.

Biogeochemical Survey

In 2005 and 2011, a total of 750 vegetation samples were collected by Liberty Star Minerals, with technical guidance from Mr Shea Clarke Smith of Nevada. Multi-element aqua-regia, ICP-MS assays were conducted by ALS and ACME Labs. These data were later assessed by geochemical consultant Dr. Pim van Geffen of VanGeochem, who compared lab methodologies and plant species to normalize assay results and produced scaled element values. A more detailed account of this work can be found in Van Geffen's report on biogeochemistry of the Hay Mountain Project. This sampling revealed a broad Cu, Mo, and Au biogeochemical anomaly in the southern part of the project area, entirely under post mineral Quaternary cover (Fig 4, 5, 6).

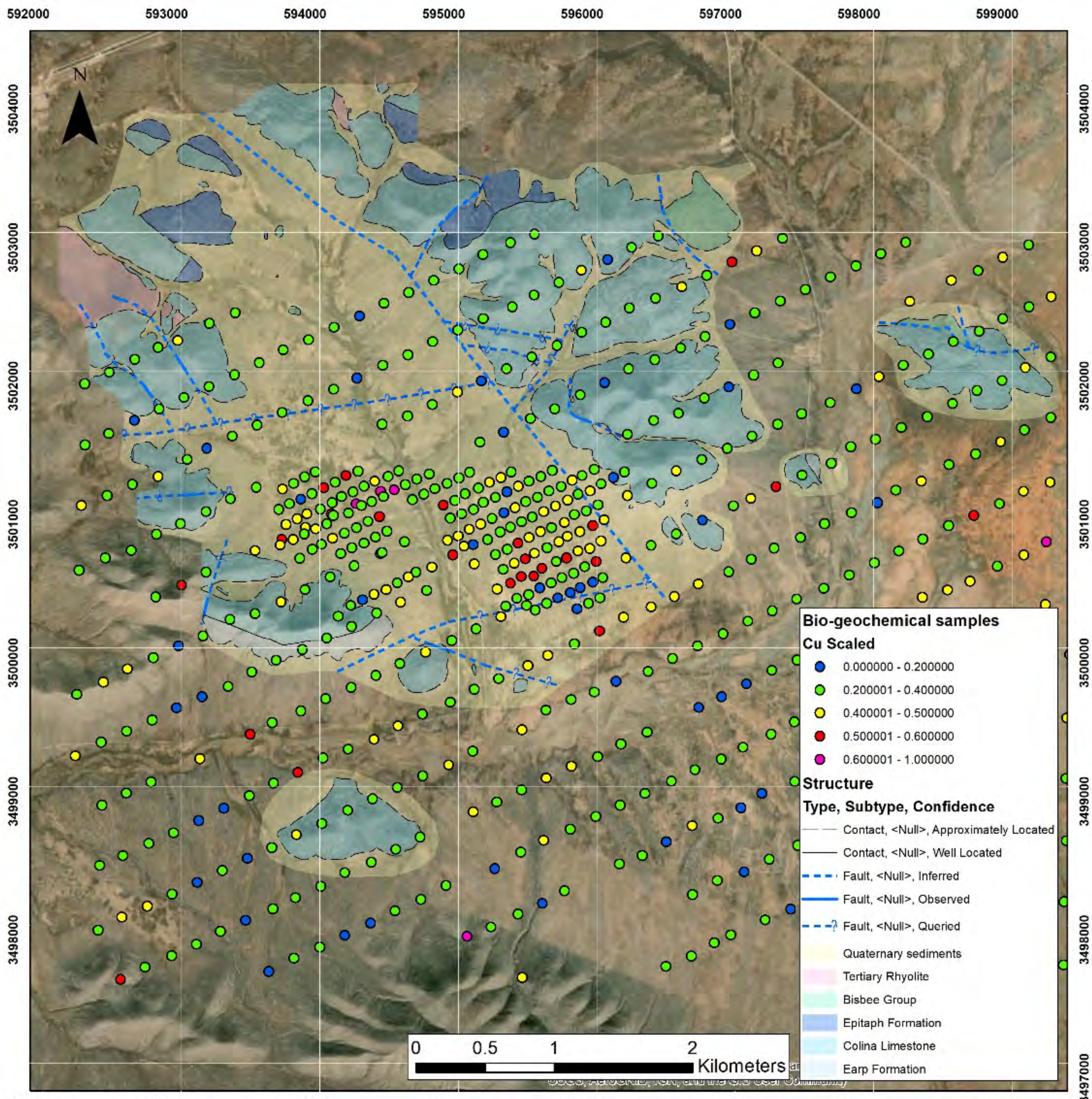

Figure 4: Lithology and structure with compiled bio-geochemical samples showing scaled Cu

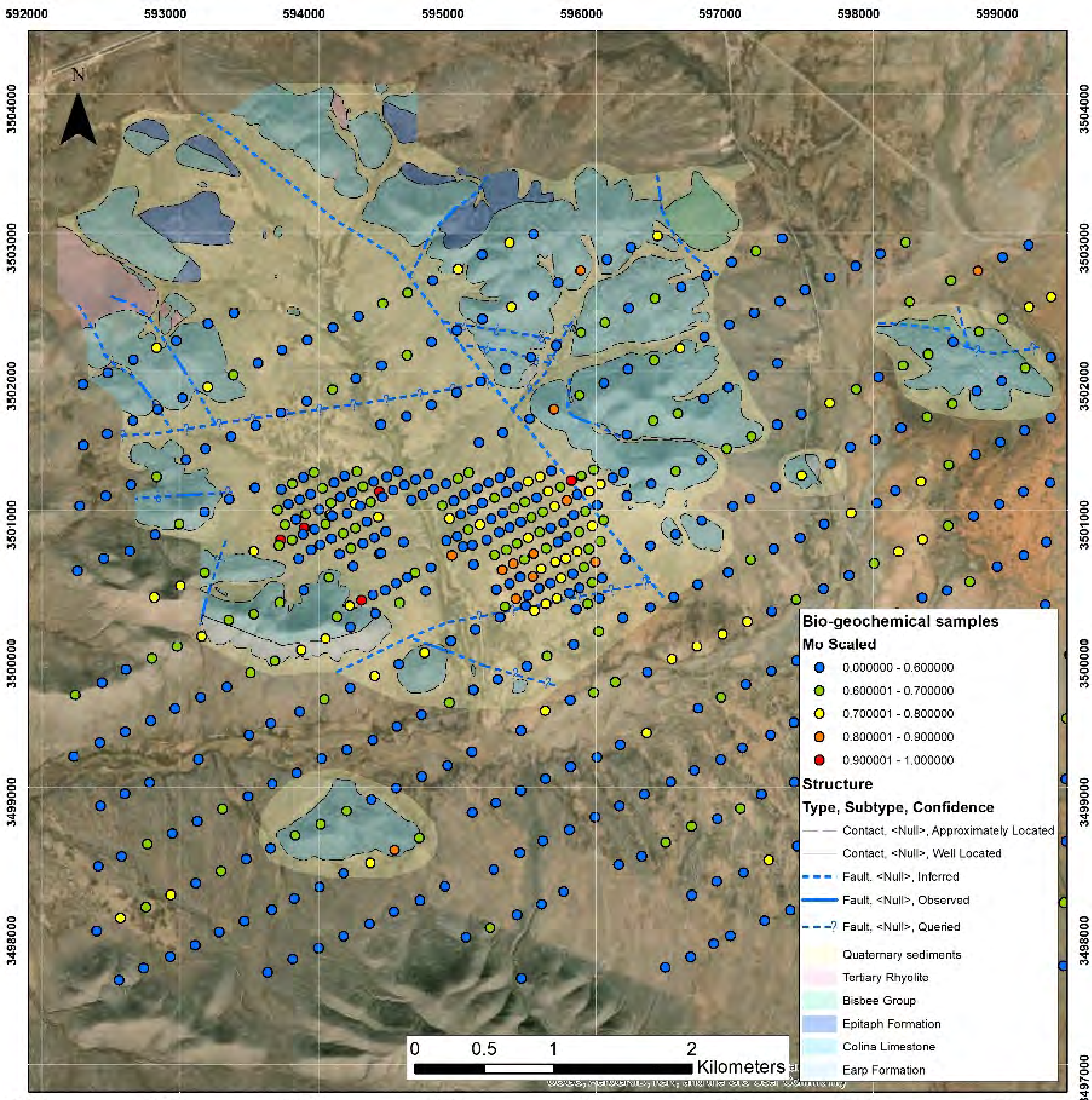

Figure 5: Lithology and structure with compiled bio-geochemical samples showing scaled Mo

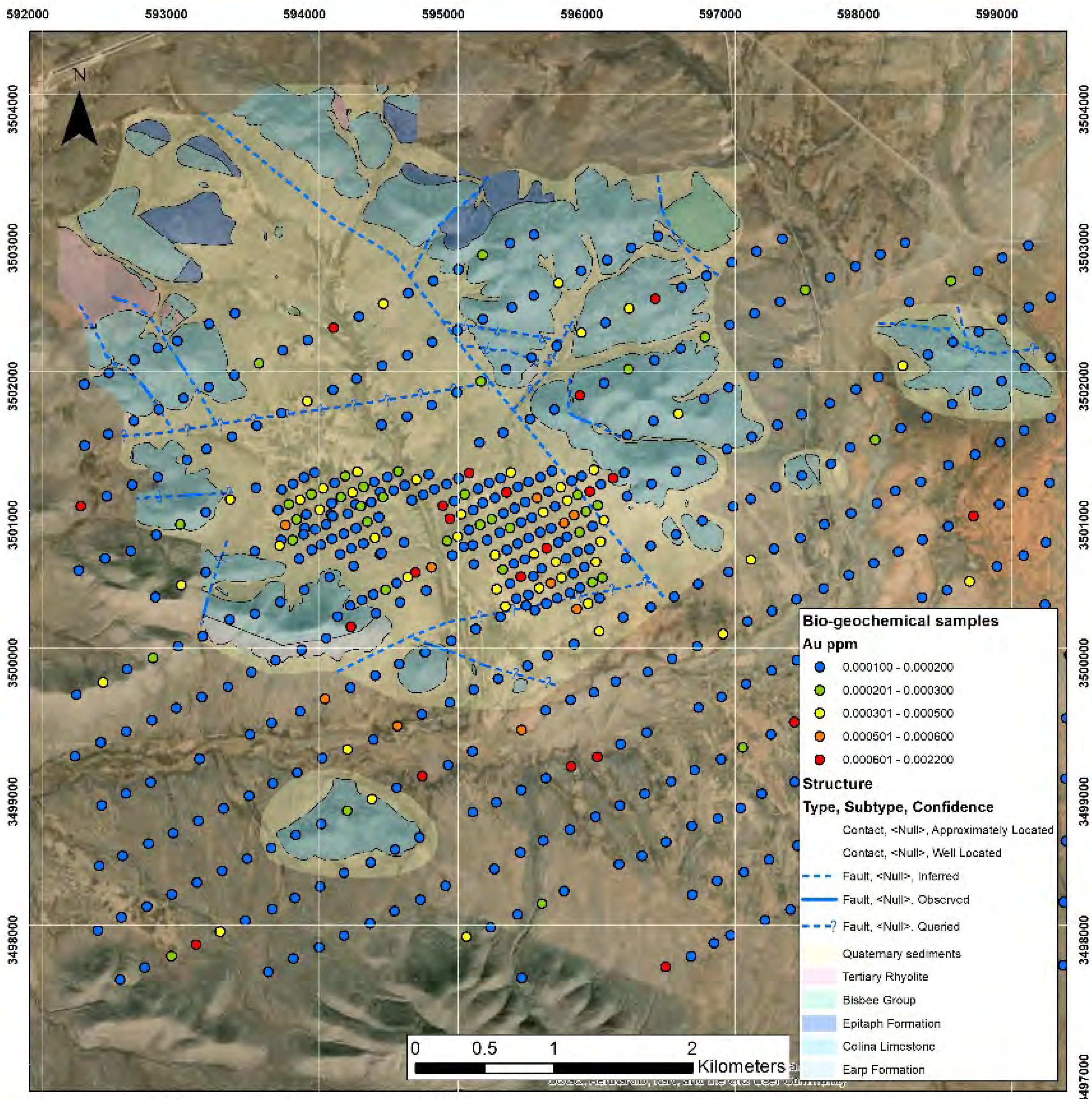

Figure 6: Lithology and structure with compiled bio-geochemical samples showing Au in ppm

Airborne ZTEM and Magnetic Survey

In 2013, Geotech conducted an airborne ZTEM and magnetic survey for Liberty Star Minerals over the Hay Mountain Project and surrounding area. Geotech produced preliminary 2D ZTEM and 3D MVI inversions. Later in 2019, Geotech re-interpreted the survey results and produced more rigorous 3D inversions (Fig 7, 8). The results of this are detailed in Geotech's 3D ZTEM and 3D MVI Inversion Result

Summary. These were later analyzed by Alan King of Geoscience North in 2019 and a 3D model was produced. These results are detailed in Alan King's Liberty Star Geophysical Review.

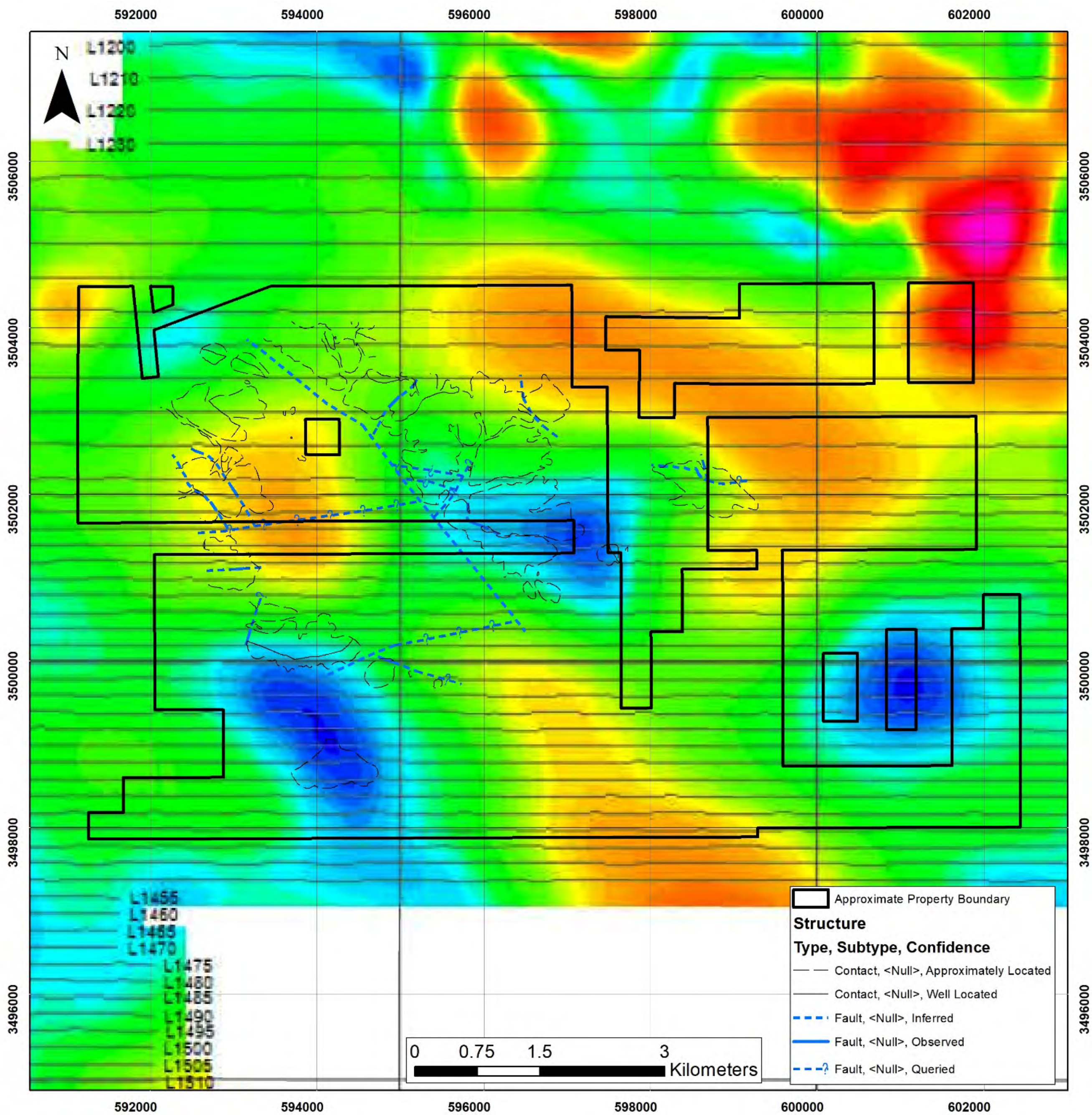

Figure 7: 3D MVI Inversion depth slice at 800m showing mag low between two map highs in the central basin. Mapped structures including contacts have been overlaid for correlation to surface geology.

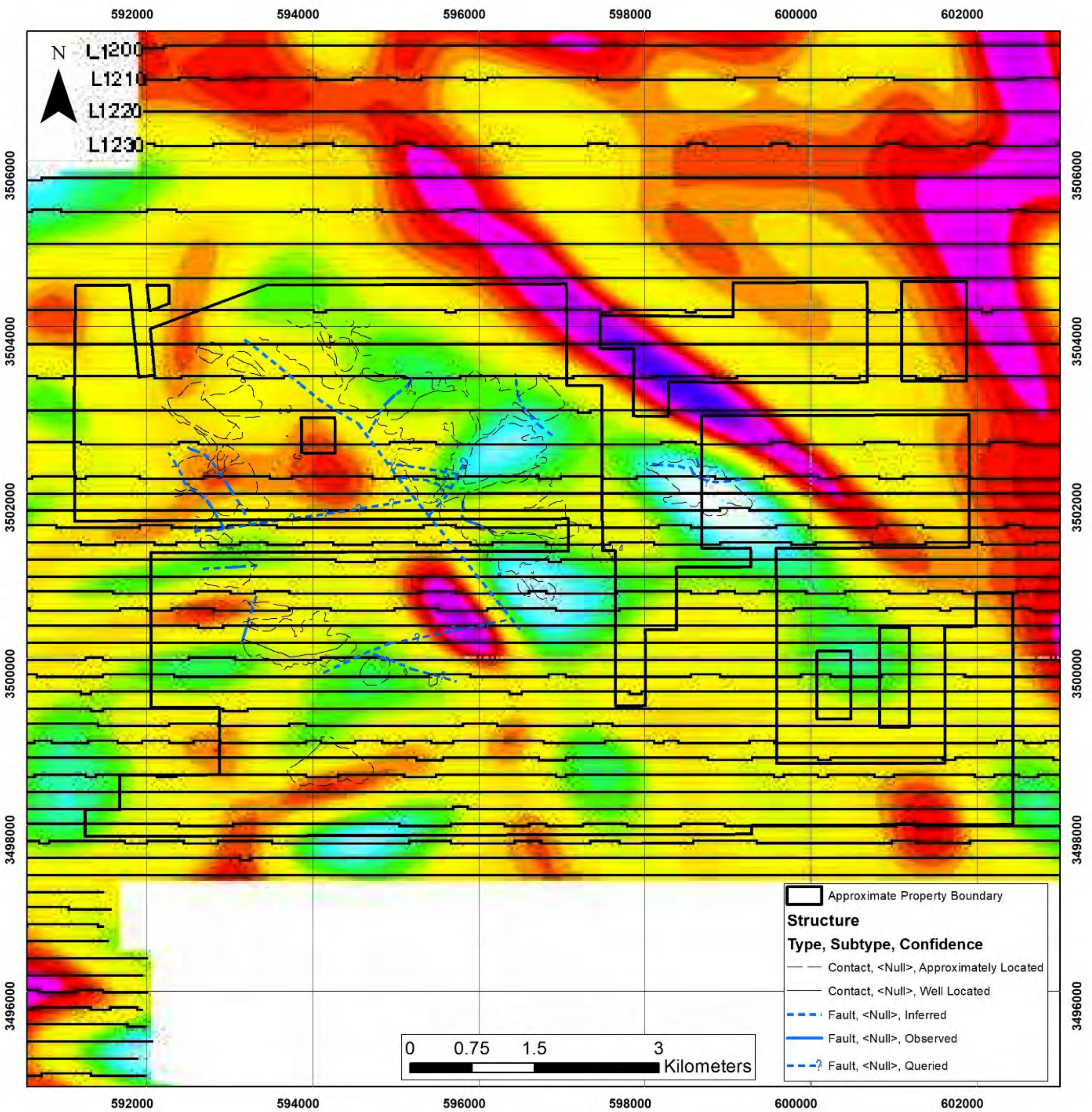

Figure 8: 3D ZTEM Inversion depth slice at 800m showing resistivity low (<100 Ohm-m). Mapped structures including contacts have been overlaid for correlation to surface geology.

Hay Mountain Project Geology

Outcropping lithology in the project area consists dominantly of Paleozoic carbonates of the middle to upper Naco Group that is overlain by (0 to 100m depending on erosion) Late Jurassic to Early Cretaceous lower Bisbee Group (Fig 9). Intruded into this stratigraphy is a Tertiary intrusive rhyolite. Mantling these rocks is a likely thin covering of Quaternary sediments. The lower Paleozoic stratigraphy and Proterozoic basement are not exposed in the project area but are exposed in the Tombstone area and are projected at depth in section A-A’ (Fig 10). Due to a lack of subsurface information, a conceptual cross section was drawn from A to A’ using mapped lithology and structure. Previous mapping conducted by James Gilluly in 1956 was referenced during field mapping. Later mapping was conducted by Force in 1996, however, this map was not available at the time of field work.

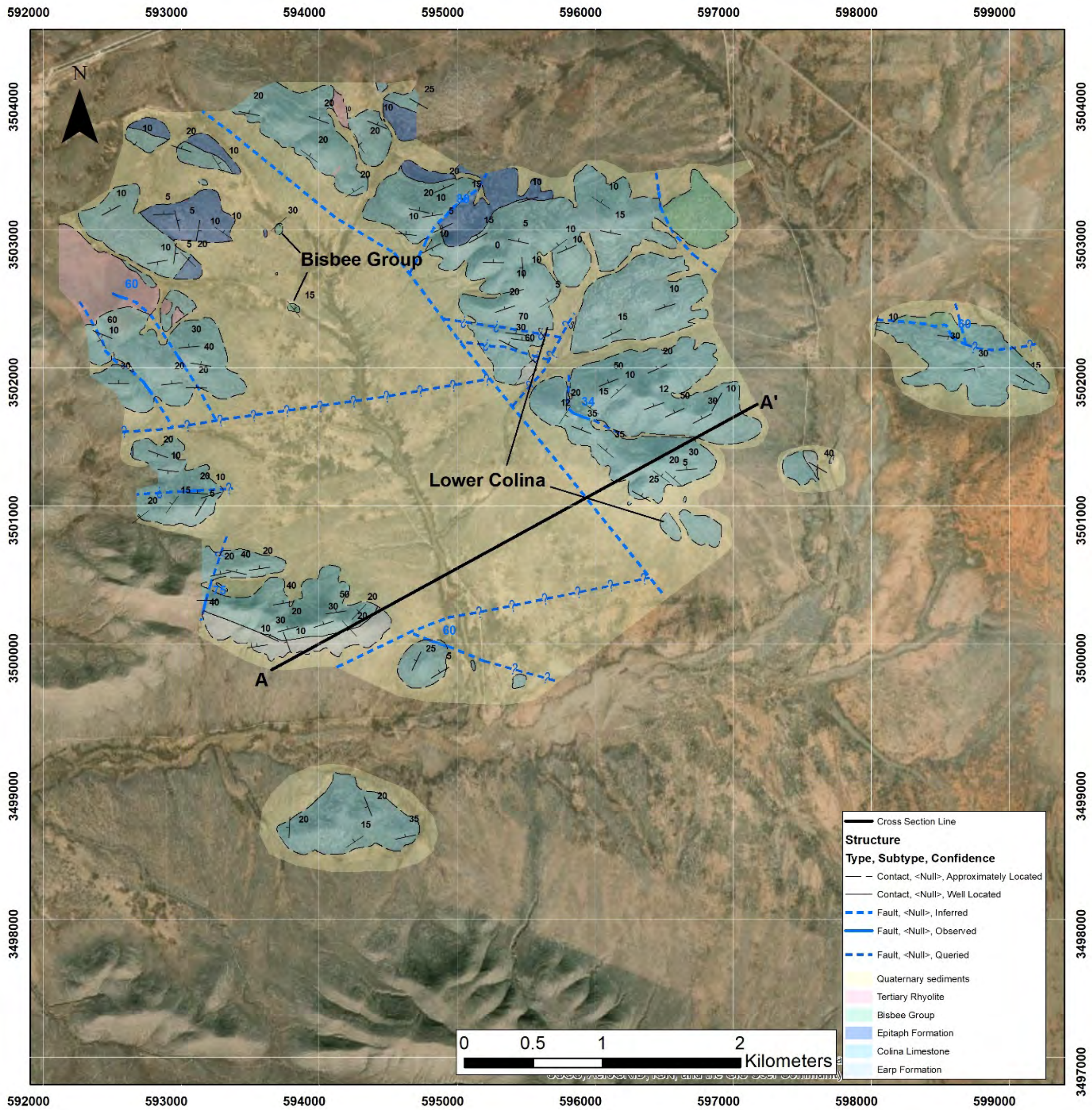

Figure 9: Lithology, structure, and bedding orientations

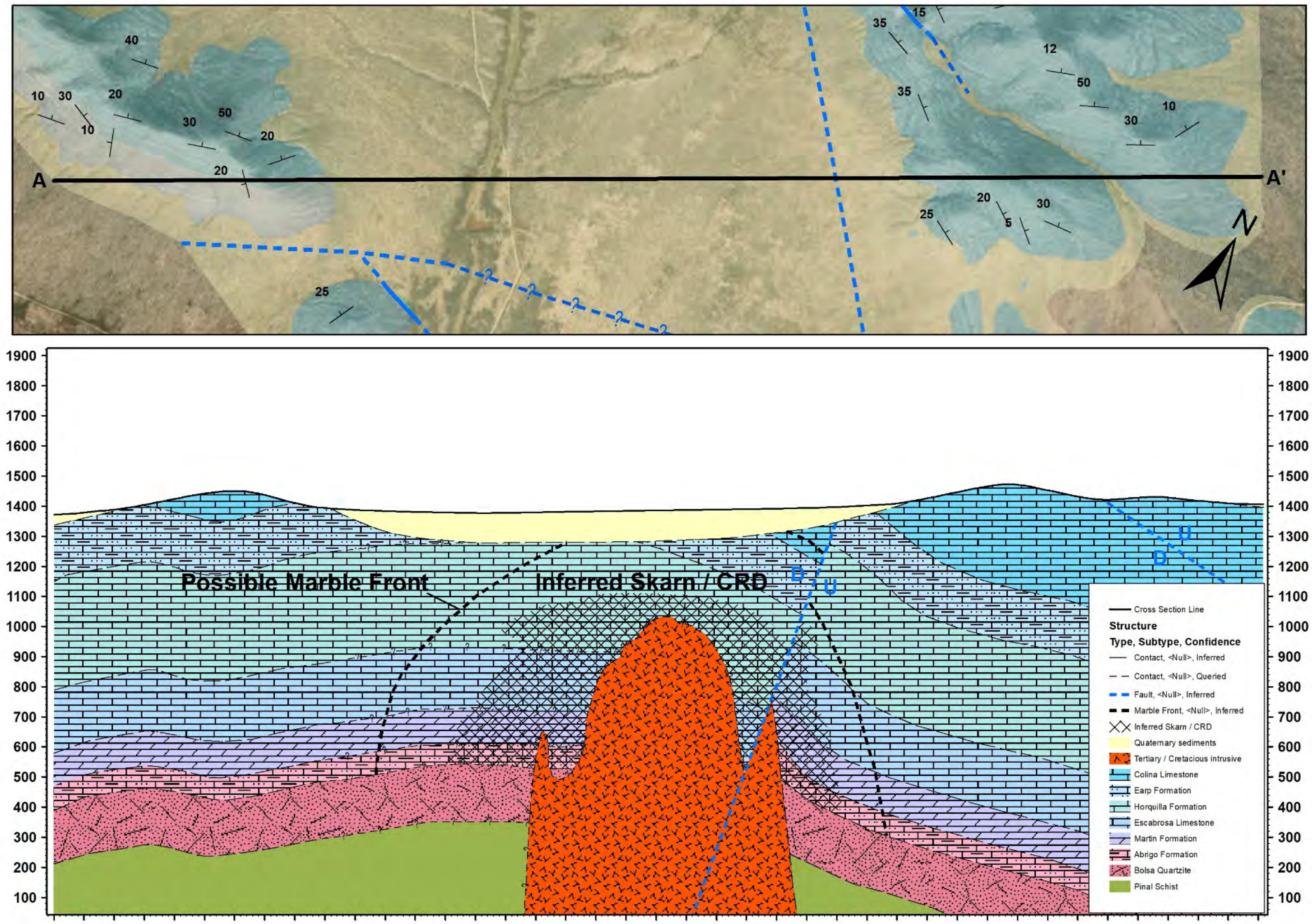

Figure 10: Conceptual cross section from A to A' showing Paleozoic stratigraphy, Proterozoic basement, inferred Laramide intrusive, and alteration. No vertical exaggeration.

Permian Earp Formation

The lower Earp Formation in not exposed on the property. Gilluly describes the lower Earp as predominantly thin shaley limestone and reddish shale with a few interbedded limestone and sandstone beds. The upper most Earp is exposed along the base of Earp Ridge (Fig. 9). Here, the Earp is characterized by approximately 0.5m thinly laminated tan to light brown limestone beds (Fig 11). Beneath this is a 2m pale greyish pink limestone bed overlying 0.25 to 0.5m light grey fossiliferous limestone beds with prominent 5cm chert beds (Fig 12). No complete and unfaulted thickness of the upper Paleozoic stratigraphy exists within the project area and surrounding area. Unit thicknesses are estimate based on published descriptions by Blakey, Gillully, and others. The Earp is described as consisting of approximately 33m of calcareous siltstone and limestone, 75m of limestone, dolomitic siltstone, and sandstone, and 67 meters of limestone and dolostone for a total thickness of 175m.

Figure 11: Tan limestone beds in the upper Earp Formation

Figure 12: Light grey limestone with chert bedding in the upper Earp

Permian Colina Limestone

The Colina Limestone accounts for the majority of outcropping lithology in the project area. The base of the Colina is well exposed along Earp Ridge. Here, the Colina is represented as typically 0.5m dark grey to blue grey (often grey to dark grey on weathered surfaces) massive limestone beds often with a mottled red color. For approximately 20 to 30m above the contact 0.25 to 0.5m beds of a tan to light brown silty limestone are present. Above this are thin 20 to 30 cm red shaley beds. Overlying this is a 5 to 6m cliff forming dark grey limestone. The Colina conformably overlies the Earp formation. The contact can be located anywhere in a 20 to 30m zone of interbedded dark grey and tan limestone beds. The first occurrence of a dark grey massive limestone bed above the Earp was chosen as the contact. The lower contact of the Colina is poorly exposed elsewhere on the property but the occurrence of similar tan limestone beds, red shaley beds, and dark grey mottled red limestone beds were used to identify the lower Colina directly north and south of the Zebra Hills and to estimate apparent offset along faulting in these areas (Fig 9). The middle to upper Colina is a ubiquitous dark grey massive to micritic limestone often with fossiliferous beds containing gastropods and urchin spines. The upper contact with the Epitaph Formation can readily be identified by mottled brown and dark grey limestone bedding often with 2 to 3 cm quartz nodules. The entirety of the Colina is exposed across the property, however, due to faulting exact unit thickness could not be measured in the field. Published estimates place the Colina at approximately 274m thick. This thickness generally agrees with early schematic cross sections drawn across the property during the course of field mapping.

Figure 13: View of Colina Limestone in the Zebra Hills note the small-scale folding of beds. Looking north.

Permian Epitaph Formation

The Epitaph Formation is exposed in the northern portion of the property. Here, the Epitaph is a brown to greyish brown massive dolostone. The Epitaph can be clearly distinguished from the underlying Colina as the first occurrence of a brown weakly to non-effervescent dolostone often with 2 to 3 cm quartz nodules (Fig 14). Erosion has removed most of the Epitaph formation in the project area prior to the deposition of the Bisbee Group. Outcrops of the Epitaph/Colina contact and the approximate location of the Epitaph/Glance contact (Fig. 9) were used to estimate the thickness of the Epitaph in the project area. The total thickness is approximately 40m.

Figure 14: Epitaph Formation looking down. Note the quartz nodules.

Late Jurassic - Early Cretaceous Bisbee Group

The Bisbee Group is exposed on Jay's Hill, the northern edge of Quartz Hill, and in small outcrops in the northern part of the central basin (Fig 9). The basal member of the Bisbee Group is the Glance Conglomerate. The Glance is outcropping on Jay's Hill and the northern most exposure in the central basin. The Glance is a pebble to cobble clast supported conglomerate with sparce boulders and a reddish-brown coarse sand matrix (Fig 15). Clasts are entirely of the underlying Paleozoic limestones. Outcrops of the Bisbee Group on Quartz Hill are of a medium to coarse grained yellowish-brown feldspathic sandstone. Additional outcrops in the basin are of a dark brown sandy limestone. The sandstone and limestone outcrops are tentatively correlated with the Morita Formation (Fig 16). The total thickness of the Bisbee Group is variable across the property due to recent erosion. Where preserved in fault contact with the Colina Limestone the Bisbee Group may be between 10 to 100m depending on preservation. This thickness is based on published descriptions of the Glance Conglomerate and schematic cross sections drawn during the course of field mapping.

Figure 15: Glance Conglomerate outcropping on Jay's Hill

Figure 16: Dark brown limestone outcropping in the central basin. Likely Morita Formation.

Tertiary intrusive rhyolite

Outcrops of an intrusive rhyolite dike are present in the Redrock Canyon area and a larger intrusive body of the same rhyolite is exposed in the Rhyolite Hills area. This rhyolite contains approximately 2 to 3% 1 to 2 mm euhedral quartz phenocrysts, 5 to 7% 2mm plagioclase, and 1 to 2 % 1 to 2mm biotite flakes. The groundmass is tannish-pink quartz plus orthoclase and likely plagioclase. Previous age dates place this intrusive at 65Ma (Marvin and Cole, 1978).

Figure 17: Hand sample of intrusive rhyolite

Quaternary Sediments

These sediments are typically poorly consolidated to unconsolidated alluvium and colluvium basin fill. Where incised by channels, cm to m thick beds of calcrete are present. Clasts are typically locally derived from nearby drainages. The total thickness of these sediments is variable depending on basin depth but likely no more that 100m at their thickest. The central basin in the project area is expected to deepen to the southeast based on the orientation of the main channel (Fig 9). This basin is characterized by broad gentling dipping slopes surrounded by gently dipping hillsides of Naco Group rocks (Fig 18). There are no surface indications of basin bounding faults that could be significantly deepening the basin. There is a fault inferred along the eastern side of the basin under cover based on apparent offset of the stratigraphy. While it is possible this fault may be deepening the basin, it is interpreted that these sediments are mantling this fault and not infilling a fault-controlled basin.

Figure 18: Example of basin topography. Note the gently dipping basin surface and low rolling hills in the background.

Alteration

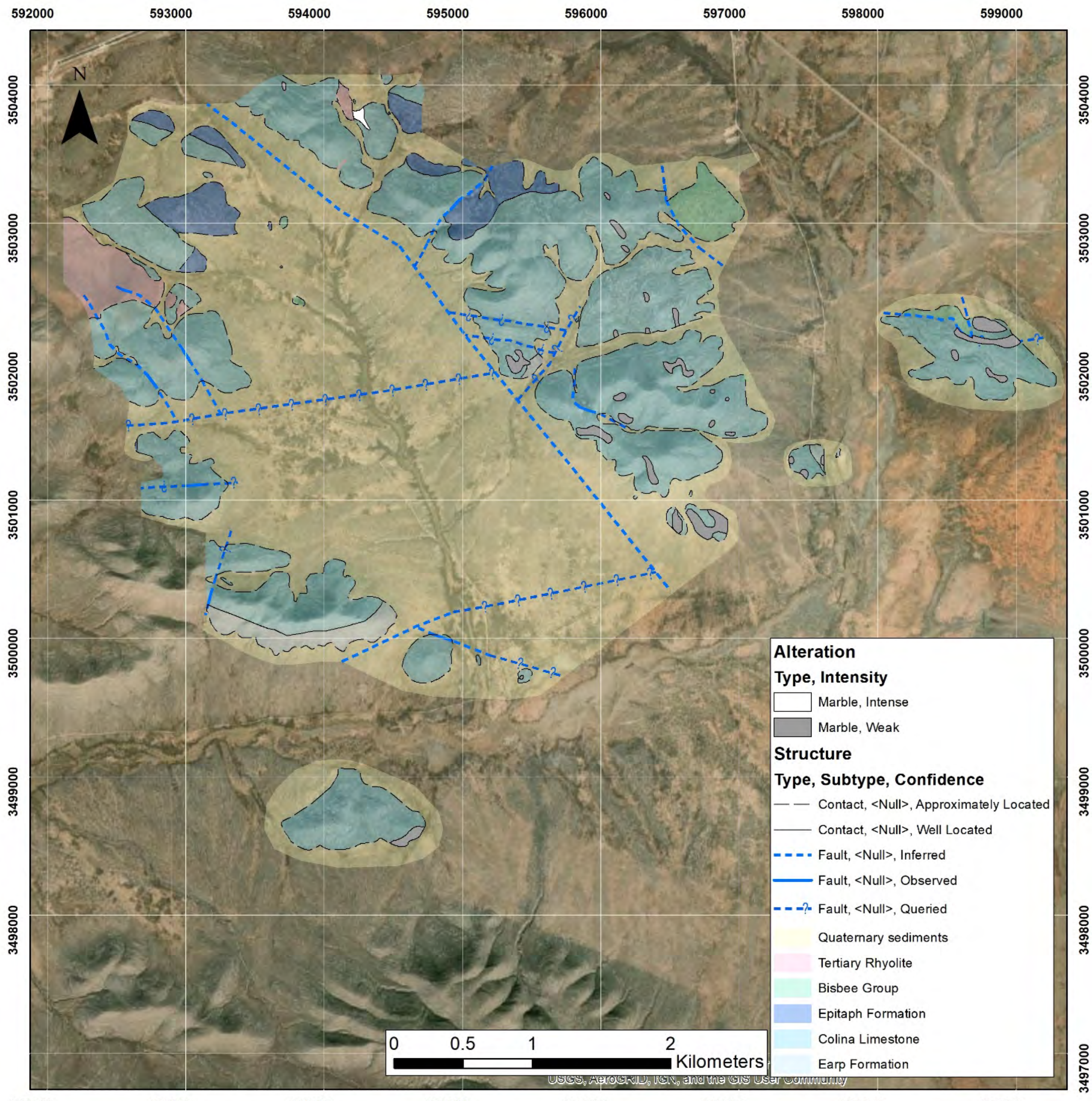

Figure 19: Lithology and structure with outcrops of marbleization

Marbleization

No broad marble front was observed in the project area (Fig 19). Proximal to higher density of type 1 and 2 (carbonate) veining and local replacements, narrow (10-20 cm wide) alteration halos have been observed as a bleaching of the limestone from a dark grey to a lighter grey or a slight brown color (Fig 20, 21). These halos are discontinuous and patchy in outcrop. The halos are still effervescent and appear slightly recrystallized on fresh surfaces. As such, these are interpreted as patchy weak marbleization of the limestone as opposed to dolomitization. The Colina Limestone is generally a dark grey massive limestone, however, close to the upper and lower contacts of this formation with adjacent units, lighter grey and silty tan to brown beds are present. The color changes near the contacts are interpreted as formational changes and not local marbleization unless a clear association with veining was observed. Likewise, minor color changes in the Colina (dark grey to a slightly lighter grey) are interpreted as formational unless a clear association with veining was observed. No broad zonation could be determined from this patchy marbleization. Generally, however, this alteration is more readily identifiable in the eastern half of the property (Fig 19).

Figure 20: Recrystallization and discoloration of limestone adjacent to replacements located south of Zebra Hills

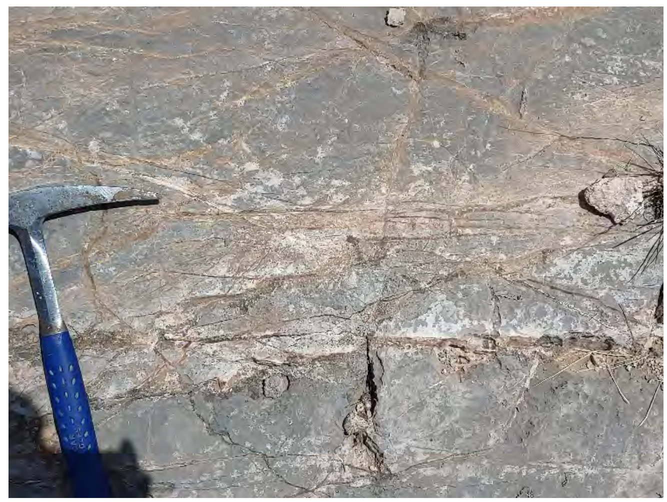

Figure 21: Local recrystallization and discoloration of limestone around carbonate veining

In the Redrock Canyon area (Fig. 2), a narrow bleached marble front is present adjacent to a dike of Tertiary rhyolite (Fig. 19). The dike in this area has moderate to strong low temperature clay alteration represented by a bleaching of the groundmass, replacement of biotite with clay (possibly illite) + hematite, and partial replacement of plagioclase phenocrysts by clay. No marbleization was observed around the larger body of Tertiary rhyolite in the Rhyolite Hills area. It is currently unclear if this marble is related to the intrusion of this dike or secondary alteration of this dike possibly related to Type 3 quartz veining and silicification in the Redrock Canyon area.

Polymetallic Replacements

Hydrothermal replacement of the limestone occurs locally in the southern and eastern portions of the property. Gossanous replacements are typically discontinuous (Fig. 23), range from 1 to 10 cm wide, and often follow type 1 carbonate veins (Fig. 22). The replacements are typically so oxidized that original mineralogy cannot be determined, however pXRF readings typically show elevated Mo (50 to 300ppm and as high as 800ppm), Zn (170 to 800ppm), +/- Pb (150 to 300ppm), +/- Cu (100 to 200ppm). In several outcrops gossanous pseudomorphs after pyrite were identified.

Figure 22: Polymetallic replacements along type 1 carbonate vein

Figure 23: Polymetallic replacements south of the Zebra Hills

Type 1 Veins

White carbonate (likely calcite) veins with limonite (typically goethite-dominant) occur across much of the project area, though are most prevalent in the eastern and southern portions of the property (Fig 26). Veins are typically 2 to 3mm wide with a discontinuous 3 to 4mm orange to orange red limonite (goethite > hematite) plus carbonate center vein. In outcrop these veins are irregular in shape, frequently infilling fractures with apparent right lateral offset (Fig 25). The limonite plus carbonate center vein is typically discontinuous along strike length creating irregular vein total thicknesses from 2mm to 2cm (Fig. 24). Limonite smears were created for veins in the Zebra Hills area to estimate goethite/hematite ratios, and in general, limonites are dominated by goethite, though with a noticeable increase in hematite content on the north side of the Zebra Hills.

Figure 24: Type 1 veins cut by type 2 veins

Figure 25: Type 1 carbonate plus limonite vein. Note the irregular of the vein.

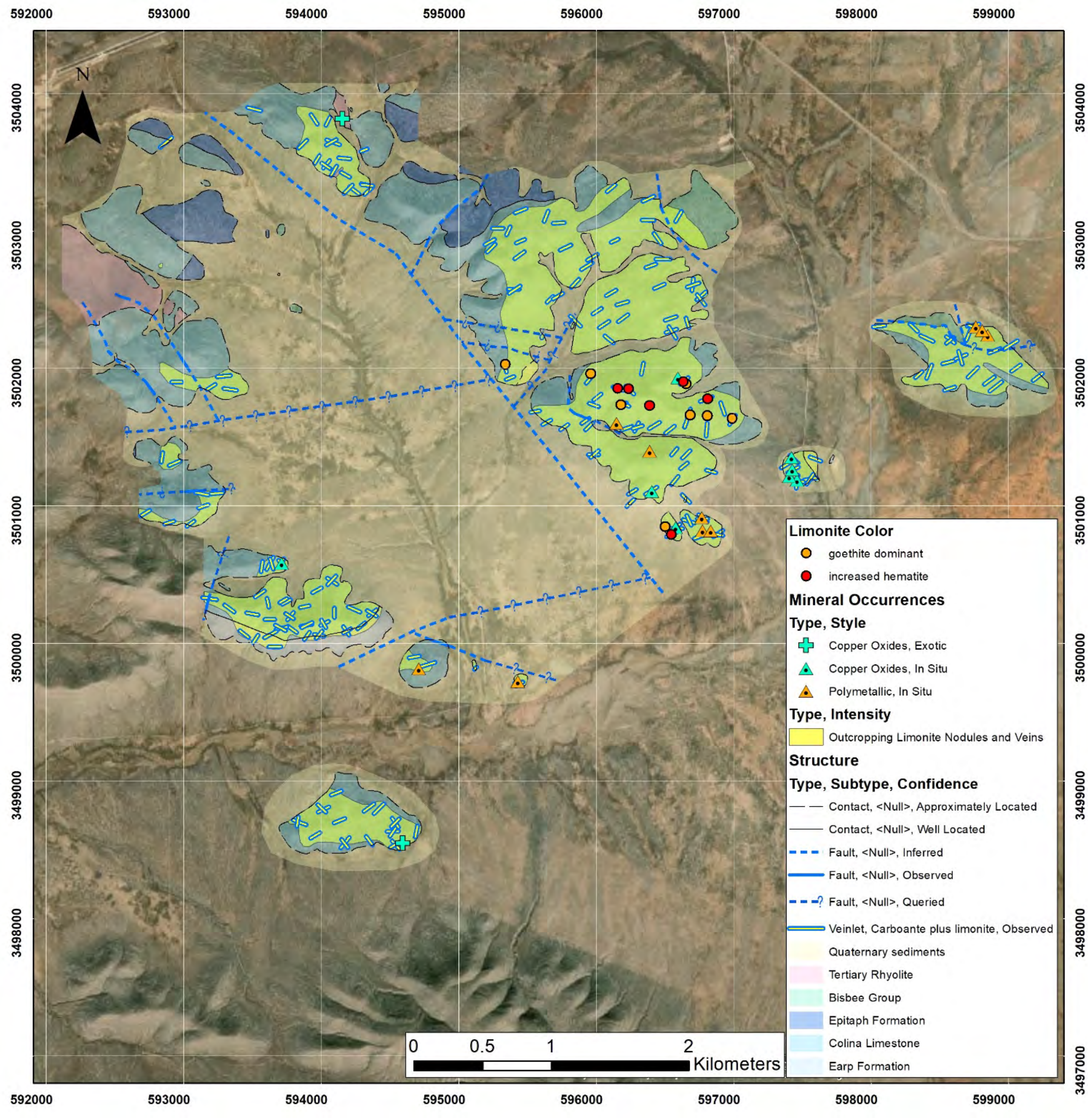

Figure 26: Lithology, structure, and mineral occurrences with mapped type 1 veins and extent of veining plus limonite nodules and limonite smear colors

Type 1 veins are locally associated with carbonate-limonite nodules in the limestone. This alteration is not widespread and typically restricted to where this vein type is present (Fig 27). In several outcrops carbonate plus limonite veins were observed cutting and replacing gastropod fossils in the Colina Limestone (Fig 28).

Figure 27: Limonite nodule rimmed by carbonate

Figure 28: Gastropod fossils cut by type 1 veins and replaced by limonite

Figure 29: Type 1 veining with associated Malachite

Vein orientation is variable across the property, although there is a noticeable east-northeast to west-southwest (approximately 050-070 azimuth) orientation to many of these veins. Veins are typically steeply dipping to subvertical.

In the Chrysocolla Block area and the exposures south of the Zebra Hills type 1 veins are associated with Cu mineralization. Cu mineralization is present as chrysocolla +/- malachite with associated goethite. pXRF reading along these veins typically generate S anomalies of >400ppm. Veining in the Zebra Hills area show anomalous Mo of >60ppm.

Type 1 veins crosscut the late Jurassic Glance Conglomerate (lower Bisbee Group) although they do not appear to cut the Tertiary rhyolite. These field relations suggest type 1 veins are post late Jurassic and probably Cretaceous (Laramide) in age.

Type 2 Veins

White to orange carbonate (likely calcite) veins are present throughout most of the property. These veins are typically <1mm to 3mm wide, laterally discontinuous and show no clear association with mineralization.

Vein orientation is variable, however, a north-northwest to south-southeast orientation to many of these veins is apparent (Fig 30). Veins are typically steeply dipping to subvertical although a generally east-west striking, moderately to gently dipping set of type 2 veins occurs in the Zebra Hills area and along Earp Ridge (Fig. 2). This vein set is poorly exposed due to its orientation and may be underrepresented in the mapping.

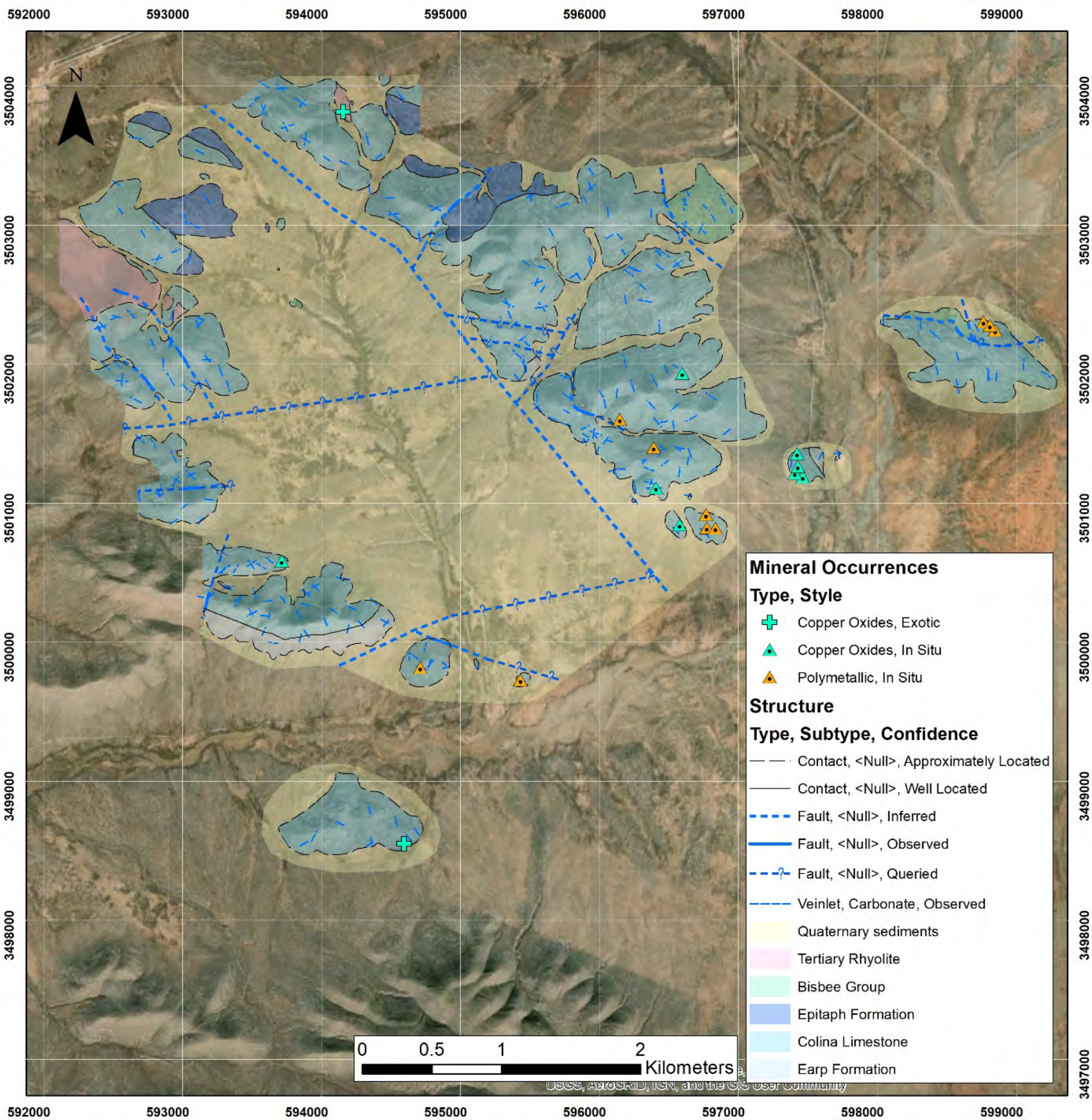

Figure 30: Lithology, structure, and mineral occurrences with mapped type 2 veins

Figure 31: Type 2 veins

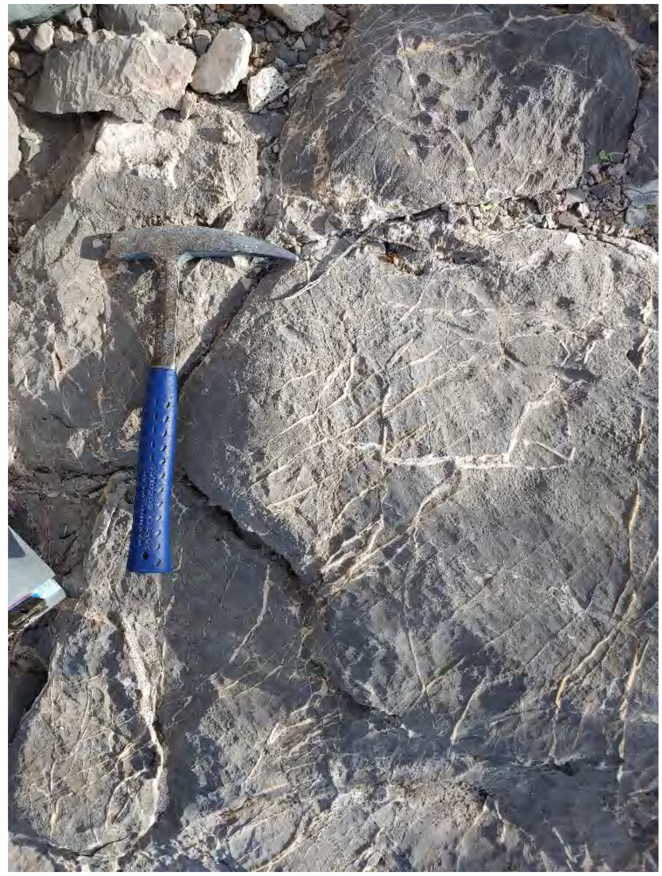

Figure 32: Type 2 veins cutting type 1 veins

Type 2 veins were observed to crosscut type 1 veins in multiple outcrops (Fig. 32). As with Type 1 veins, type 2 veins do not appear to crosscut the Tertiary rhyolite.

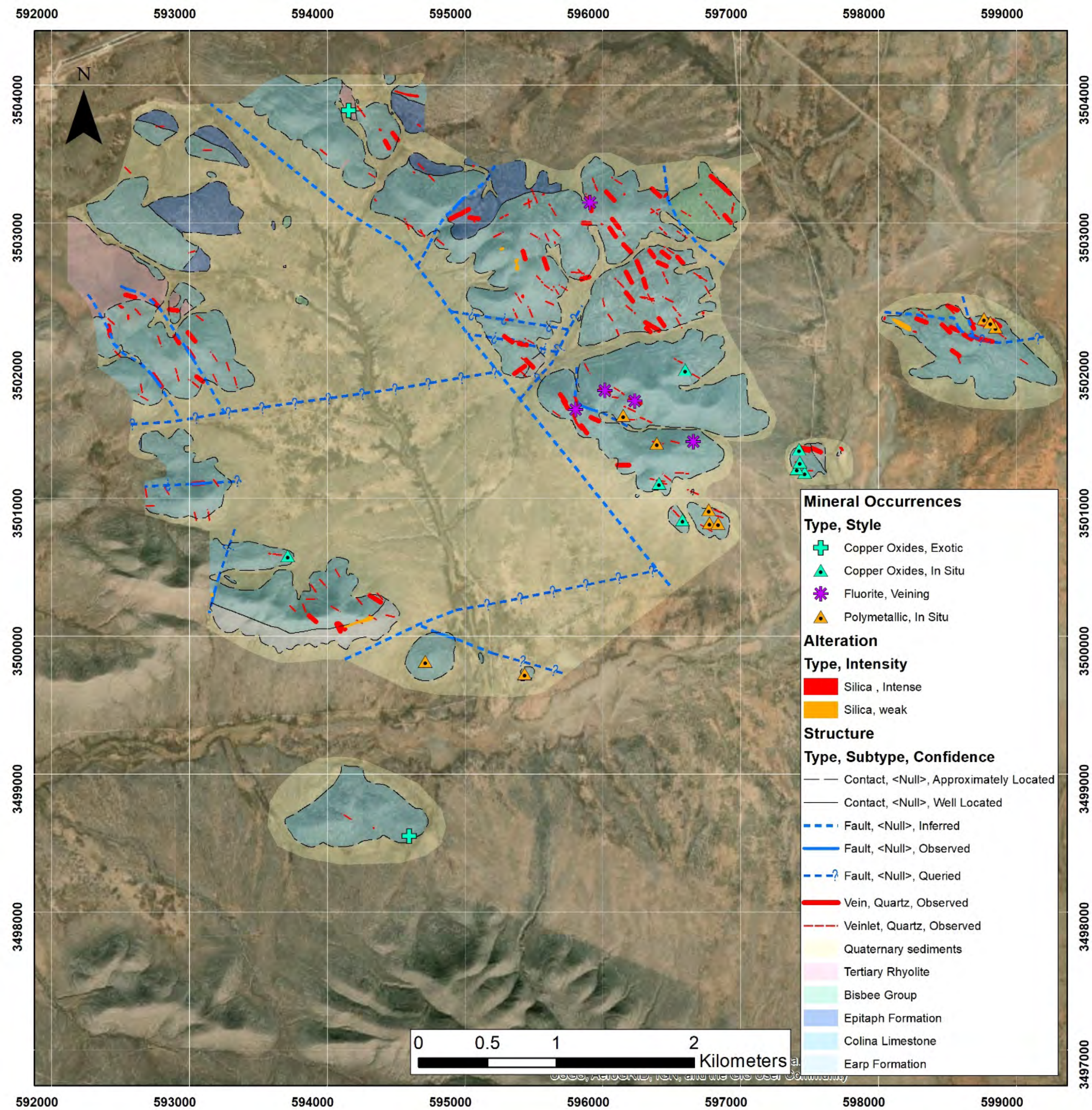

Figure 33: Lithology, structure, and mineral occurrences with mapped type 3 veins, breccias, and silicification. Due to the scale of mapping type 3 vein sets are symbolized as veinlets (dashed red lines), structurally controlled breccias are symbolized as thick veins (thick red line), and silicification as discrete outcrops (red and orange polygons).

Type 3 Veins

Type 3 veins are characterized by three styles of infill and related hydrothermal alteration.

1. 2 to 3mm wide open space sheeted quartz veins. Type 3 veins are typically only quartz veins, however, north of the Zebra Hills quartz veins were observed with 1 to 2 cm grey carbonate

(likely calcite) center veins (total vein thickness of 1.5 to 2.5 cm). Type 3 veins are typically on strike with breccias and silicified lenses described below. Vein density is generally low across the property (0.5 to 1%) but increases proximal to breccias and silicified lenses (up to 5 to 7%). In the area north of the Zebra Hills dense (locally >20%) sheeted vein sets are present (Fig 35). The strike length of individual veins was not determined in the field, however, mapping revealed outcrops of these veins along strike with each other for 0.5 to 1km along strike (Fig 33). Type 3 veins are generally steeply dipping to sub-vertical striking northwest to southeast.

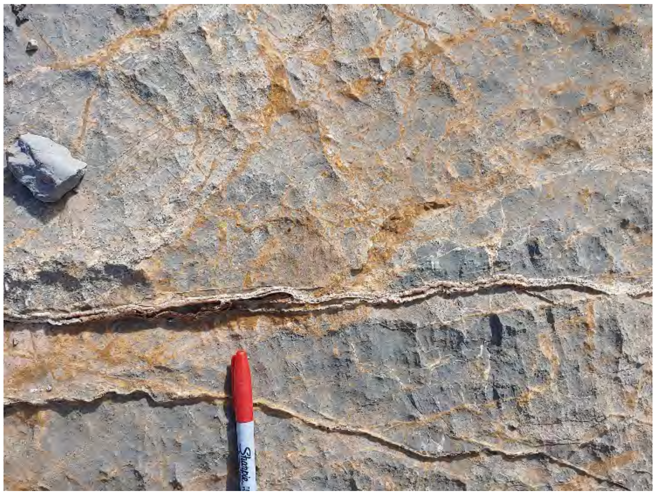

Figure 34: Type 3 vein cutting type 2 veining

Figure 35: Dense sheeted type 3 veining located north of the Zebra Hills

2. Structurally controlled, 0.5 to 1m wide hydrothermal breccias with cryptocrystalline quartz and terminated quartz cement (Fig 36, 37). Clasts and surrounding wall rock within 5 to 10cm are intensely silicified. These breccias are typically exposed for 10 to 15m in strike length before pinching out. Type 3 veins and silicified lenses can be found along strike for as much as 0.5 to 1km. In the Redrock Canyon area, fine (<0.2mm) goethite after sulfides and box works after pyrite are present in quartz cement and clasts of silicified limestone. In the Zebra Hills area, these breccias display 2 to 3mm box works after pyrite and coarse 2 to 3cm green and purple fluorite. pXRF readings of goethite after sulfides in the Redrock Canyon area show anomalous Au (150 to 20 ppm), and Mo (up to 6000 ppm). These breccias match the descriptions of chips samples taken by PD in 1989 which assayed for anomalous Au (Fig 3). Several outcrops showed impressions of a bladed mineral. This mineral was found in outcrop in the Rhyolite Hills area to be a pale grey carbonate (likely calcite) with an apparent bladed habit (Fig 41, 42).

Figure 36: Structurally controlled breccia in the Zebra Hills

Figure 37: Structurally controlled breccia south of Redrock Canyon

Figure 38: Clasts of silicified limestone with fine goethite after sulfide (likely pyrite) in a structurally controlled breccia in the Redrock Canyon area.

Figure 39: Green and purple fluorite and open space quartz along a structurally controlled breccia from the Zebra Hills

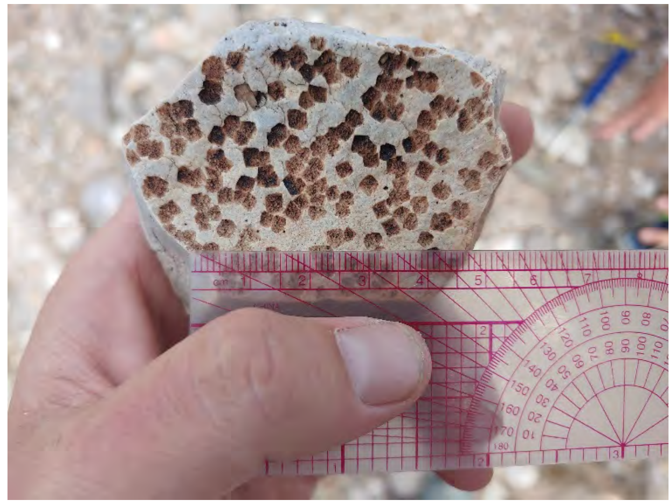

Figure 40: Pyrite box works from structurally controlled breccias north of the Zebra Hills

Figure 41: Impressions of a bladed mineral from structurally controlled breccia north of the Zebra Hills.

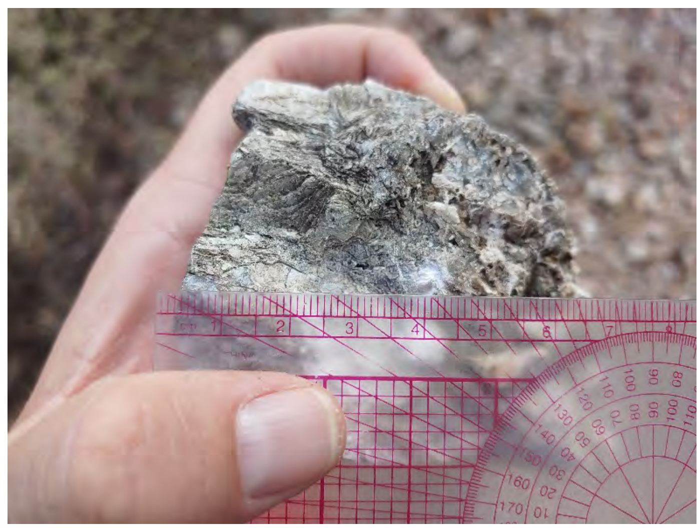

Figure 42: Grey carbonate (likely calcite) from a structurally controlled breccia in the Rhyolite Hill. Note the bladed habit.

3. Local silicification of the limestone occurs as small discontinuous lenses and bedding parallel zones. Silicified lenses are often elongate in a northwest to southeast orientation. These lenses vary in strike length from 0.25 to 2m and are often 0.25 to 0.5m wide (Fig. 43). Local beds in the Zebra Hills and Redrock Canyon areas are intensely silicified forming sub horizontal to gently dipping silicified bedding parallel zones (Fig. 44, 45). The Zebra Prospect is named for an occurrence of one of these silicified beds forming banded jasperoid and terminated quartz with associated fluorite referred to as "Zebra rock" (Fig. 44, 46). The total extent of these silicified beds is unknown, however, there is exposure of silicification at the Zebra Prospect over approximately 200m.

Figure 43: Lens of silicification in limestone

Figure 44: "Zebra Rock." Banded jasperoid and terminated quartz from the Zebra Prospect

Figure 45: Silicification along bedding in the Redrock Canyon area. Note that the surface of the outcrop is bedding parallel.

Figure 46: Hand sample of "Zebra Rock" showing banded jasperoid and terminated quartz.

Collectively, these Type 3 alteration styles show a strong northwest to southeast orientation across the property (Fig 33). Sheeted type 3 quartz veins crosscut both type 1 and 2 veins. Structurally controlled breccias crosscut the Tertiary rhyolite in prospect pits in the Rhyolite Hills and Redrock Canyon areas (Fig 47), indicating they are younger in age than the 65Ma rhyolite intrusions or related to some phase of this intrusion.

Figure 47: Hand sample from structurally controlled breccia crosscutting Tertiary rhyolite from the Rhyolite Hills

XRF Zonation

A total of 183 carbonate vein chip samples were collected for UVF response. At each sample location pXRF readings were taken of the sampled vein using a Niton XL5 handheld XRF device. Each reading is effectively a point reading along the sampled vein. While this is not as rigorous as geochemical rock chip sampling, comparing pXRF readings on carbonate veins property wide provides a quick view of base metal zonation. Due to their association with type 1 veins, CuOX bearing veins and local replacements have been included with these readings.

Cu Zonation

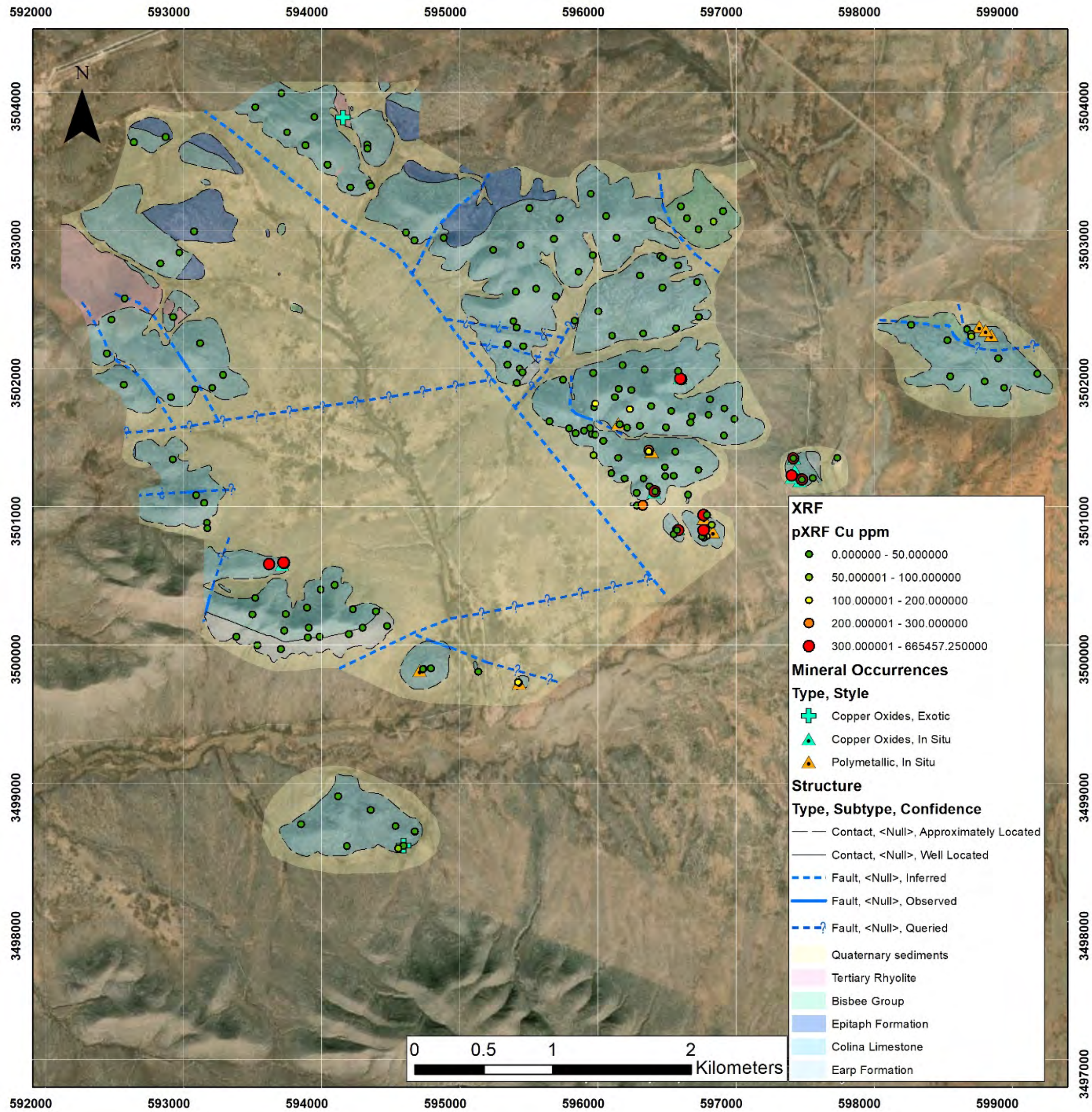

Figure 48: pXRF sample locations showing Cu values

pXRF readings on type 1 and type 2 veins show very few Cu anomalies apart from where visible CuOX mineralization is present. Several Cu anomalies are present in the Zebra Hills (Fig. 48) typically coinciding with mapped polymetallic replacement and CuOX bearing type 1 veins.

Mo Zonation

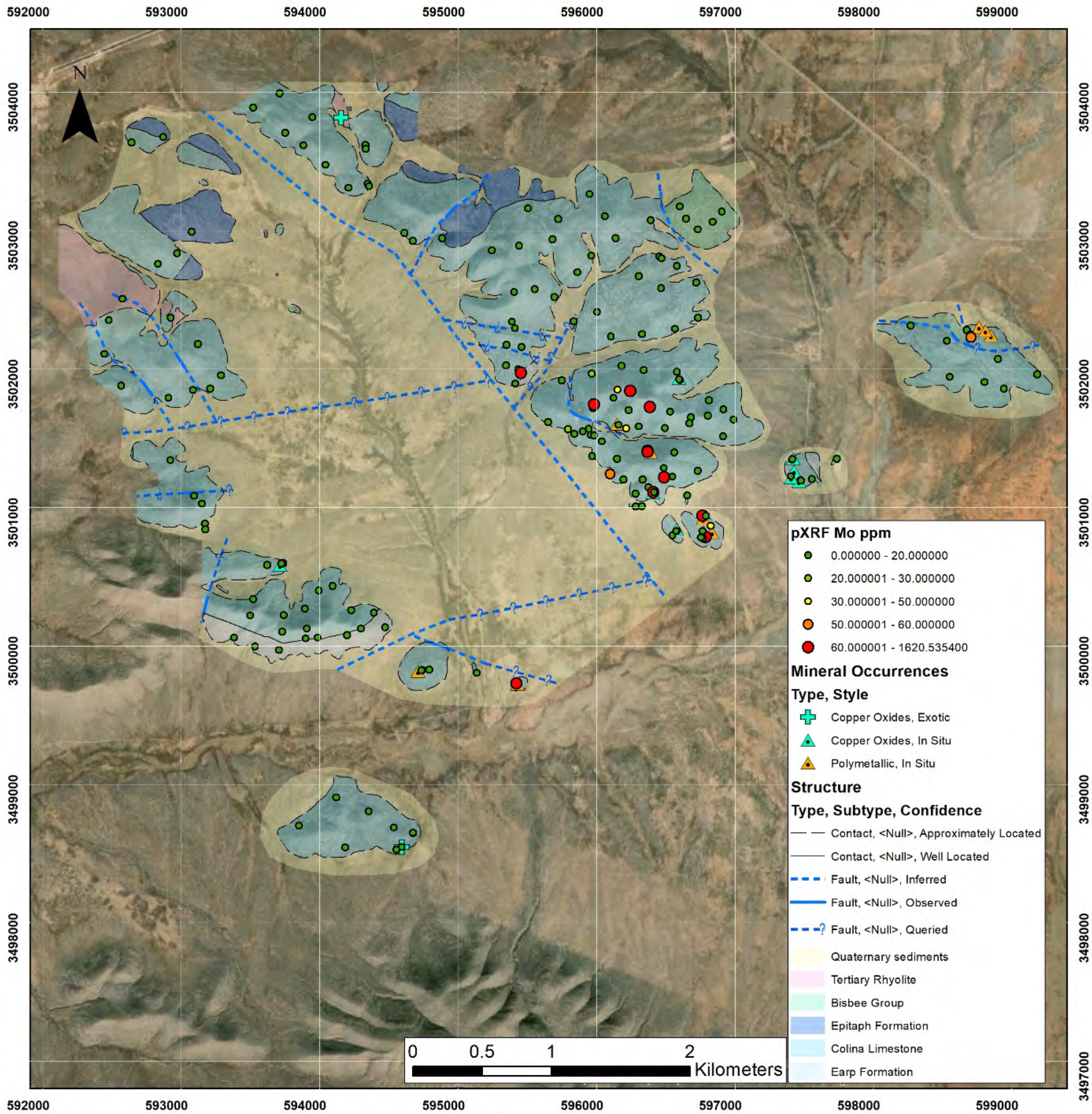

Figure 49: pXRF sample locations showing Mo values

pXRF readings show several Mo anomalies in the Zebra Hills area (Fig 49). While several of these readings correlate with mapped polymetallic replacements, most of the anomalies in the in the Zebra Hills occur along type 1 carbonate veins.

Pb Zonation

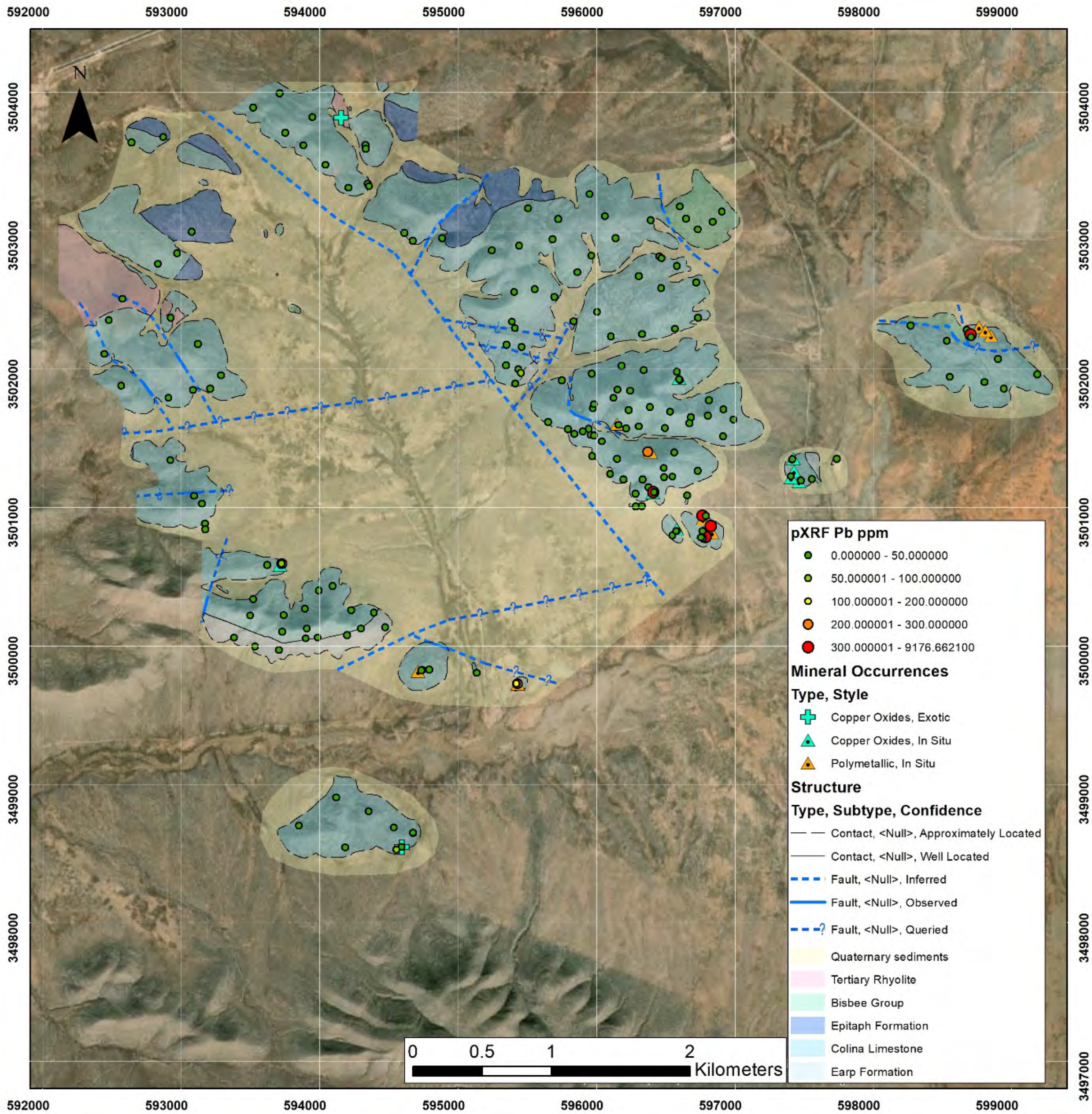

Figure 50: pXRF sample locations showing Pb values

pXRF readings show little to no Pb associated with type 1 and type 2 carbonate veins. All recorded Pb anomalies correlate with mapped polymetallic replacements (Fig. 50).

Zn Zonation

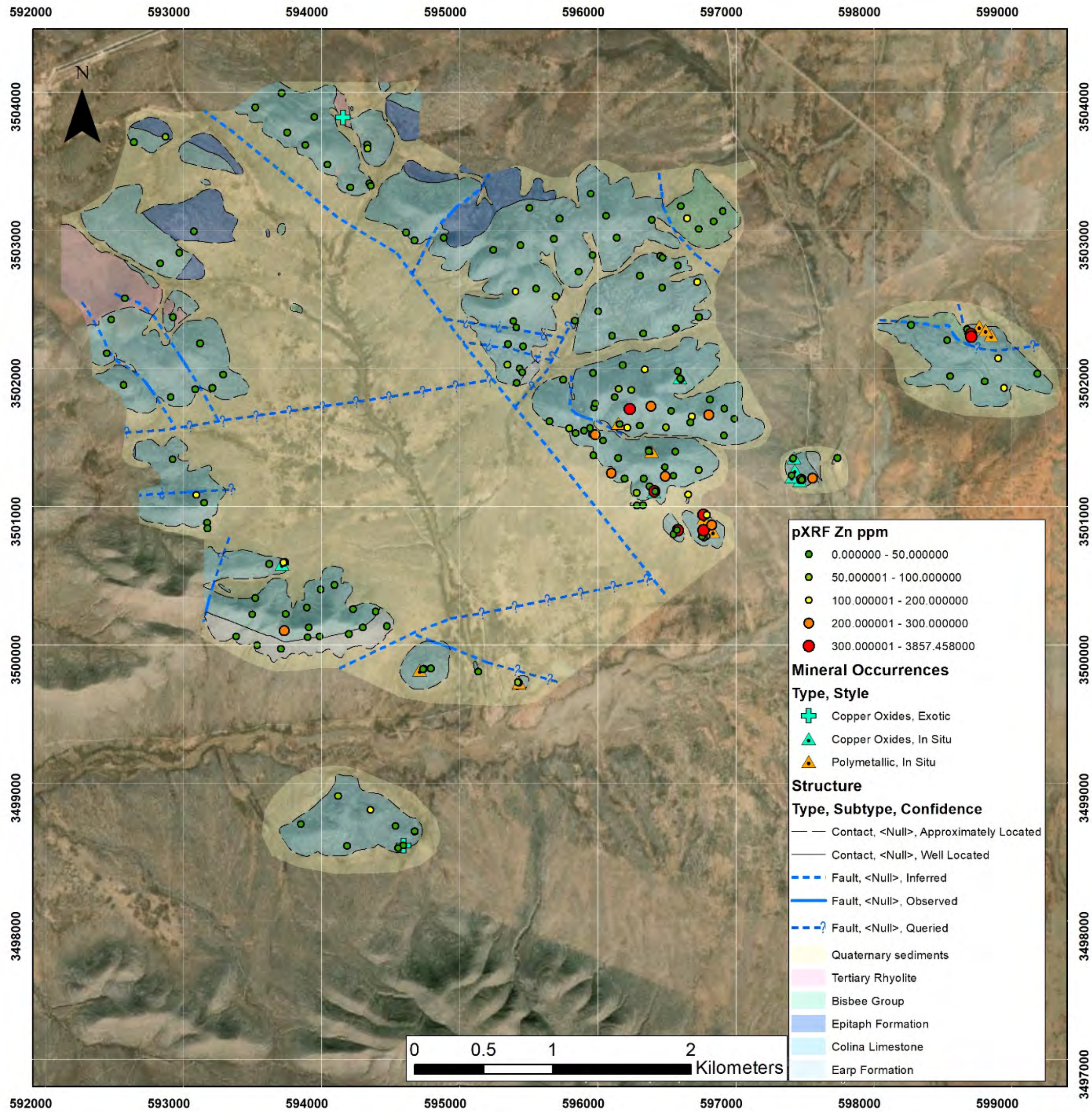

Figure 51: pXRF sample locations showing Zn values

pXRF readings show several Zn anomalies across the property with the majority located in the Zebra Hills. While some correlate with mapped polymetallic replacements (Fig. 51), several of these anomalies are located in type 1 veins.

As Zonation

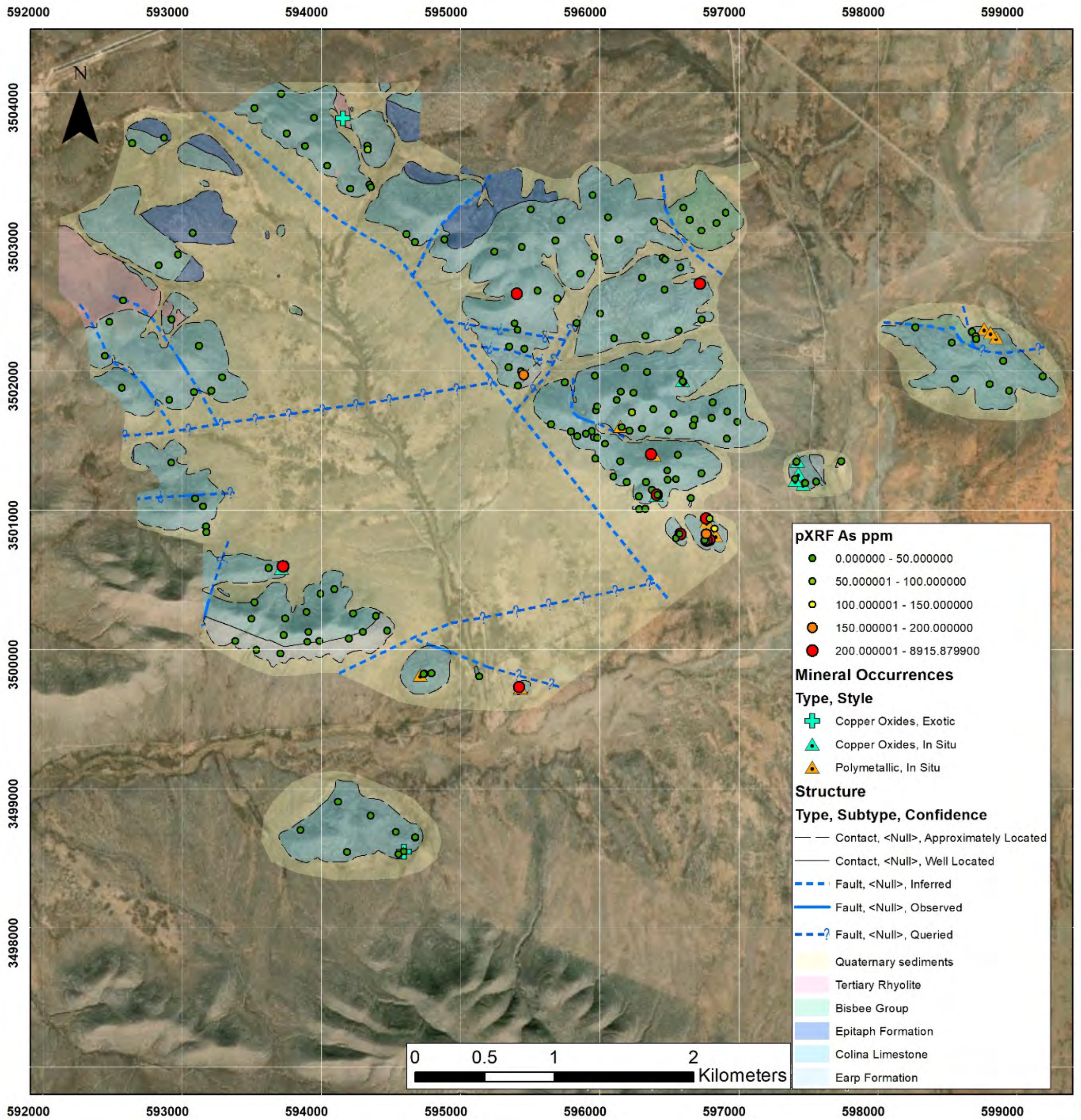

Figure 52: pXRF sample locations showing As values

pXRF readings show few As anomalies in the project area. The majority of these correlate with mapped polymetallic replacements (Fig. 52) and visible CuOX mineralization. A select few north of the Zebra Hills and north of Earp Ridge are correlated with type 1 veins.

S Zonation

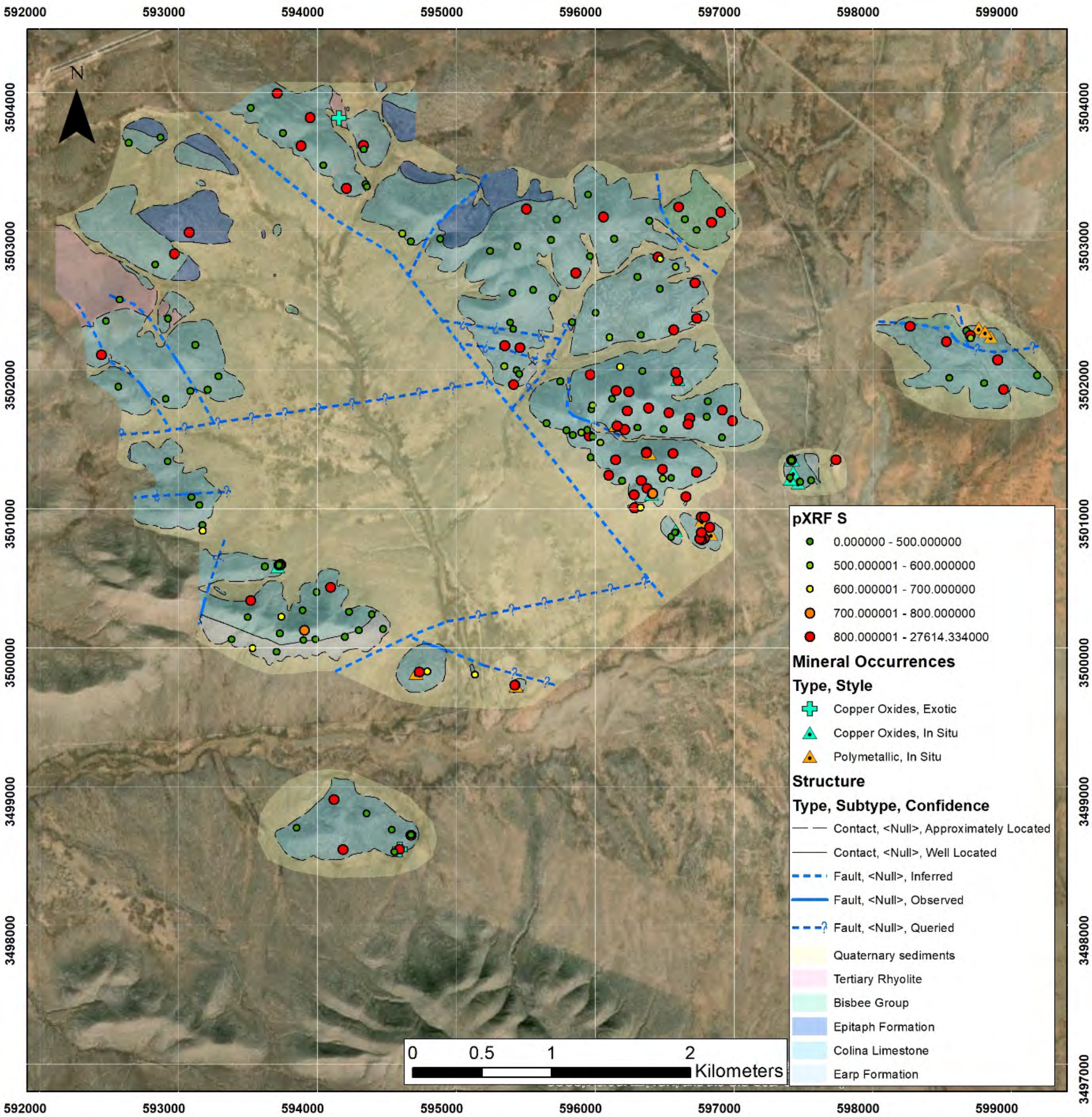

Figure 53: pXRF sample locations showing S values

pXRF readings show S anomalies across most of the project area. These readings correlate to polymetallic replacements, type 1 and type 2 veins.

Ultraviolet Fluorescence (UVF) of Vein-hosted Carbonate

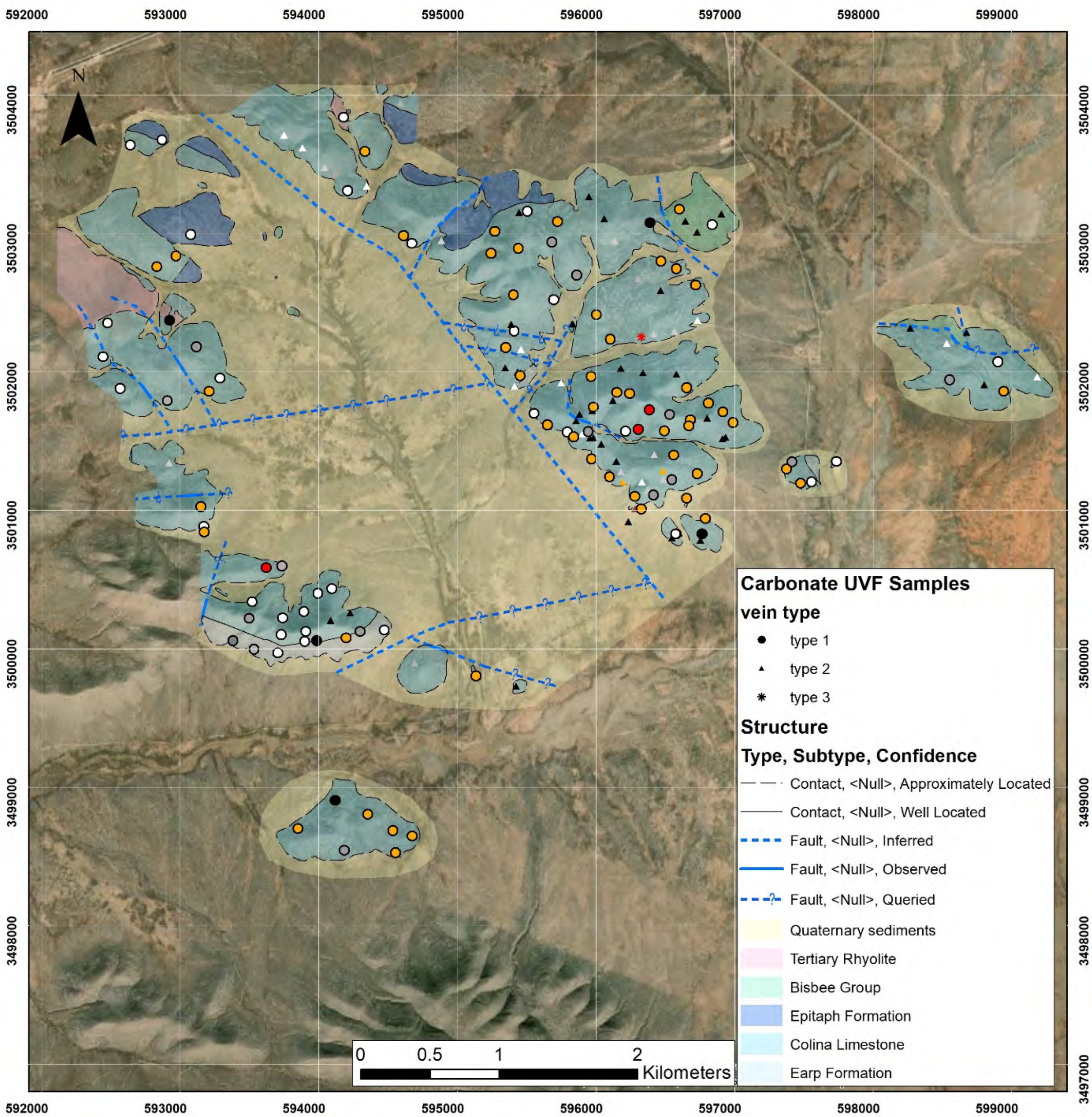

Figure 54: Lithology and structure with UVF sample locations. Samples are colored with primary UVF response. Any sample with an orange or red UVF response is colored accordingly

Background

Previous work on UV fluorescence in carbonates was conducted by Dr. Abraham Escalante as part of a PhD thesis describing distal alteration around the Antamina Cu-Zn skarn and Uchucchacua Ag – base metal vein deposit in Peru (Escalante, 2008). Sawed calcite vein samples were collected between <1m to 160m away from mineralization and examined under a shortwave handheld UV lamp. Orange and red fluorescence (ORF) has been described as related to Mn + other impurities (Ag, Ga, In, Pb, Zn, Tl) in calcite (Escalante, 2008). It was determined that strong ORF response correlated with both proximity to sulfide mineralization and timing of the calcite veins. Moderate to strong red ORF defined alteration halos 30m wide around sulfide mineralization with weaker ORF responses occurring distally. Additionally, syn-mineral veining typically shows strong orange to red ORF with yellow and white fluorescent halos around red fluorescent calcite. Post mineral veins typically do not fluoresce but occasionally show a weak orange ORF (Escalante, 2008).

Methods

A total of 183 carbonate vein chip samples were collected during the mapping. Where possible, veins were broken to gain a cross-sectional view of the vein. Often, weathering of the outcrop did not permit this. Small chips of vein material (often no more than a few chips due to time constraints) were collected and stored in plastic bags. Cloth bags were used on a few samples, but it was discovered later that these shed fibers that readily fluoresce under UV light. These samples were analyzed in the field using a pXRF and later examined under a handheld UV light. It was noticed that weathered surfaces would display a bright orange fluorescence that was not representative of fresh carbonate fluorescence. Because of this, only fresh surfaces were examined under UV light. Ultraviolet fluorescence (UVF) responses were recorded for all samples. In general, carbonate veins would display multiple colors under UV light. The two dominant colors were recorded, and the dominant UVF color was used for display purposes (Fig 54). Any samples with an orange or red UVF were symbolized accordingly.

Results

Samples taken from type 1 veins were the only samples that would consistently show a pale orange UVF response (Fig 55). Carbonate samples from type 2 veins were typically non-fluorescent. Three type 1 vein samples display a red UVF response (Fig. 54), indicative of higher Mn content, potentially closer to a magmatic source, or closer in time to a mineralizing event (Escalante, 2008).

Two samples were collected from a prospect pit in the Rhyolite Hills and a prospect pit north of the Zebra Hills. These pits were along sheeted type 3 quartz veins and structurally controlled hydrothermal breccias. The sample from the Rhyolite Hills was dark grey to non-fluorescent, while the sample north of the Zebra Hill showed a red UVF response. Given that there is only a single sample from this location, it is unknown how representative this response is for carbonate related to type 3 veins. Given the crosscutting relations between type 1 and type 3 veins, this may represent earlier carbonate veining that has been reopened by later quartz veining.

Generally, samples from the Zebra Hills area show a more common pale orange UVF response. Samples taken in the Red Rock Canyon area and western side of the property show less orange UVF responses and are typically white to grey or non-fluorescent.

Figure 55: Type 1 vein showing orange UVF. Top photo is under UV light bottom photo is under daylight.

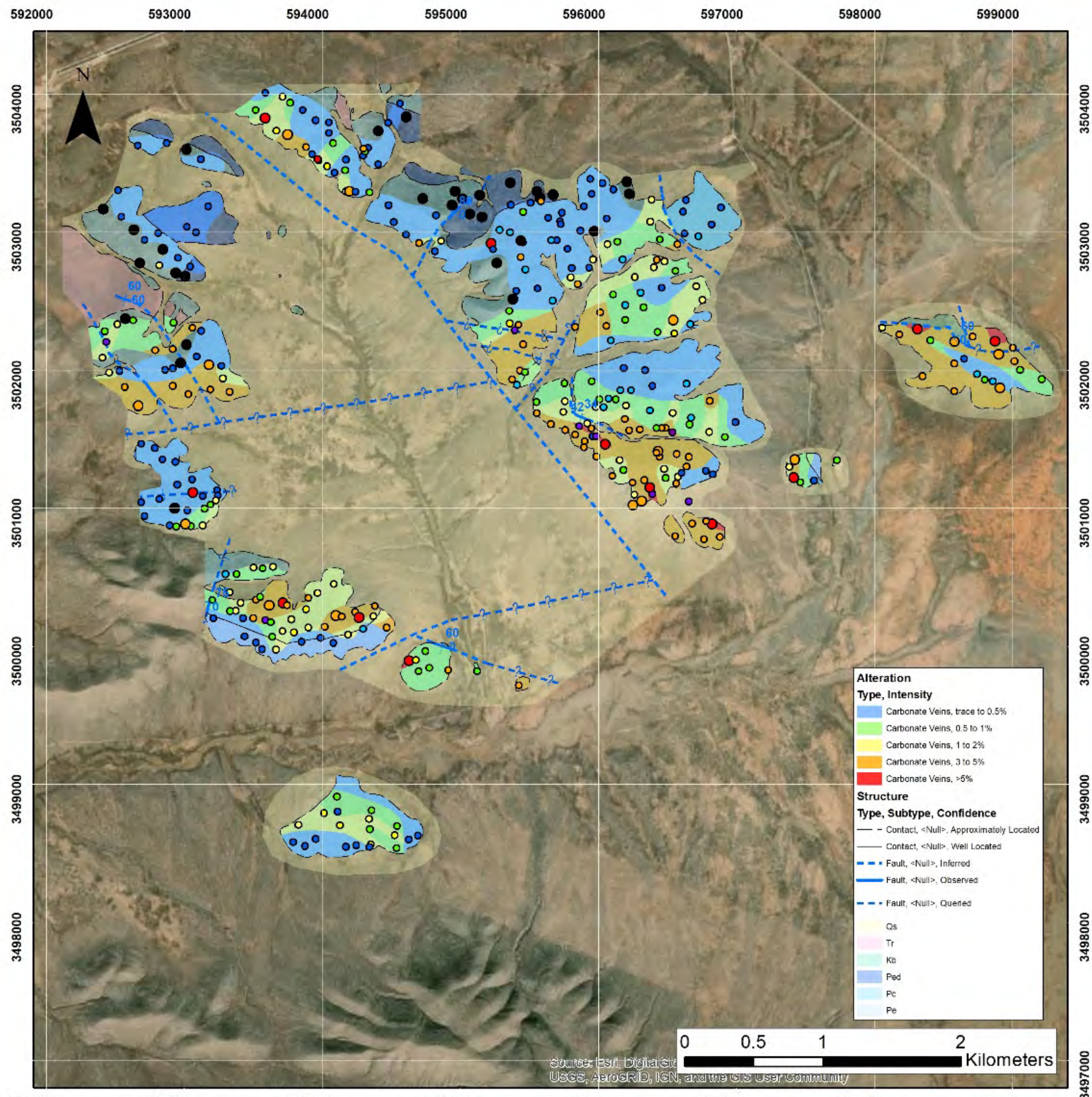

Figure 56: Lithology and structure with total carbonate vein intensity points and vein intensity contours. Vein intensity points and vein intensity contours use the same color scheme.

Type 1 and 2 Vein Intensity

During the course of mapping, vein orientations were recorded as per the dominant orientation in outcrop. In addition, a visual estimate was made of total carbonate vein intensity on a volume percent / m basis. Vein intensity can vary widely from outcrop to outcrop and because of this, estimates were made across several outcrops to capture total vein intensity over an (approximately 20 by 20 m to 10 by

10m) area. Notwithstanding the relatively low number of data points, preliminary vein intensity contours were drawn around these data points to create a heat map (Fig 56). Outlier datapoints were not used in order to capture broader trends in vein density although these datapoints are included in the heat map for completeness.

The Zebra Hills area is the largest zone of higher vein density. This can tentatively be correlated with veining along Earp Ridge as an east-northeast-west-southwest striking area of veining. The Quartz Hill area is the second largest area with consistent veining. A similar east-northeast-west-southwest area of veining may connect the hills just south of the Rhyolite Hills and the area north of the Zebra Hills.

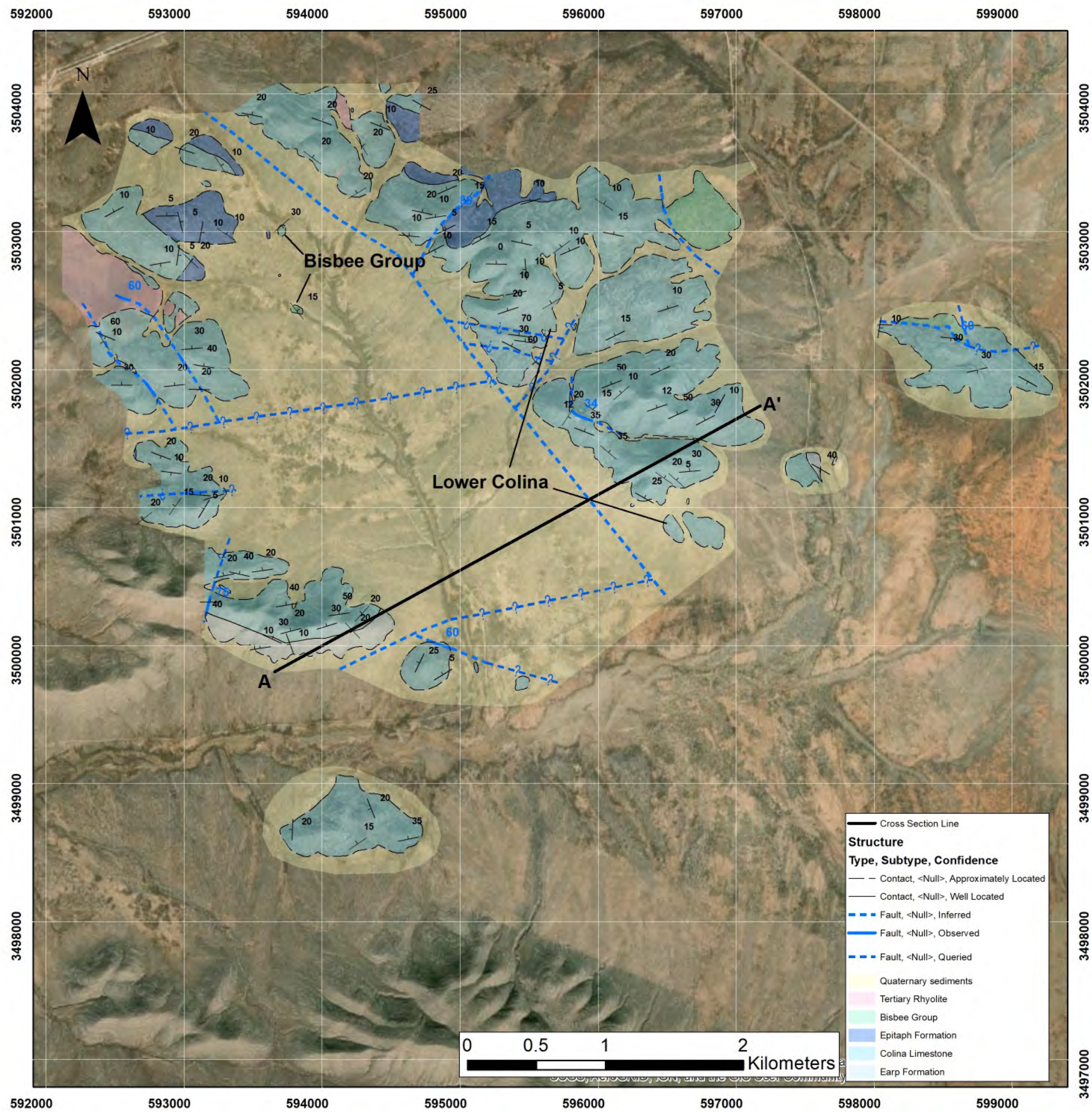

Figure 57: Lithology and structure with bedding orientations

Structure

Folding and Reverse Faulting

Much of southern and eastern Arizona has been subjected to compressional deformation related to the Late Cretaceous Laramide Orogeny (Keith and Wilt, 1986, Leveille and Stegen, 2012). This compressional event is bracketed between 75Ma and 65Ma. The Naco Group rocks exposed in the project area show a general moderate to gentle dip to the north. Broad gentle folding is present in the project area and smaller scale folding can be seen in the Zebra Hills area. Exact orientations of fold axes were not determined, however, bedding orientations in the Redrock Canyon area infer an approximate northwest to southeast strike. Here, gently dipping (15 to 20 degrees) beds of Colina Limestone surround outcrops of Epitaph Formation defining a small syncline (Fig 57). Given the similar orientation of bedding observed across the property, this structure is used as an analog for the style of compress across the property. No evidence of tight folding or the development of large reverse faults was observed in the project area. Only one example of a reverse fault could be identified in the field, where a fault exposed in a road cut near the Zebra Prospect contains slickensides in carbonate minerals indicative of reverse motion. This fault almost immediately disappears under cover and could not be found in nearby outcrops. The stratigraphy is relatively unchanged across this fault and little offset is inferred.

Possible Pre-mineral Normal Faulting

A series of generally east to west steeply dipping faults are present north of the Zebra Hills and south of the Rhyolite Hills. These faults are poorly exposed and can only be approximately located on surface by apparent offset of the stratigraphy across drainages and linear alignments of silicified breccias. Offset of marker beds (a thin red shaley bed and tan silty limestone beds) north of the Zebra Hills indicate minimal apparent offset (10 to 15m). A possible pre-mineral origin for these faults is indicated by intrusion of carbonate (possibly related to type 2 veining) along a fault in this orientation south of the Rhyolite Hills. A set of northeast to southwest steeply dipping normal faults is inferred to crosscut the east to west set of faults. The interaction of these fault was not observed in outcrop, however, north of the Zebra Hills east to west faults could not be traced across a northeast to southwest drainage. Apparent offset of the Colina/Earp contact across this drainage infers a fault in this orientation. Faulting along Earp Ridge and southeast of Redrock Canyon was observed in a similar orientation. As such, these faults are interpreted as representing a set of northeast to southwest striking normal faults.

Northwest-southeast Normal Faulting

A series of northwest to southeast striking faults is present in the Rhyolite Hills area, Jay's Hill area, and a prominent fault in this orientation is inferred beneath cover in the central basin based on apparent offset of the stratigraphy. Faulting of this generation is intruded by type 3 quartz veins and type 2 carbonate veins the Rhyolite Hills and by type 3 quartz veins near Jay's Hill. While this implies a pre-mineral origin for these faults there is a decrease in carbonate vein density across the fault placing Glance Conglomerate against Colina Limestone near Jay's Hill. This could indicate post-mineral reactivation along these faults. Based on the apparent offset of lower Bisbee Group placed against middle to upper Colina near Jay's Hill and the northern end of the central basin, these faults may have 200 to 300m of offset.

Possible System Tilt

No exposures of Miocene aged sediments were located within the project area. Miocene sediments are described as syn-Mid Tertiary extension and rotation sediments (Dickinson, 1991). Fanning dips in these sediments can be used to measure the extent of rotation from Mid Tertiary extension. Outcrops of Tertiary sediments and volcanics are mapped by Gilluly north of the project area. No age dates have been located for these volcanics. Gilluly describes the volcanics as probably Pliocene in age and overlying the Tertiary sediments. The exact age of these sediments is unknow, however, an angular unconformity is described (Gilluly, 1956) between the possibly Pliocene volcanics and Tertiary sediments. Given this record of rotation during or after deposition, the Tertiary sediments represent the best approximation of Mid-Tertiary rotation in the project area. Bedding in these sediments varies from 10 to 30 degrees typically to the east. Outcrops directly north of the project area show bedding dipping 10 degree to the east.

Stylolites and carbonate dissolution veining

Dissolution of Paleozoic carbonate rocks related to Laramide compression (Davis and Reynolds, pers comm, 2020) is present in southeast Arizona. The presence of carbonate dissolution veins can be determined by occurrences of dissolution features (stylolites) along bedding (Davis, 2008) or parallel to fold axes. Typically, stylolites and carbonate dissolution veins will preferentially form in silty limestone or bedding with slatey cleavage that has been strongly folded. Carbonate dissolution veins lack trace impurities as opposed to carbonate veins related to a hydrothermal system. As such, veins related to Laramide compression should show no ORF response under UV light (Alan Wilson, pers comm, 2020). No occurrences of bedding parallel stylolites were observed in the project area. The lack of tightly folded beds in the project area also indicates that significant development of stylolites in unlikely.

Conclusion

Field mapping conducted at 1:10,000 scale from July 14th through Aug 5th has identified three styles of veining and alteration. Type 1 veins have been correlated with secondary Cu mineralization as malachite + chrysocolla and local gossanous polymetallic replacements. Type 2 veins cut type 1 and show no clear relation to mineralization; however, type 2 veins are interpreted as a later event related to the same hydrothermal system as type 1 veins. The orange UVF response of type 1 veins, the association of type 1 veins with secondary Cu mineralization, and the anomalous S in pXRF reading indicate that these veins are not related to carbonate dissolution from Laramide compression. Type 1 and type 2 veins are thus interpreted as fluid escape structures representing the distal and possibly upper expression of a porphyry system at depth. The overall extent of type 1 and type 2 veining across the property could indicate significant skarn and CRD development at depth. The lack of a marble front at surface indicates that the center of the system likely lies lower in the Paleozoic stratigraphy. The overall decrease in vein density from the Zebra Hills and Earp Ridge to the northern half of the property creates a vector from north to south. The greater abundance of type 1 veins, in-situ Cu mineralization, and polymetallic replacements on the eastern half of the property creates a vector from west to east. This correlates with the Cu, Mo, and Au biogeochemical anomalies identified by Dr, Pim van Geffen, and the magnetic and ZTEM anomalies identified by Alan King's 3D model. Because of this, the center of the inferred porphyry system at Hay Mountain is interpreted to be southwest of the Zebra Hills under post-mineral cover. Type 1 and 2 veins cut the Late Jurassic to Early Cretaceous Glance Conglomerate indicating a post Jurassic possibly Laramide age of this system. While the age of this system could overlap with the age of Laramide compression in the Tombstone area, Laramide porphyry systems in Arizona are typically post folding. The lack of tight folding or evidence of extreme Mid-Tertiary rotation indicates that the system is relatively upright. Northwest to southeast normal faults on the property are inferred as having post-mineral movement. It is likely that the northwest to southeast fault is causing some offset of the system. Without a stronger control on the location of this fault and the center of the system it is unclear what control this could have on mineralization.

Type 3 veins, breccias, and alteration clearly crosscut type 1 and 2 veins. Type 1 and 2 veins are cut by the Tertiary rhyolite which is cut by type 3 veins. The main intrusive body of this rhyolite did not show any clear evidence of mineralization. A small dike of this rhyolite in the Redrock Canyon area shows moderate to strong clay alteration and is creating a narrow marble front in the surrounding limestone. It is unclear if this dike is related to type 3 veining and mineralization or of it is only a host. Type 3 veining and alteration show fluorite mineralization in the Zebra Hills area and Au anomalies in the Redrock Canyon area. The greatest abundance of type 3 veins is located north of the Zebra Hills and shows no clear correlation with the biogeochemical and geophysical anomalies in the basin. Because of this apparent disconnect between type 3 veining and the inferred porphyry center, cross cutting relations between type 3, and types 1 and 2 veins, and the occurrence of fluorite, type 3 veining and alteration is interpreted as a separate mineralizing event postdating the inferred porphyry copper system at Hay Mountain.

References

- Bournas, N., Izara C., Mokubung K., Data E., Legault J., 2020. 3D ZTEM & 3D MVI inversion results summary for Liberty Star Uranium & Metals Corp. Hay Mountain Project, Tombstone, Arizona. unpublished manuscript, Geotech Ltd.
- Blakey, R. C., Knepp, R., 1989. Pennsylvanian and Permian Geology of Arizona. In Jenney, J. P., and Reynolds, S. J., 1989, Geologic evolution of Arizona; Tucson, Arizona Geological Society Digest 17, p. 313-347.
- Davis, G. H., 2008. Quasi-flexural folding of pseudo-bedding. Geological Society of America.
- Dickinson, W. R., 1991. Tectonic setting of faulted Tertiary strata associated with the Catalina core complex in southern Arizona. Geological Society of America Special Paper 264.
- Drewes, H. D., 1981, Tectonics of Southeastern Arizona. Geological Survey Professional Paper 1144.
- DuHamel, J., 1989. Examination report Zebra Prospect. unpublished manuscript, Phelps Dodge.
- van Geffen, P., 2019. Biogeochemistry of the Hay Mountain Project, Tombstone District, Arizona for Liberty Star Minerals. unpublished manuscript, Vancouver Geochemistry.
- Escalante, A., 2008. Patterns of distal alteration zonation around Antamina Cu-Zn Skarn and Uchucchacua Ag-base metal vein deposits, Peru: Mineralogical, chemical, and isotopic evidence for fluid composition, and infiltration, and implications for mineral exploration. PhD Thesis. The University of British Columbia.
- Geotech Ltd., 2013. Summary interpretation report on a helicopter-borne Z-axis tipper electromagnetic (ZTEM) and aeromagnetic geophysical survey. unpublished manuscript, Geotech Ltd.
- Keith, S., Wilt, J., 1986. Laramide Orogeny in Arizona and adjacent regions, a strato-tectonic synthesis. Arizona Geological Society Digest Vol. XVI
- Gilluly, J., 1956. General geology of central Cochise County Arizona. Geological Survey Professional Paper 281.
- Gilluly, J., Cooper, J. R., Williams, J. S., 1954. Late Paleozoic Stratigraphy of Central Cochise Country Arizona. Geological Survey Professional Paper 266.
- King, A., 2019. Liberty Star geophysical review. unpublished manuscript, Geoscience North
- Leveille, R. A., Stegen, R. J., 2012, The Southwest North America porphyry copper Provence. Society of Economic Geologists, Inc. Special Publication 16. pp. 361-401
- Marvin, R.F., Cole, J.C., 1978, Radiometric Ages: Compilation A, U.S. Geological Survey: Isochron/West, No. 22, P.3-14.
- Rasmussen, J., 2011. Hay Mountain Exploration Report Tombstone District, Arizona. unpublished manuscript, SRK Consulting (U.S.) Inc.