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Correlating geochemical anomalism, surface geology, with potential styles of mineralization in North-East Queensland

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Table of Contents

Abstract

Intrusion Related Gold Systems (IRGS) are one of the most important styles of mineral deposit in North Queensland, Australia. IRGS are a recently defined style of mineralization with great economic potential. This project investigates a field area near Catalina, southwest of Georgetown, Queensland, Australia where a series of geochemical anomalies in soils have suggested the area may host a large mineral deposit. Lithologies observed in the Catalina prospect include granite, metasediments, porphyritic intrusions and breccias. The granitoid body is called the Gongora batholith, which is part of the Kennedy Igneous Association, a large collection of igneous bodies which are associated with a major mineralisation event and related to many North Queensland deposits.

The aim of the thesis is to use geochemical data and surface geology to evaluate whether the areas could host a major mineral deposit at depth, and through comparison of the metal zonation pattern in the soil and rock samples with existing deposits in the region, further constrain the mineral deposit type observed in Catalina. The results show that the geochemical zonation pattern at Catalina is characteristic of felsic and/or intermediate polymetallic IRGS deposit styles. Geochemical anomalies have proven efficient in identifying the potential mineralisation styles occurring in the area, however further exploration in the form of further mapping and drilling will be needed to confirm the style of mineral deposit occurring in the area.

Acknowledgement

I would like to start by thanking AngloGold Ashanti for giving me the opportunity to work on this project and enable me to complete my Bachelor thesis. Thank you to Ben Hames, I really appreciate the guidance and advice you provided! Thank you to Guy Boughton and Michael Pacey for your ongoing support throughout.

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To my family, we have done it! A special thank you to my wife, Natalie, for always being supportive and simply being here for me when I needed the most.

List of figures

List of Tables

Chapter 1: Introduction

1.1 North Queensland mineralisation

Queensland, Australia hosts a significant number of world class mineral deposits and potential exists for mineral discoveries of significance in a range of deposit styles (Beams, 1995; Witnhall & Cranfield, 2013). Mineral deposits occur in the oldest Paleoproterozoic rocks to most recent Holocene sediments. Gold mineralisation styles in North Queensland are related to slate belt, plutonic, volcanogenic, epithermal, and/or intrusion-related gold systems (Morison et al., 2019). Intrusion related gold systems (IRGS) are a relatively recently defined deposit type which is of great economic significance with gold being the primary commodity. The most well-known and studied deposits occur in Canada and Australia, and it is a prime mineralisation target in North Queensland, Australia (Mckay & Wake, 2015).

1.2 Geochemical anomalies as an exploration method

Geochemical survey methods are considered an efficient tool and are commonly used in the mineral exploration industry. Surface geochemistry studies such as soil and rock sampling on a regional or local scale provides a low cost and efficient way to screen outcropping bedrock. Furthermore, it is a crucial first step in understanding the distribution of chemical elements in different geological settings (Beams, 1995; Morrison & Beams, 1995, Ovchinnikov & Grigoryan, 1978). Over the past 50 years, exploration geochemistry has played a key role in the discovery of many mineral deposits in North Queensland (Beams, 1995) and Western Australia (Mazzucchelli, 1996).

Soil sampling is considered an effective approach to identify geochemical anomalies. Its concept is based on the chemical composition of the material sampled being different when in proximity of a mineral deposit as supposed to a sample where no mineral deposit occurs (Butt & Zeeger, 1992). The observed mineralisation can then be targeted and subjected to further research. This method has been linked to several discoveries worldwide including countries of relatively different climatic conditions such as Canada, Finland, Chili, Australia (Beams, 1995; Dempster, 2016; Ovchinnikov, 1978). In North Queensland, surface sampling methods including soil sampling, rock chip sampling were effective in the Kidston and Mt Leyshon deposits (outcropping deposits) as well as the sub cropping deposit Mt Wright (Beams, 1995).

Dempster (2016) suggests that studies of soil geochemistry can independently demonstrate and target suitable areas of potential metallic mineralisation. In Canada and Finland, where glaciated terranes are common, till is the dominant sediment type. Despite material being transported away from their source, correlation of ice flow direction, bedrock lithology and geochemical surveys has proven efficient in locating areas of mineralisation (Dempster, 2016; Ovchinnikov, 1978). In the Yilgarn Block, Australia, significant gold deposits have been found where thick sediment cover prevails, with little or no outcrop occurrences over large areas. In such environments Mazzucchelli (1996) suggested anomalies detected through geochemical surveys can reflect bedrock mineralisation at depth but this depends on the regolith characteristics (regolith types can affect the effectiveness of soil geochemistry). These geochemical anomalies can be a result of various dispersion processes in the Yilgarn region; normal clastic dispersion processes, upward movement of gold or other metal-bearing groundwater, uptake of anomalous gold from depth and deposition in surface soils through the vegetation cycle, and/or bioturbation by burrowers

(Mazzucchelli, 1996). In North Queensland, geochemical exploration is commonly used. However, due to a lack of data, the regolith cover and its units is poorly understood (Beams, 1995).

Regolith is a direct product of weathering (chemical, physical and biological), and consists of the material (loose or reconsolidated) overlying bedrock (Hocking et.al, 2001; Nasa, 1997). Hocking et al. (2001) differentiate three major classes to describe regolith types in an idealize landscape profile: residual, erosional and depositional which is defined as follow:

- Residual: Remnant, reworked or degraded materials derived from weathered land surface.
- Erosional: Areas subjected to erosion where removal of material occurs. Typically, of thin soil, with outcropping bedrock.
- Depositional: Relative to the residual or/and erosional source, material that is increasingly reworked and redistributed.

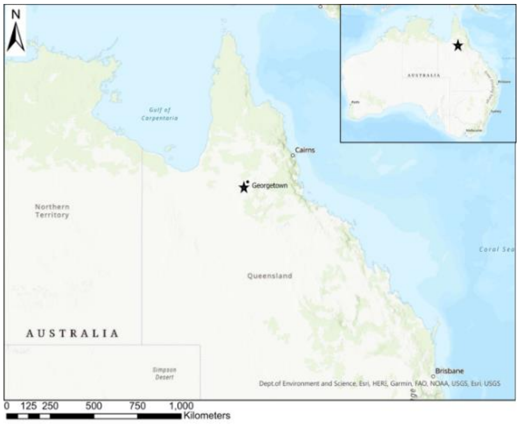
Main differences are associated in the geochemical response of such classes. Butt & Zeegers (1992) differentiate between transported and residual material. The former, associated to depositional regolith, need to be treated with caution as the geochemical response may well be inaccurate or obliterated whereas this has not been proven to be the case for residual or erosional material. Erosional regolith are best tested sampling remnant outcrops, a method referred to as rock sampling. Wilson & Taylor (2012) propose that soils are strongly influenced by the underlying lithology and its mineral content in such climatic zones.

In summary, geochemical anomalies can be detected through various geochemical survey methods, in various environments. Generally, only the compilation of data allows mineral deposit discoveries (Dempster, 2016; Mazzucchelli, 1996; Ovchinnikov, 1978). Butt & Zeeger (1992) also highlights: “a geochemical anomaly, whether positive or negative – is not an absolute measure, in many cases it varies as a function of the analytical technique used”; indicating that correlation and proven accuracy of data is of necessity to confirm a potential geochemical anomaly. Geochemical survey methods have been proven successful globally and have certainly played an important part in the discoveries of the North Queensland’s deposits.

1.3 Study Area

1.3.1 Location

The prospect area, Catalina, is located 65Km southwest of Georgetown, and 650km southwest of Cairns, Queensland, Australia (refer to Figure 1). The exploration tenement owned by AngloGold Ashanti in the Georgetown area, include several cattle stations. Catalina is located on Heliman Station.



Dept.of Environment and Science, Esri, HERE, Garmin, FAO, NOAA, USGS, Esri, USGS

Figure 1. Map of Queensland, Australia. The study area is indicated by a star on the map, near Georgetown.

1.3.2 Local geology

The geology of the area is dominated by Paleoproterozoic fine-medium grained metasedimentary rocks that have been intruded by Permian-Carboniferous aged granitoid intrusions (Budd, 2001; Rossiter, 1975). The Gongora intrusion is an early-Permian granodiorite with coarse grained biotite and some K-feldspar phenocrysts. It is represented on the map, in Figure 2, as Permo-Carb felsic intrusive. Paleoproterozoic metasediments surrounds the Gongora batholith, late-Tertiary sediments and quaternary sediments mainly consist of flood-plain alluvium including clay, silt, and gravels. The Gongora intrusion is covered by mid to late Jurassic sediments, mainly sandstone / arenite (refer to Figure 2).

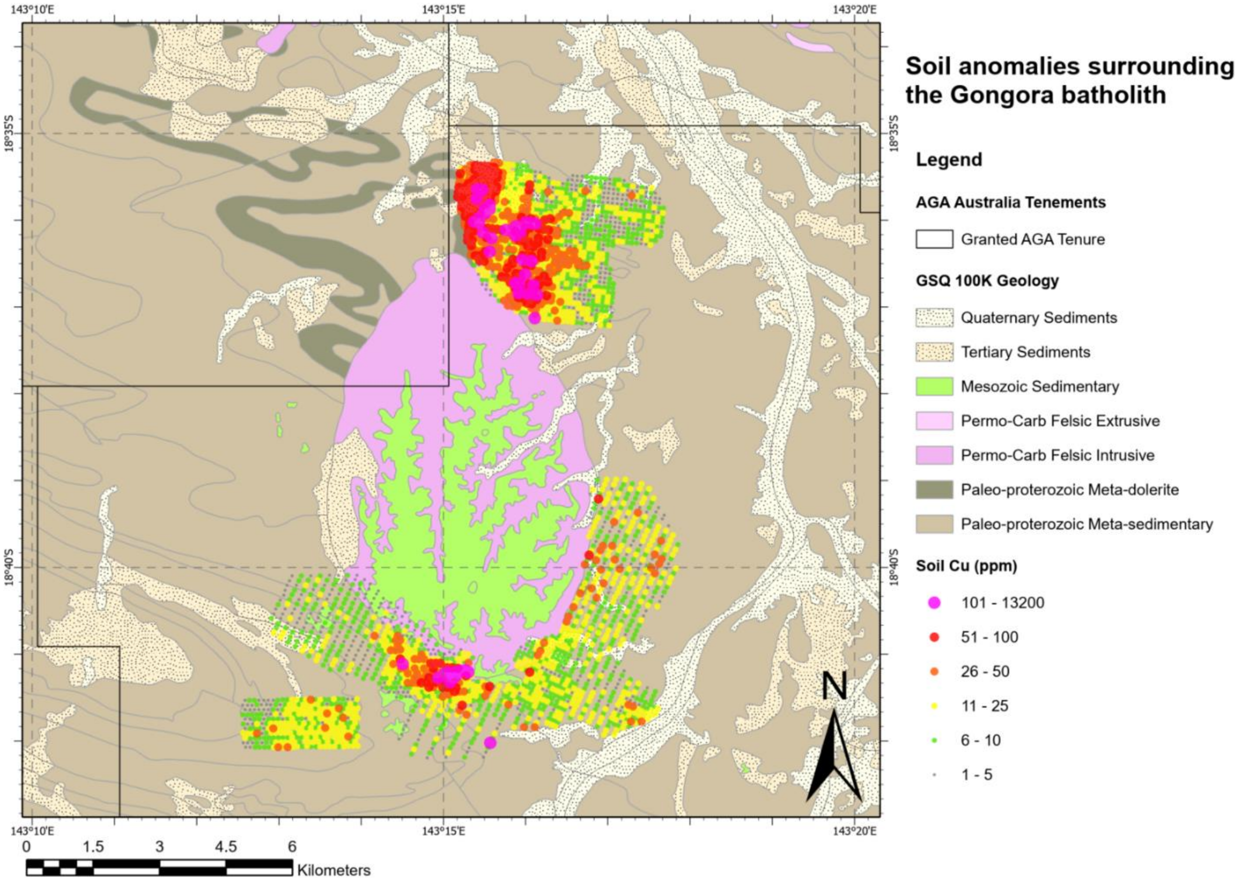


Figure 2. Study Area, Catalina, directly South of the Gongora (Permo-Carb felsic intrusive) batholith. Main lithologies highlights Paleo-Proterozoic metasedimentary rocks intruded by Permo-Carb granitoids. Soil anomaly highlights Copper (Cu) anomaly in ppm. *Geology data grouped and modified from Geoscience Australia portal.*

1.3.4 Previous work completed in and adjacent of the study area

AngloGold Ashanti has thoroughly reviewed historical working within the tenement and followed on with several exploration programs including reconnaissance field mapping, airborne geophysical surveys, and satellite multispectral interpretation. Soil sampling activities were carried on at a later stage around the Gongora batholith and several anomalies were detected (Figure 2, 11 & 12). The Mt Clark prospect, located North of the latter in Figure 2, was explored by CRA prior to AngloGold Ashanti through a regional stream sampling and cyanide leach program. CRA also conducted mapping and rock sampling activities: 307 samples of outcropping breccias and quartz veins yielded 21 samples above 1 ppm Au with a peak of 18.7ppm Au. Since, AngloGold Ashanti, pursued a drilling program of nine diamond-hole at several locations which were deemed unsuitable for further exploration activities. In 2021, soil sampling activities conducted by AngloGold Ashanti within the study area, Catalina, reveals several soil anomalies. The Catalina prospect offers a define copper anomaly with soil samples varying from 2.77ppm to 900ppm and a defined core samples ranging from 51ppm to 900ppm (refer to Figure 11&12). The gold (Au) anomaly observed in this area includes samples ranging from <1 ppm up to 600ppm (refer to Figure 12).

1.4 Aims

The aim of this thesis is to investigate the soil and rock geochemical anomaly in the Catalina study area and use the anomaly to attempt to constrain the style of mineralisation that occurs in the area. A key question is whether the anomaly shows specific features such as zoning or metal associations that can help define the style of mineralisation occurring at depth and be correlated with existing mineral deposits of the area, especially IRGS in North Queensland. The methods used to carry out the project include geological mapping in the area, soil sampling, rock sampling, interpreting geochemical data from analyses of collected samples. Tools to analyze data include ArcGIS to generate maps of the geology and geochemical anomalies, and ioGAS software to define element correlation and represent anomalies spatially.

Goals:

1) The project aims to characterize the style of mineralisation occurring at depth in the Georgetown area.
2) The project will evaluate the ability of soil geochemical data and its accuracy for the characterization of mineralisation occurring at depth. The project will fit the soil geochemical anomaly into the geology of the local area to help identify the controls on mineralisation.
3) Specific research questions that aim to be answered throughout this project include:

- Does the geochemical anomaly in the Catalina prospect show a specific style of mineralisation?
- Is a zoning pattern observed in the study area? If so, can this zonation further constrain the style of mineralisation when compared to the known IRGS deposits of North Queensland?
- Have factors such as assay accuracy; regolith cover been considered to evaluate the observed soil anomaly?
- Doe soil and rock sample geochemical anomalies correlate? If so, is a certain rock type controlling this anomaly?

Chapter 2. Literature review

2.1 IRGS characteristics

Intrusion related gold systems refer to incoherent group of deposits with wide-ranging characteristics, granitoid association and tectonic setting. Morrison & Beams (2015) put forward a description for IRGS as being a "mineralized magmatic-hydrothermal system where gold is the dominant commodity and where a genetic link can be established to an intrusive complex".
Characteristics of IRGS include (Baker & Lang, 2001; Hart, 2005):

- Metaluminous to sub-alkalic intrusions of intermediate or felsic compositions that lie near the boundary between ilmenite and magnetite series.
- Carbonic hydrothermal fluids.
- A metal assemblage that variably combines gold with elevated Bi, W, As, Mo, Te and/or Sb and low concentrations of base metals.
- A low sulphide mineral content and reduced ore mineral assemblage typically consisting of arsenopyrite, pyrrhotite and pyrite and lack of hematite or magnetite.
- Comparatively restricted zone of weak hydrothermal alteration.
- Tectonic setting well inboard of inferred or recognised convergent plate boundaries.
- A location in magmatic provinces best or formerly known for tungsten and/or tin deposits.

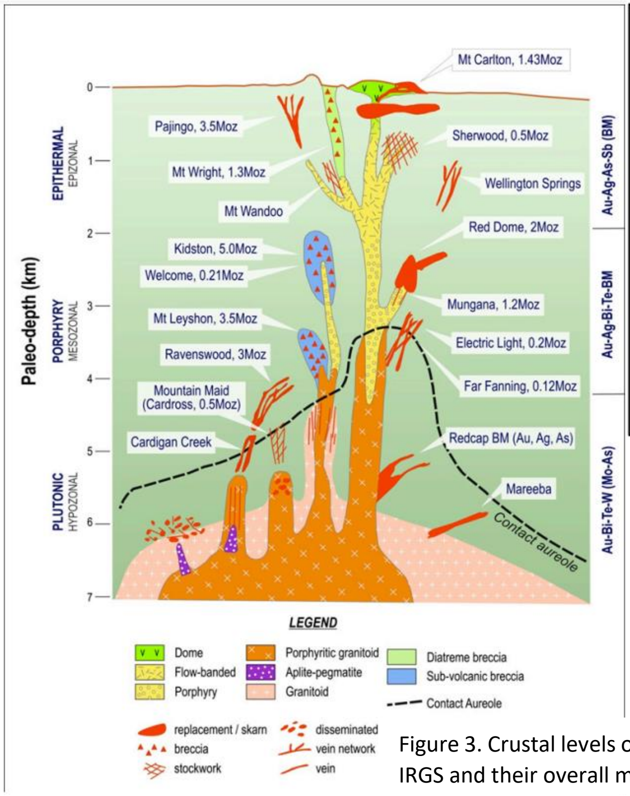


Figure 3. Crustal levels of North Queensland's IRGS and their overall metal association.

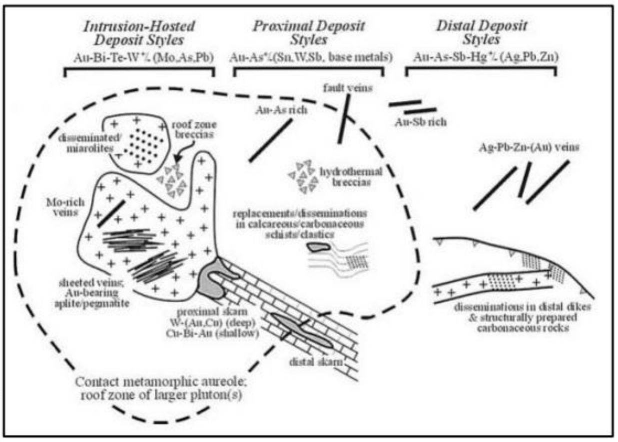


Figure 4. Intrusion related gold systems (IRGS) model. IRGS can be subdivided between Intrusion-hosted, proximal and distal deposit styles. Each deposit styles have a preferred element suite associated to its model.

Source Figure 3 and 4: Morrison & Beams (2016)

Other characteristics of IRGS include their varied mineralisation style, with ore occurring both proximal and distal to the mineralizing intrusion. This is illustrated in figure 3 & 4 (source: Morrison & Beams (2016)) and include sheeted veins and stockworks, breccias, disseminated deposits, skarns, and distal base metal bearing fissure veins (Mckay & Wake, 2015). IRGS are commonly zoned with zoning occurring laterally and vertically as seen in figure 3.

Deeper systems have a high concentration of Mo and W, whereas shallower systems are dominated by Au-Bi. These shallower systems are commonly referred to as breccias and porphyry breccias, and often display a sericite-carbonate alteration (McKay & Wake, 2015; Morrison & Beams, 2016).
The following metal association, as seen in figure 3, specific to its deposit type is observed:

- Plutonic (deep): Au-Bi-Te-W (Mo-As); Bi-Te (absence of BM) association is a common signature of this deposit type.
- Porphyry (deep): Au-Ag-Bi-Te-BM (Base Metals), base metals are an indicator of porphyry levels.
- Epithermal (shallow depth): Au-Ag-As-Sb, especially As-Sb that are typical of epithermal systems.

Commonly, gold mineralisation is associated with carbonate, potassic, sodic and/or later stage sericitic alteration (McKay & Wake, 2015; Morrison & Beams, 2016).

2.2 IRGS deposits of North Queensland

2.2.1 North Queensland

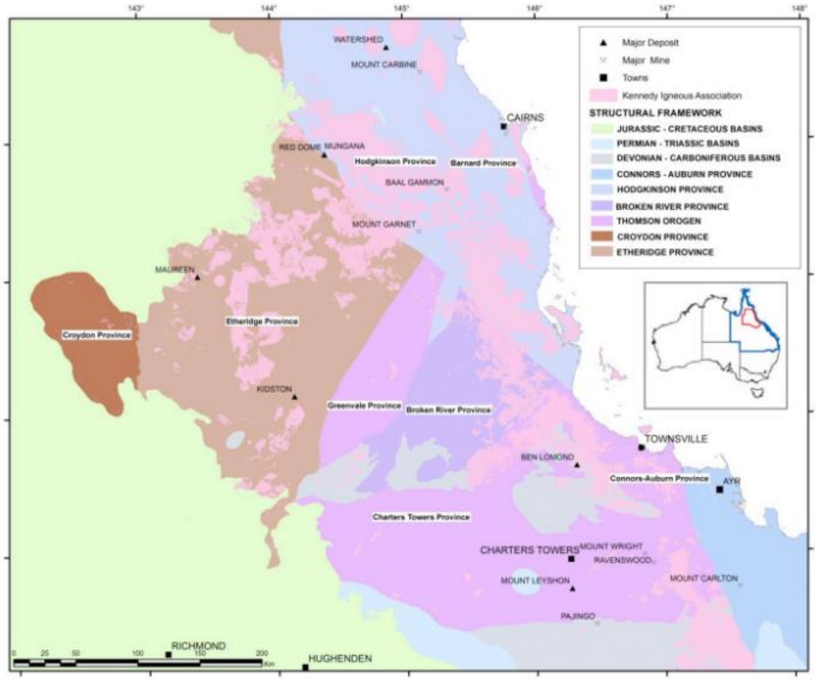


Figure 5. Tectonic provinces of northeast Queensland after Withnall & others, 2013. Source: Dhnaram & Lisitsin (2015)

North Queensland hosts more than 130 IRGS in the region, including the Kidston, Mt Leyhson, Mt Wright, and Ravenswood deposits; all thought to be related to the Kennedy Igneous Association as seen in Figure 5 (Beams, 1995; Dhnaram, 2015; Morrison, 2017; Morrison & Beams, 2015; Mustard et al. 2004). The Kennedy Igneous Association (KIA) is a grouping of igneous rocks mostly of felsic composition dominated by I-type granites and dated to 345Ma to 280Ma (Morrison et al., 2019; Witnhall & Cranfield, 2013). Witnhall & Cranfield (2013) associate the KIA with many mineral deposit styles occurring throughout North Queensland. The 5 Moz Kidston deposit (Au) and the 3.5 Moz Leyhson deposit (Au) are referred to as a porphyry related breccia gold deposits or sub-volcanic breccia hosted deposit and are both examples of such deposit style (Beams, 1995; Morison, 2007; Morison & Beams, 2015).

2.2.2 Georgetown Inlier

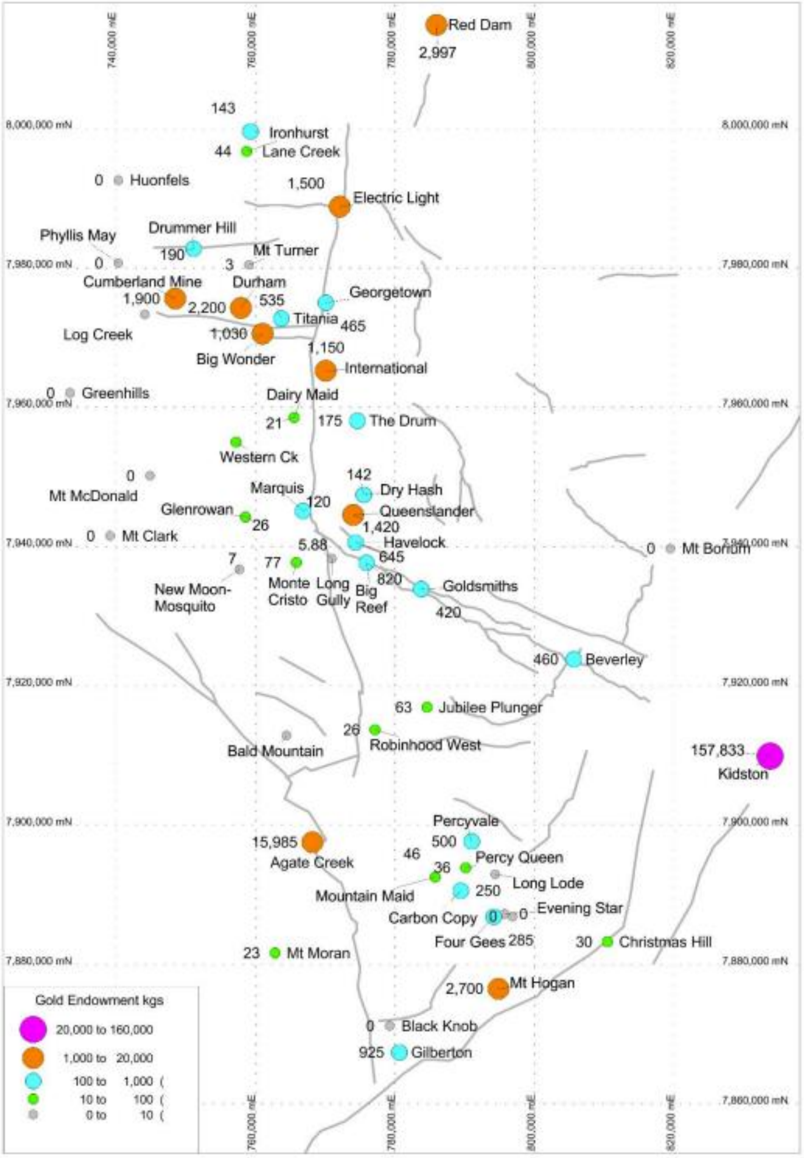


Figure 6. Map of Georgetown and Forsayth region showing location of historical gold mines and gold endowments.

Extensive mineralisation styles dominate the Georgetown Inlier, and thus the Georgetown region (Morison & Beams, 1995). The Georgetown region is located within the Etheridge province (as seen in Figure 6), itself part of the North Australian Craton. The Georgetown Inlier (25 000Km^2 to 50 000Km^2) is dominated by metamorphosed sedimentary and volcanic rocks of Paleo to Mesoproterozoic age that have been intruded by Proterozoic to late Paleozoic granitoids (Budd, 2001; Morrison et al., 2019; Withnall & Cranfield, 2013). The Etheridge province is considered a dislocated fragment of Paleoproterozoic crust which consists of passive margin sediments metamorphosed up to amphibolite and granulite facies. Intrusive and extrusive magmatism has occurred throughout the terrane from the Paleoproterozoic to Permian period (Withnall & Cranfield, 2013). The province has been overprinted by the KIA, which in turn is associated to the mineralisation observed around the region (Morison, 2023). The region has a long multi-commodity mining history, with over a thousand mines, most of which are related to gold deposits, including the Kidston deposit which produced over 144 tons, as seen in Figure 6 (Beams, 1995; Morison et al., 2019, Witnhall & Cranfield, 2013). As emphasized by Morison et al. (2019), the Georgetown region suffers from a lack of modern and thorough exploration, that is despite its numerous existing deposits.

2.3 Zoning in IRGS

2.3.1 Kidston deposit

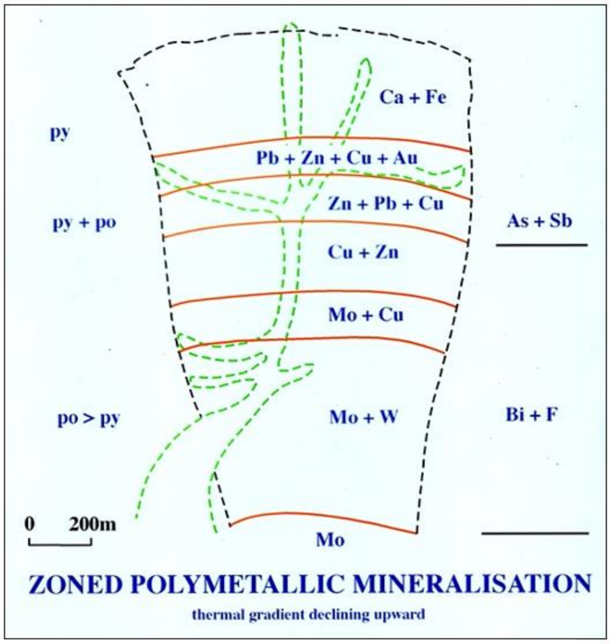


Figure 7. Kidston gold deposit. Metal zonation in the breccia pipe, from W-Mo-Bi at the base through to Au closer to surface. Source: Morison & Beams (2016)

The Kidston deposit is located within the Georgetown inlier (refer to Figure 5, 6 & 7). This breccia system is associated with rhyolite dikes of Permo-Carboniferous age. The felsic dykes have been subjected to phyllic alteration (quartz-sericite-pyrite) and are characterized by being crowded or sparse porphyritic with main phenocrysts being quartz, plagioclase, and alkali feldspar (Morison, 2007; Morison & Beams, 2015; Morison et.al, 2019). The gold mineralisation occurs within the breccia pipe and metal zoning reveals a typical polymetallic porphyry system with a Molybdenum (Mo) core. The surface, however, is rather barren of any significant elements as illustrated in Figure 7 (Morison, 2007; Morison & Beams, 2015; Morison et.al, 2019).

2.3.2 Mt Leyshon deposit

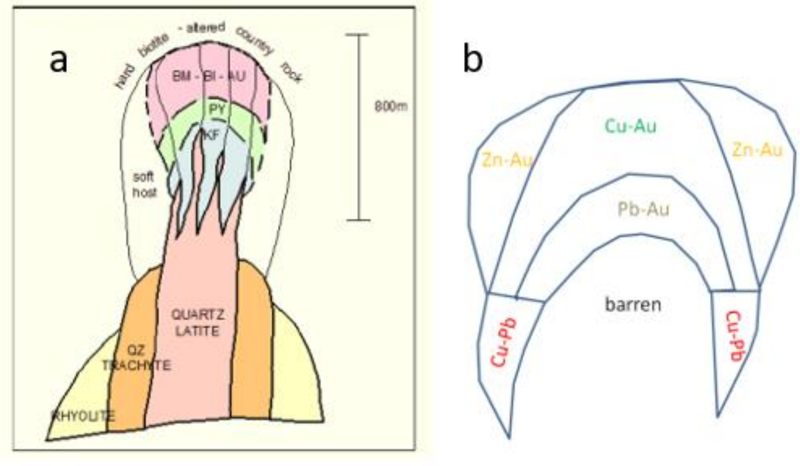


Figure 8. Zoning models Mt Leyshon (a & b). Source: Morison & Beams (2016)

Mount Leyshon also is a hydrothermal breccia complex, associated with rhyodacite intrusive. In Figure 8, the illustration “a” represents the overall zoning pattern. The illustration “b” represents the zoning of the BM-Bi-Au envelope presented in “a”. The barren core is related to the later dykes and thus base-metal poor. The zoning consists of peripheral Zn and Cu-Pb in the inner sections of the system. Gold is associated with Bi and closely follows Cu, Pb and Ag although seem to favor the overlap with Zn zone. Mt Leyshon is considered an intermediate IRGS, in this instance, the occurrence of Mo might be related to a pre-breccia phase event (Morison, 2007; Morison & Beams, 2015; Morison et.al, 2019).

2.3.3 Mt Wright deposit

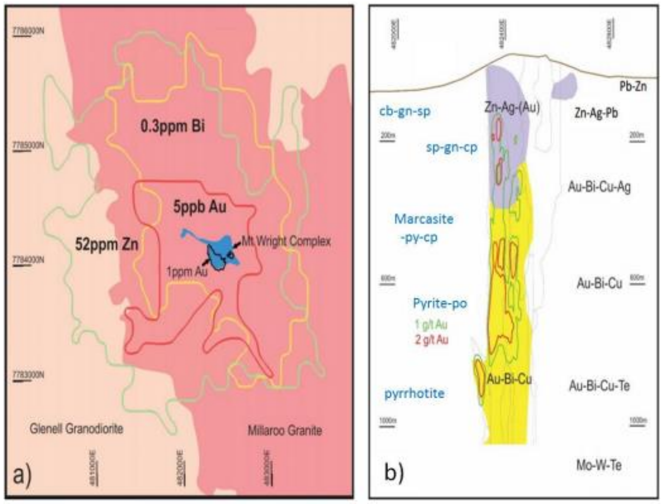


Figure 9. Zoning models Mt Wright.a). Soils. b) Cross section. Source: Morison & Beams (2016)

Mount Wright deposit is hosted within a breccia pipe and is characterized by a series of overprinting, including rhyolite intrusions and hydrothermal breccias, which mineralisation is related to. Strong sericite alteration is also observed (Lisowiec et al., 2007). Morison & Beams (2016) describe this IRGS as felsic due to its overall enrichment suite: Au, Ag, Cu, Bi, Zn, Pb, Te (Mo/W), especially noticeable for Bi. Figure 9a) illustrates zoning based on surface geochemistry in Mt Wright: 3Km diameter anomaly with Zn, Bi and weak Au anomaly (< 5 ppb). Figure 9b) illustrates the vertically well zoned system with best Au ore, 500 to 800meters below surface (Morison, 2017).

2.3.4 Porphyry related hydrothermal systems

Morison & Beams (2015) subdivide porphyry level IRGS and suggest differentiating deposit types using multi-metal data. The discovered and studied deposits, of relatively similar mineralisation age, allowed an IRGS zoning pattern to be defined. Morison & Beams (2015) differentiate the following IRGS:

- Felsic IRGS, such as Mt Wright where the predominant elements are Au+/-Ag, Cu+Pb+Zn+As+/-Sb, Bi. Typically, the core of the system is Mo-W-Bi.
- Intermediate IRGS, such as Mt Leyshon where the predominant elements are Au+/-Ag, Cu+Pb+Zn+As+/-Sb, Bi, Te. Typically, the core of the system is Cu-Mo.
- Intermediate mafic IRGS, such as Mt Remarkable where the predominant elements are Au+/-Ag, Cu+Pb+Zn+As+/-Sb, Te, Bi. Typically, the core of the system is Cu-Mo or Cu-Au.
- Mafic IRGS, such as Ravenswood where the predominant elements are Au+/-Ag, As+/-Sb, Bi, Te+/-Cu+Pb+Zn+As+/-Sb. Typically, the core of the system is Cu-Au.

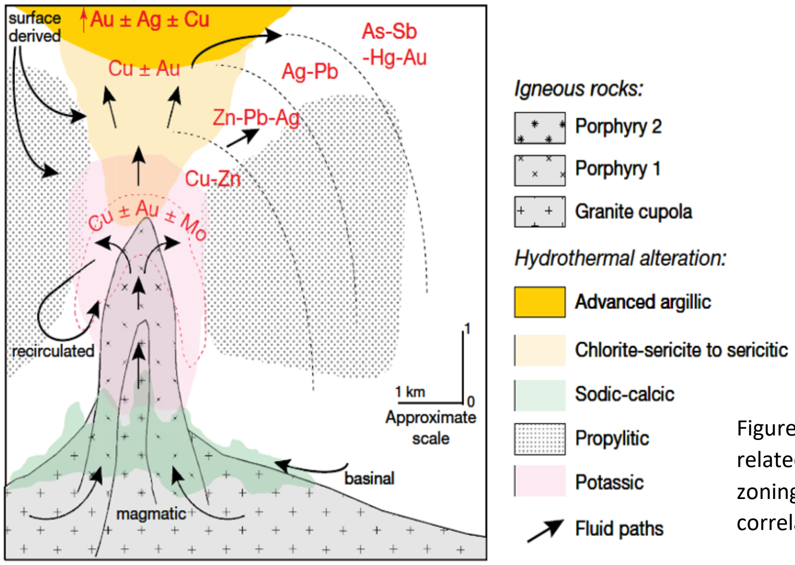
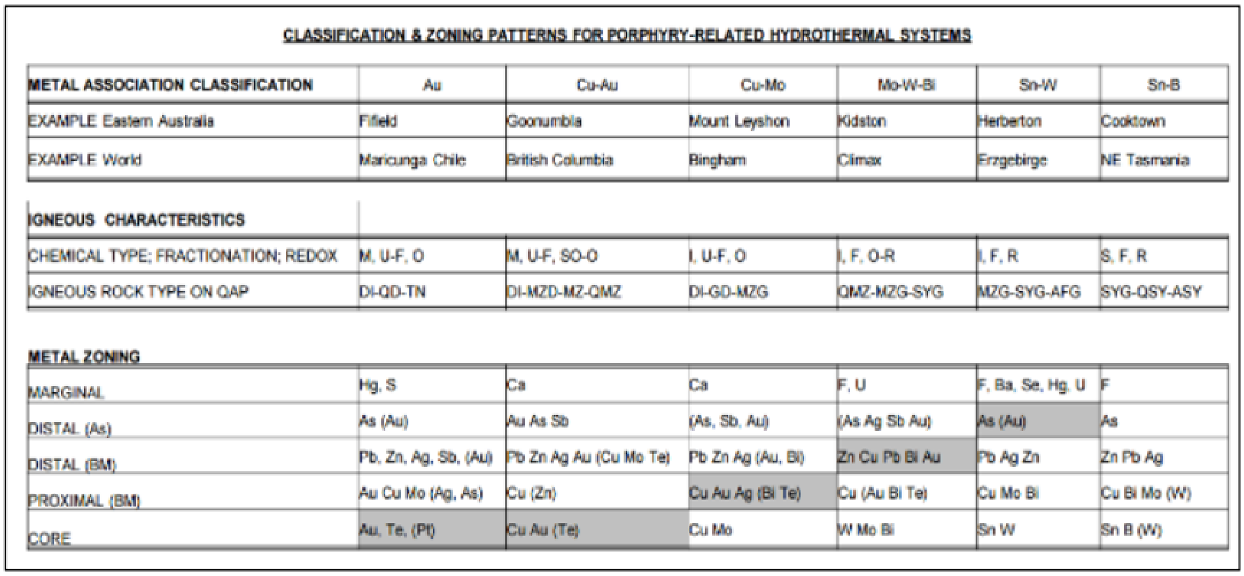


Figure 10. Model of porphyritic Intrusion related systems in North Queensland. Metal zoning observed in these systems usually correlates with local alteration.

IRGS of porphyry styles, in North Queensland, are polymetallic and all expose a compatible zoning pattern where gold is usually concentrated in specific zones. Several alteration zones are detected within these systems and are also occurring in distinct zones as seen in Figure 10. Table 1 provides a series of global and local (Queensland) examples of such zoning in these systems.



CLASSIFICATION & ZONING PATTERNS FOR PORPHYRY-RELATED HYDROTHERMAL SYSTEMS

METAL ASSOCIATION CLASSIFICATION	Au	Cu-Au	Cu-Mo	Mo-W-Bi	Sn-W	Sn-B
EXAMPLE Eastern Australia	Fifield	Goonumbla	Mount Leyshon	Kidston	Herberton	Cooktown
EXAMPLE World	Maricunga Chile	British Columbia	Bingham	Climax	Erzgebirge	NE Tasmania
IGNEOUS CHARACTERISTICS						
CHEMICAL TYPE; FRACTIONATION; REDOX	M, U-F, O	M, U-F, SO-O	I, U-F, O	I, F, O-R	I, F, R	S, F, R
IGNEOUS ROCK TYPE ON QAP	DI-QD-TN	DI-MZD-MZ-QMZ	DI-GD-MZG	QMZ-MZG-SYG	MZG-SYG-AFG	SYG-QSY-ASY
METAL ZONING						
MARGINAL	Hg, S	Ca	Ca	F, U	F, Ba, Se, Hg, U	F
DISTAL (As)	As (Au)	Au As Sb	(As, Sb, Au)	(As Ag Sb Au)	As (Au)	As
DISTAL (BM)	Pb, Zn, Ag, Sb, (Au)	Pb Zn Ag Au (Cu Mo Te)	Pb Zn Ag (Au, Bi)	Zn Cu Pb Bi Au	Pb Ag Zn	Zn Pb Ag
PROXIMAL (BM)	Au Cu Mo (Ag, As)	Cu (Zn)	Cu Au Ag (Bi Te)	Cu (Au Bi Te)	Cu Mo Bi	Cu Bi Mo (W)
CORE	Au, Te, (Pt)	Cu Au (Te)	Cu Mo	W Mo Bi	Sn W	Sn B (W)

Table 1. Zoning models of IRGS.

In Table 1, Morison (2023) put forward a metal zoning pattern identified in a series of known deposits. Global and local (Queensland) examples demonstrate a zonation pattern can be interpreted at core level, proximal and distal (using base metal concentrations), distal (using As concentration) and marginal level (using Hg, S, Ca, F, U, Ba and Se).

Chapter 3: Methodology

3.1 Soil Sampling

The soil sampling program completed by AngloGold Ashanti was conducted in 2021. The soil grid, 100m x 100m spacing, was determined by the Senior Geologist in charge. Sampling was conducted on foot by two trained staff members. Sampling involved the following steps (in order):

- Dig using a mattock to the B horizon (typically 10-20cm deep depending on soil).
- Sieve soil through a 1.6-2.0mm mesh using gloves.
- Collect and bag about 300g of soil (Geochem bags must be numbered for correlation).
- Fill the hole to avoid disturbance for wildlife or erosion.
- Navigate to the next sample location using GPS device.
- Repeat the task and drop off collected samples at a pre-arranged location for pick up.

The collected samples were checked and weighted daily to avoid any missed, or insufficient amount of soil collected for assay. Final check was conducted prior to dispatch of samples to the laboratory. The data specific to the study area involves 314 soil samples collected and assayed including 13 duplicate samples and 13 “standards”. Duplicate samples are two samples taken at the same location; its purpose is to check accuracy of the assay method (including laboratory results, sampler method). Standards are samples of known element composition for QA/QC (soil sampling quality assurance) purposes.

3.2 Rock sampling

Rock sampling activities were carried out in the Catalina prospect, samples taken aimed to be fresh (minimize weathered surface), and weighted > 500g. All samples were recorded through the Survey123 application including field notes such as location, lithology type, mineral occurrences, structural measurements where applicable and general description. The sampling of outcrops is design to accumulate data and especially assays to support/test the soil anomalies detected.

3.3 Field Mapping

Field mapping was conducted to help correlate the copper anomaly detected with the local geology of the study area. Using a similar set up to the 2021-soil sampling campaign, the field mapping was run from a fly (temporary) fully sustainable camp using solar energy. The exercise took place in August 2022, in the dry season, with temperatures averaging 35 to 40 degrees Celsius, while air humidity was averaging 80%. This survey included mapping the different lithologies observed in the area, taking field notes and photos (observations) as well as rock samples. The material available to accomplish the task included:

- Hand lens for identification of grain size, matrix composition and mineral occurrences.
- Compass for structural measurements and navigation.
- Scriber pen to assess hardness and magneticity.
- Estwing rock pick for samples and/or chipping rocks for observation purposes.
- Numbered calico bags for collection of samples.

- Phone and/or GPS device for navigation
- Phone and tablet (iPad) to record samples, observations and have access to base maps including regional geology (refer to Figure 14), and “no-go zones” such as heritage areas.
- All safety equipment including snake bite kit or personal first aid kit, InReach satellite device, two-way radio, food, water, and PPE (Personal Protective Equipment) was also provided by AngloGold Ashanti and always carried due to the remote location of the work.

The ArcGIS suite was the preferred choice to conduct the mapping using iPad devices. Two programs/applications were preferred, Field Maps and Survey123. The former was used to map the different lithologies observed, while the latter recorded field notes (observations) and samples taken. Observations have proven useful in the creation of detailed maps of the study area. Lithologies were recorded walking around or on the outcrops using the Field Maps application (depending on lithology types: veins, dykes, basement rock etc..). Size, measurements, notes, and samples were documented in the Survey123 application. Field Maps allows to capture and share data (with GPS location), data can be synchronized when multiple devices are used simultaneously. Survey123 can be used to accumulate data, create surveys and is an efficient tool to review and analyze the data collected. The combination of the two applications is crucial to the success of the task undertaken, so that 2D data collected in Field Maps can be supported by observations and field notes recorded in Survey123.

The benefit of this method is the ease of navigation, data collection and GPS accuracy. It is also possible to represent several important descriptive features of the observed lithologies as many different layers can be added to one mapped outcrop (i.e., an alteration layer can be added to a metasedimentary rock). However, caution must be taken in the interpretation of the lithologies mapped. Indeed, the latter (refer to Figure 19) were predetermined in the Field Maps database, later suited to the project area in consultation with the geologists involved. The pronounced weathering surface of the rocks, difficult terrane and heat also contributed to the complexity of the task.

3.4 Data collection

Field activities encompasses the rock samples and infield observations. In addition to rock sampling (266 samples), several in-field observations (> 250 observations) were made and recorded through Survey123. Figure 14 gives a representation of the observations and samples taken in the study area. Some of the rocks encountered are also introduced. Observations allows photos to be collected as well as field notes, which has proven useful to produce a detailed map of the area (Figure 19), and evidence to support lithologies selected for the latter. In Figure 14, observations and sampling activity points are distinguished by their color brightness, observations being slightly darker red colored with green contours.

ArcGIS Pro was used to create maps and illustrate the collection of field data. The layers used were provided by the Australian Government, Geoscience Australia and are accessible online through the Geoscience Australia Portal. The “GSQ 100K Geology layer” used as a background in most of the generated maps was modified to group rock types of the area, especially due to the diversity of sediments and metasediments in the area. The regolith map was generated from field observations and satellite imagery using ArcGIS.

ioGAS software was employed to develop diagrams to correlate elements and help define the occurrence or non-occurrence of a metal zonation pattern in the study area. The preferred method was to represent spatially the element distribution and their correlation using the Pearson correlation (linear). The elements were selected based on the literature review, to best suite IRGS models.

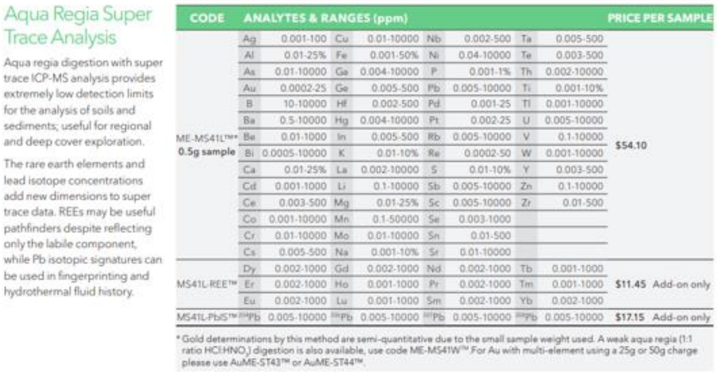
3.5 Sample processing

All samples were processed by ALS laboratory, in Townsville and Brisbane. The soil preparation package (PREP-41) consists of drying the sample at a temperature lower than 60 degrees Celsius and sieve it to less than 180 microns. It is then processed using the Aqua Regia Super Trace Analysis, which allows a multi-element geochemical suite to be produced with extremely low detection limits. Table 2 provides further details of the process, the elements assayed, and detection ranges.

Rocks are prepared using the PREP-31 package which consists of drying (in some cases), crushing, splitting, and pulverizing samples. The ME-MS61 method follows the preparation process, that is the four-acid digestion process. Table 3 provides further details of the process, the elements assayed, and ranges obtained.

The other process used for rock samples is the fire assay for gold analysis. This technique provides accurate and low detection levels, which is suited for exploration projects.

To ensure accuracy of the geochemical results, AngloGold Ashanti conducts their own QA/QC using the duplicate field samples and standards samples. The work program related to the soil samples in Catalina included 13 standards and 13 duplicate samples for a total of 314 samples. Duplicate samples are used to ensure precision and analysis of reference materials to constrain accuracy of the results. Regular visits and inspections of the ALS facility is also conducted by the Senior Geologist (at least once/year).



Aqua Regia Super Trace Analysis

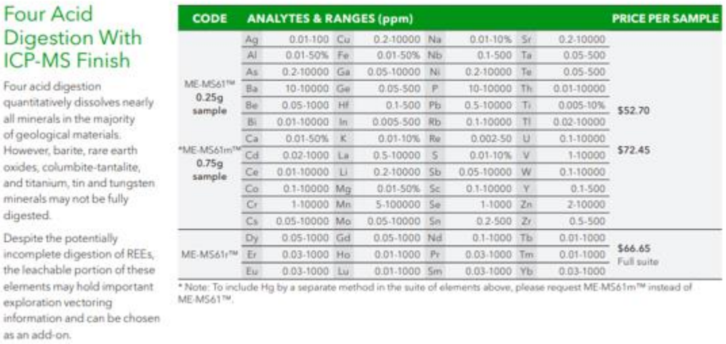
Aqua regia digestion with super trace ICP-MS analysis provides extremely low detection limits for the analysis of soils and sediments; useful for regional and deep cover exploration.

The rare earth elements and lead isotope concentrations add new dimensions to super trace data. REEs may be useful pathfinders despite reflecting only the labile component, while Pb isotopic signatures can be used in fingerprinting and hydrothermal fluid history.

CODE	ANALYTES & RANGES (ppm)								PRICE PER SAMPLE
ME-MS41L™* 0.5g sample	Ag	0.001-100	Cu	0.01-10000	Nb	0.002-500	Ta	0.005-500	$54.10
	Al	0.01-25%	Fe	0.001-50%	Ni	0.04-10000	Te	0.003-500	
	As	0.01-10000	Ga	0.004-10000	P	0.001-1%	Th	0.002-10000	
	Au	0.0002-25	Ge	0.005-500	Pb	0.005-10000	Ti	0.001-10%	
	B	10-10000	Hf	0.002-500	Pd	0.001-25	Tl	0.001-10000	
	Ba	0.5-10000	Hg	0.004-10000	Pt	0.002-25	U	0.005-10000	
	Be	0.01-1000	In	0.005-500	Rb	0.005-10000	V	0.1-10000	
	Bi	0.0005-10000	K	0.01-10%	Re	0.0002-50	W	0.001-10000	
	Ca	0.01-25%	La	0.002-10000	S	0.01-10%	Y	0.003-500	
	Cd	0.001-1000	Li	0.1-10000	Sb	0.005-10000	Zn	0.1-10000	
	Ce	0.003-500	Mg	0.01-25%	Sc	0.005-10000	Zr	0.01-500	
	Co	0.001-10000	Mn	0.1-50000	Se	0.003-1000			
	Cr	0.01-10000	Mo	0.01-10000	Sn	0.01-500			
	Cs	0.005-500	Na	0.001-10%	Sr	0.01-10000			
MS41L-REE™	Dy	0.002-1000	Gd	0.002-1000	Nd	0.002-1000	Tb	0.001-1000	$11.45 Add-on only
	Er	0.002-1000	Ho	0.001-1000	Pr	0.002-1000	Tm	0.001-1000	
	Eu	0.002-1000	Lu	0.001-1000	Sm	0.002-1000	Yb	0.002-1000	
MS41L-PbIS™	[illegible]Pb	0.005-10000	[illegible]Pb	0.005-10000	[illegible]Pb	0.005-10000	[illegible]Pb	0.005-10000	$17.15 Add-on only

* Gold determinations by this method are semi-quantitative due to the small sample weight used. A weak aqua regia (1:1 ratio HCl:HNO$_3$) digestion is also available, use code ME-MS41W™ For Au with multi-element using a 25g or 50g charge please use AuME-ST43™ or AuME-ST44™.

Table 2. Element suite detected using Aqua Regia Super Method and ranges. *Source* ALS Global.



Four Acid Digestion With ICP-MS Finish

Four acid digestion quantitatively dissolves nearly all minerals in the majority of geological materials. However, barite, rare earth oxides, columbite-tantalite, and titanium, tin and tungsten minerals may not be fully digested.

Despite the potentially incomplete digestion of REEs, the leachable portion of these elements may hold important exploration vectoring information and can be chosen as an add-on.

CODE	ANALYTES & RANGES (ppm)								PRICE PER SAMPLE
ME-MS61™ 0.25g sample *ME-MS61m™ 0.75g sample	Ag	0.01-100	Cu	0.2-10000	Na	0.01-10%	Sr	0.2-10000	$52.70 $72.45
	Al	0.01-50%	Fe	0.01-50%	Nb	0.1-500	Ta	0.05-500	
	As	0.2-10000	Ga	0.05-10000	Ni	0.2-10000	Te	0.05-500	
	Ba	10-10000	Ge	0.05-500	P	10-10000	Th	0.01-10000	
	Be	0.05-1000	Hf	0.1-500	Pb	0.5-10000	Ti	0.005-10%	
	Bi	0.01-10000	In	0.005-500	Rb	0.1-10000	Tl	0.02-10000	
	Ca	0.01-50%	K	0.01-10%	Re	0.002-50	U	0.1-10000	
	Cd	0.02-1000	La	0.5-10000	S	0.01-10%	V	1-10000	
	Ce	0.01-10000	Li	0.2-10000	Sb	0.05-10000	W	0.1-10000	
	Co	0.1-10000	Mg	0.01-50%	Sc	0.1-10000	Y	0.1-500	
	Cr	1-10000	Mn	5-100000	Se	1-1000	Zn	2-10000	
	Cs	0.05-10000	Mo	0.05-10000	Sn	0.2-500	Zr	0.5-500	
ME-MS61r™	Dy	0.05-1000	Gd	0.05-1000	Nd	0.1-1000	Tb	0.01-1000	$66.65 Full suite
	Er	0.03-1000	Ho	0.01-1000	Pr	0.03-1000	Tm	0.01-1000	
	Eu	0.03-1000	Lu	0.01-1000	Sm	0.03-1000	Yb	0.03-1000	

* Note: To include Hg by a separate method in the suite of elements above, please request ME-MS61m™ instead of ME-MS61™.

Table 3. Element suite detected using Four acid digestion with ICP-MS finish. *Source* ALS Global.

Chapter 4: Results

4.1 Soil geochemistry

As mentioned in the section: “Previous work completed in and adjacent to the study area”, 314 soil samples had been collected in the project area. The Catalina prospect offers a define copper anomaly with soil samples varying from 2.77ppm to 900ppm and a defined core samples ranging from 51ppm to 900ppm (refer to Figure 11 & 12). The Au anomaly observed in this area includes samples ranging from <1 ppm up to 600ppm (refer to Figure 12)

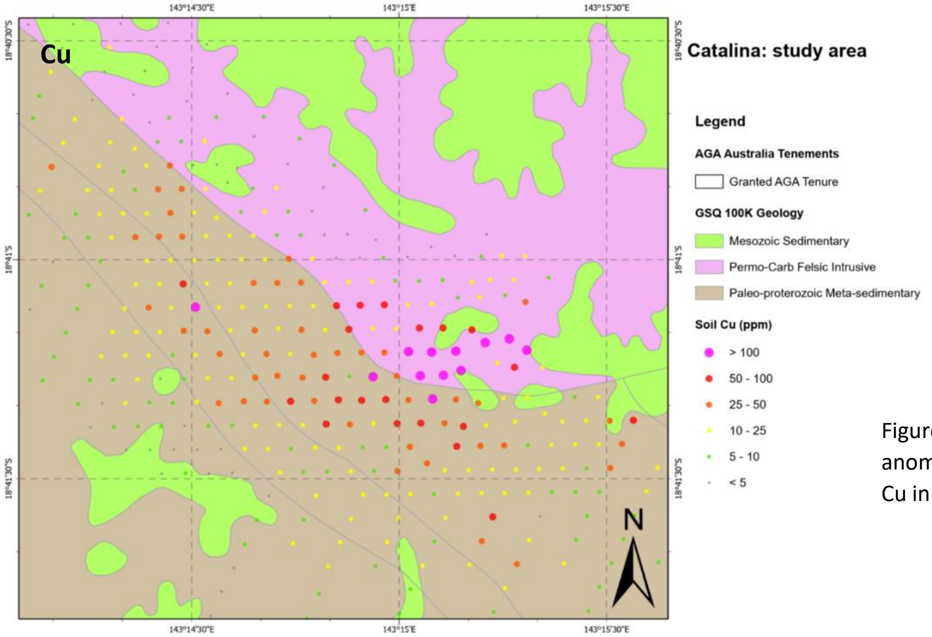


Figure 11. Map highlighting copper anomaly in soils, Catalina prospect. Cu in ppm

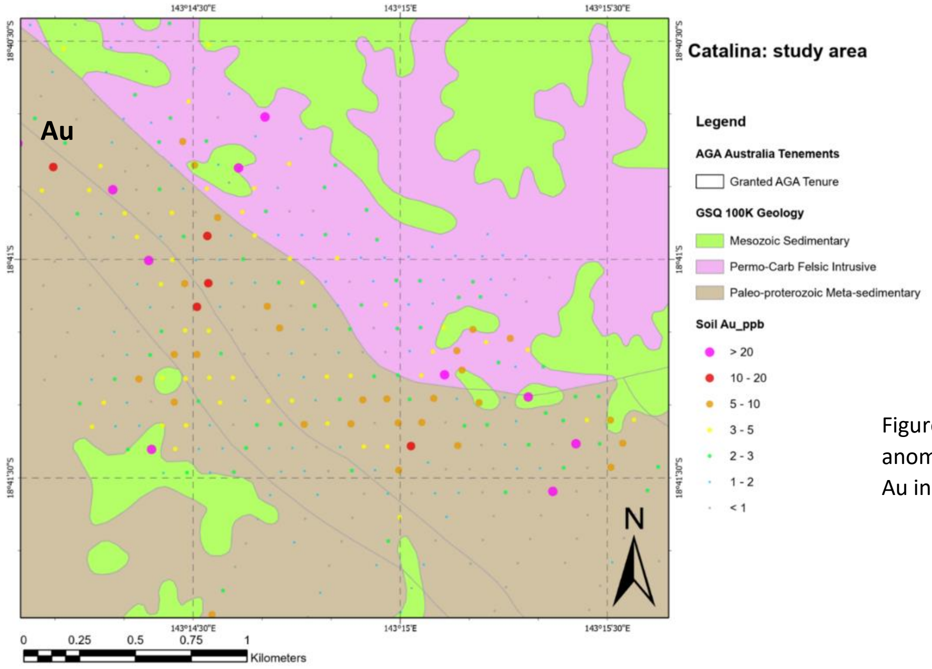


Figure 12. Map highlighting gold anomaly in soils, Catalina prospect. Au in ppb.

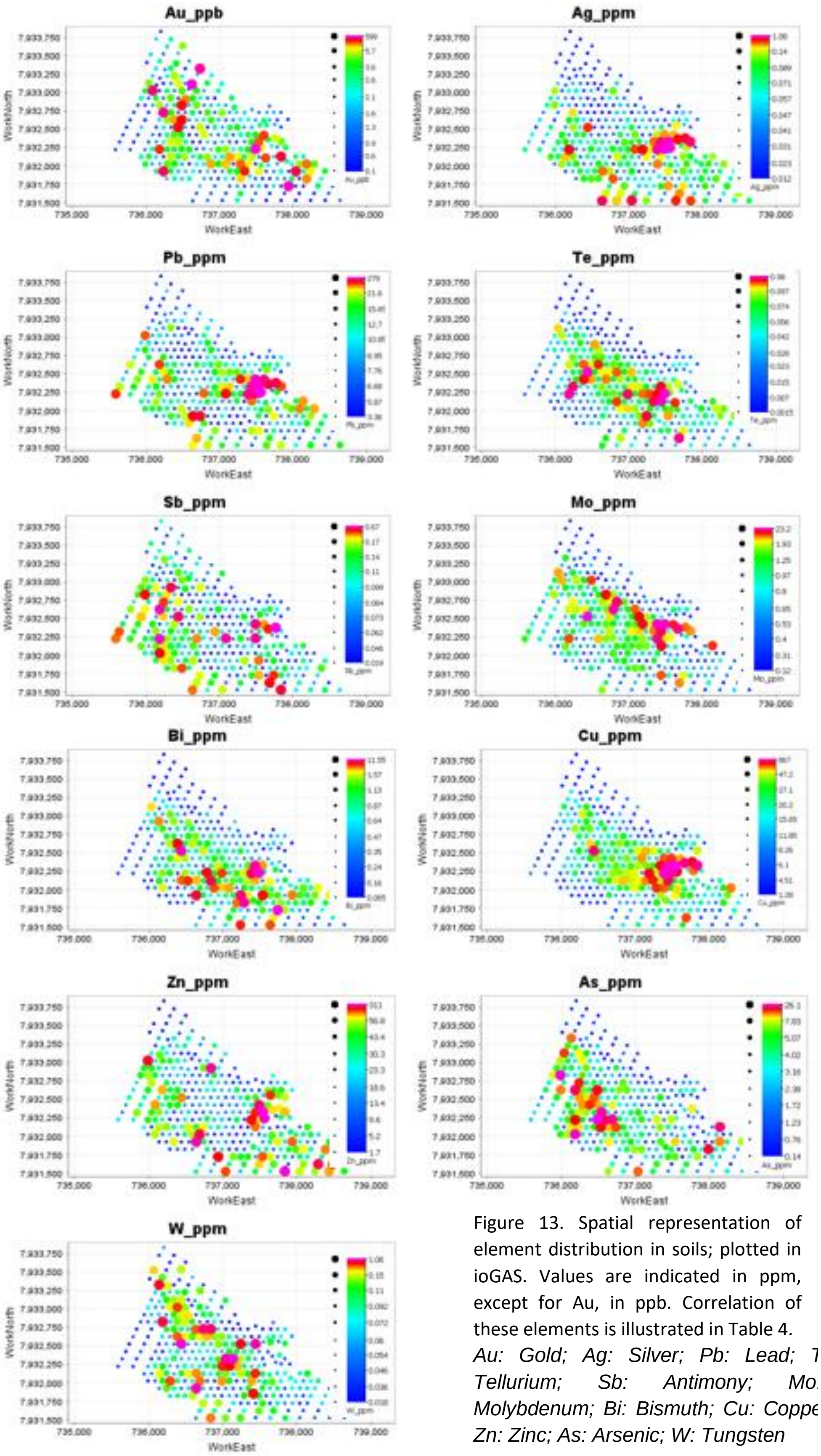


Figure 13. Spatial representation of element distribution in soils; plotted in ioGAS. Values are indicated in ppm, except for Au, in ppb. Correlation of these elements is illustrated in Table 4.

Au: Gold; Ag: Silver; Pb: Lead; T Tellurium; Sb: Antimony; Mo Molybdenum; Bi: Bismuth; Cu: Coppe Zn: Zinc; As: Arsenic; W: Tungsten

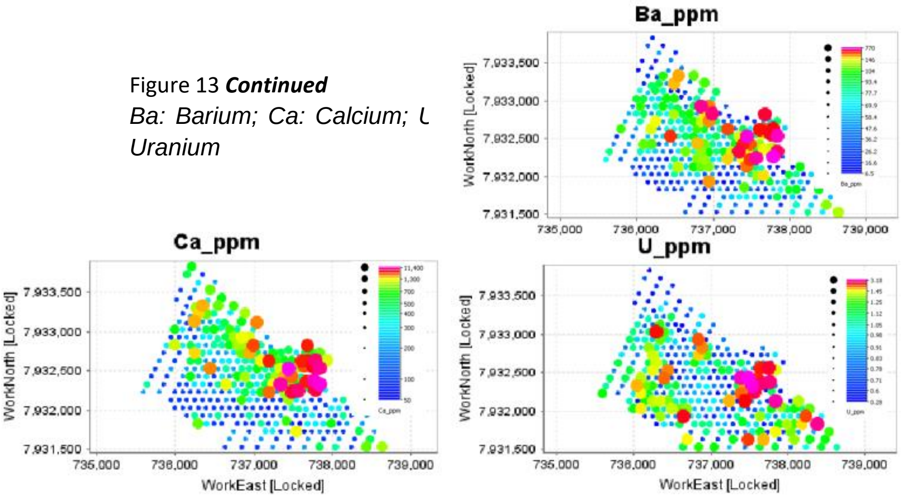


Figure 13 ***Continued***
Ba: Barium; Ca: Calcium; U
Uranium

As illustrated in Figure 13, the elements values are displayed in ppm, except from gold (Au) in ppb. It represents the element distribution in soils within the prospect area. The scale is used to represent values (in ppm or ppb). Blue indicates the lowest value whereas pink/purple represents the highest. The same applies for plotted sample sizes, smaller sizes having a lower value.

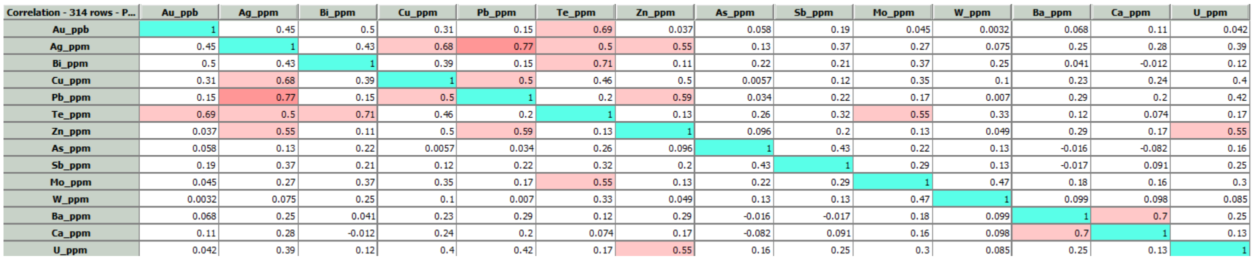
The element distribution in soils, as represented in Figure 13, reveals:

- Au, ranging from 0.1ppb to 599ppb, higher Au concentration are located west of Catalina, in a N-S direction with stronger values to the North. It also occurs within the core of the soil anomaly (Cu)and extends slightly in SE direction.
- Ag, 0.012ppm – 1.08ppm, stronger values are predominantly concentrated within the core of the soil anomaly.
- Pb, 3.36 – 279ppm, stronger values are concentrated within the core of the soil anomaly, although slightly on the NW edge. Pb concentration in soils extends in a NW-SE direction with values >10ppm. The southern edge of the Catalina prospect is also concentrated in Pb with similar values.
- Te, 0.0015 – 0.98ppm, anomaly seen at the core and to West of Catalina following a SW-NE trend.
- Sb, 0.019 – 0.67ppm, anomalous where the soil copper anomaly is, and to the West of Catalina following a N-S trend and to the south.
- Mo, 0.12 – 23.2ppm, anomalous where the soil copper anomaly is, slightly west and extending further NW.
- Bi, 0.065 – 11.55ppm, strongly anomalous where the soil copper anomaly, and in a SE-NW trend within the Catalina prospect.
- Cu, 1.28 to 867ppm, strongly anomalous, the copper anomaly is well contained within the core of the prospect, values are decreasing in an orderly manner away from the Cu-soil anomaly.
- Zn, 1.7 – 311ppm, sparse concentration essentially forming a ring on the outer side of Catalina. Strongly anomalous where Cu soil anomaly is.
- As, 0.14 – 26.1ppm, mainly located to the west of Catalina.
- W, 0.018 – 1.06ppm, despite weak detection of the element, anomalous trend detected in a SE-NW direction across Catalina.

- Ba, 6.5 – 770ppm, anomalous over most of Catalina, strong anomaly shown on edge of Cu anomaly.
- Ca, 50 – 11400ppm, not considered anomalous to the south Catalina, strong anomaly shown on edge of Cu anomaly.
- U, 0.28 – 3.18ppm, anomaly concentrated where Cu anomaly is located (soils).

Summarized below is the correlation of elements in soils, as seen in Table 4. Elements are listed to represent correlation strength, from highest to lowest:

- Au correlates with Te, and slightly with Bi and Ag (+/-Cu).
- Ag correlates well with Pb, and correlates with Cu, Zn, Pb and slightly to Au, Bi.
- Bi correlates with Te and slightly to Au, Ag, Cu and to a lesser extent Mo.
- Cu correlates with Ag and Pb, slightly to Zn, Te and to a lesser extent U, Bi, Au.
- Pb correlates well with Ag, and correlates with Zn, Cu and to a lesser extent U.
- Te correlates with Bi, Au, Mo, Ag and to a lesser extent Cu.
- Zn correlates with Pb, Ag, U and Cu.
- As, Sb correlate slightly with one another. Sb also correlates to a lesser extent to Ag and Te.
- Mo correlates with Te and slightly W.
- Ba, Ca correlate with one another.
- U correlates with Zn and slightly to Pb, Cu, Ag.



Correlation - 314 rows - P...	Au_ppb	Ag_ppm	Bi_ppm	Cu_ppm	Pb_ppm	Te_ppm	Zn_ppm	As_ppm	Sb_ppm	Mo_ppm	W_ppm	Ba_ppm	Ca_ppm	U_ppm
Au_ppb	1	0.45	0.5	0.31	0.15	0.69	0.037	0.058	0.19	0.045	0.0032	0.068	0.11	0.042
Ag_ppm	0.45	1	0.43	0.68	0.77	0.5	0.55	0.13	0.37	0.27	0.075	0.25	0.28	0.39
Bi_ppm	0.5	0.43	1	0.39	0.15	0.71	0.11	0.22	0.21	0.37	0.25	0.041	-0.012	0.12
Cu_ppm	0.31	0.68	0.39	1	0.5	0.46	0.5	0.0057	0.12	0.35	0.1	0.23	0.24	0.4
Pb_ppm	0.15	0.77	0.15	0.5	1	0.2	0.59	0.034	0.22	0.17	0.007	0.29	0.2	0.42
Te_ppm	0.69	0.5	0.71	0.46	0.2	1	0.13	0.26	0.32	0.55	0.33	0.12	0.074	0.17
Zn_ppm	0.037	0.55	0.11	0.5	0.59	0.13	1	0.096	0.2	0.13	0.049	0.29	0.17	0.55
As_ppm	0.058	0.13	0.22	0.0057	0.034	0.26	0.096	1	0.43	0.22	0.13	-0.016	-0.082	0.16
Sb_ppm	0.19	0.37	0.21	0.12	0.22	0.32	0.2	0.43	1	0.29	0.13	-0.017	0.091	0.25
Mo_ppm	0.045	0.27	0.37	0.35	0.17	0.55	0.13	0.22	0.29	1	0.47	0.18	0.16	0.3
W_ppm	0.0032	0.075	0.25	0.1	0.007	0.33	0.049	0.13	0.13	0.47	1	0.099	0.098	0.085
Ba_ppm	0.068	0.25	0.041	0.23	0.29	0.12	0.29	-0.016	-0.017	0.18	0.099	1	0.7	0.25
Ca_ppm	0.11	0.28	-0.012	0.24	0.2	0.074	0.17	-0.082	0.091	0.16	0.098	0.7	1	0.13
U_ppm	0.042	0.39	0.12	0.4	0.42	0.17	0.55	0.16	0.25	0.3	0.085	0.25	0.13	1

Table 4. Correlation of elements in the Catalina soils. The order of redness, bright to faded or absent, indicate correlation strength between elements.

4.2 Rock geochemistry

Several field observations were made to assist in targeting outcrops as seen in Figure 14.

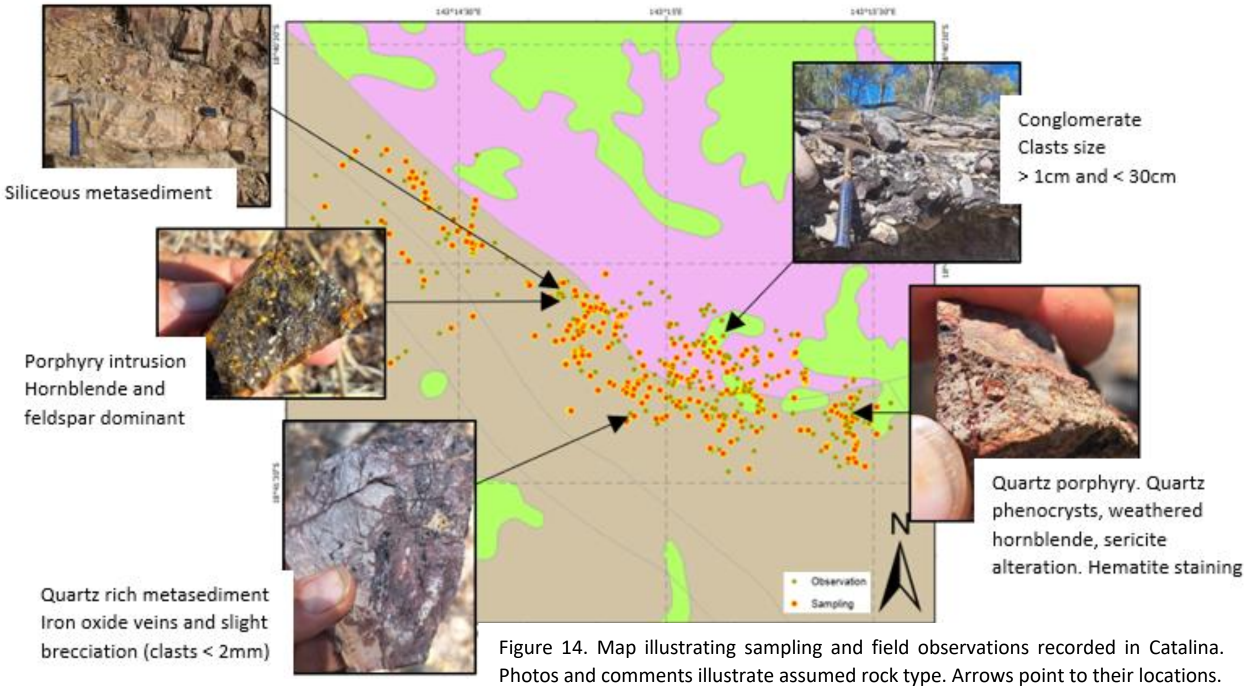


Figure 14. Map illustrating sampling and field observations recorded in Catalina. Photos and comments illustrate assumed rock type. Arrows point to their locations.

A total of 266 rock samples were taken in the survey area (refer to Figure 14 & 15). For each sample, details such as GPS location, rock type, and comments were recorded. In terms of the assay results for Cu:

- 41 samples returned values ≤20ppm (represented by white triangle symbols on the map).
- 214 samples returned values >20 ppm to ≤ 500ppm (blue triangle symbols on the map).
- 6 samples returned values > 500ppm up to 1000ppm included (green triangle symbols).
- 1 sample returned value of 3730ppm Cu (yellow triangle symbol).
- 4 samples returned values > 10 000ppm (purple triangle symbols).

The 11 highest values were obtained from the quartz felsic porphyry intrusions (9 samples) and brecciated metasediments (2 samples), some of which are included in Figure 14. and Table 5 where malachite staining can be observed. A similar observation is made for samples with assay values ranging from > 200ppm to 500ppm with the occasional occurrences of sampled quartz veins.
The obtained assay results for Au, corresponding to rock samples displayed in Figure 15 are as follow:

- 191 samples returned values ≤ 0.01 (white triangle symbols).
- 55 samples returned values > 0.01ppm up to 0.05ppm included (represented by blue triangle symbols).
- 9 samples returned values > 0.05ppm to ≤ 0.1ppm (green triangle symbols).
- 7 samples returned values > 0.1ppm to ≤ 0.5ppm (yellow triangle symbols).
- 2 samples returned values > 0.5ppm to ≤ 1ppm (brown triangle symbols).

- 1 sample returned values > 1ppm (red triangle symbol)

The highest values returned relate primarily to brecciated metasediments, followed by sampled quartz veins and porphyritic intrusions.

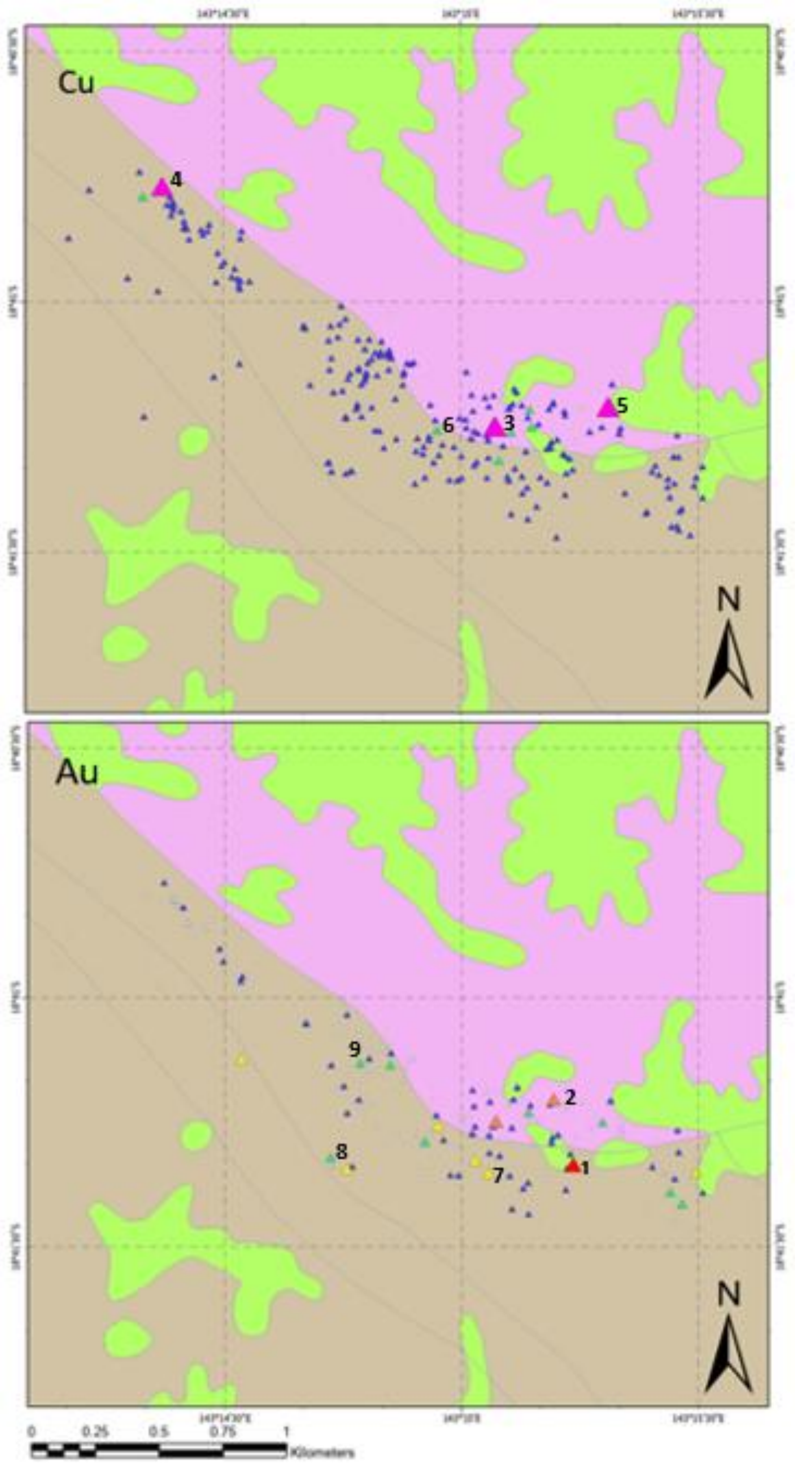


Figure 15. Rocks samples. Locations and results of rock chip sampling. The legend illustrates assay outcomes, in ppm, for Cu and Au. The top map illustrates Cu results. The lower map Au.

1


2


3


4

5

6


7


8

9

Figure 16 and Table 5.

Figure 16. Photos taken in the field. The rocks were sampled for assay.
Samples 1, 6, 7 and 8 display brecciation.
Samples 2, 3, 4, 5 and 9 relate to porphyritic intrusions.
Sample 5 shows copper minerals including malachite (green color) and azurite (bright blue color) locally.

Table 5.

Summary of (from left to right), location of samples seen in Figure 16.; sample ID, field notes & assay results for Cu and Au elements. Of note, porphyry and rhyolite are used interchangeably due to the uncertainty of the rock type, illustrating a porphyritic intrusion.

Map location / ID	SampleID	Comments	Au (ppm)	Cu (ppm)
1	75003652	Brecciation localised within metased hostrock. Very rich in iron oxides although no vein pattern identified. Metased displays some minor schistosity.	1.2	235.0
2	75003597	Smokey quartz vein 10cm wide running through porphyry (quartz phenocrysts). Matrix is sericite altered. Locally rich in iron (weathered) and weathered pyrite (cubic holes within matrix)	0.8	494.0
3	75004584	Black rock with crystalline malachite veins. Possible quartz porphyry	0.9	>10000
4	75004536	Quartz phyric porphyry	0.0	>10000
5	75004581	Outcrop with hematite & malachite. Rock is silicious with quartz phenocrysts; possibly rhyolite	0.0	>10000
6	75003651	Laminated veins striking ~10 subvertical. Through breccia- fault or hydrothermal? Breccia with strong presence of hematite. Partly weathered	0.3	763.0
7	75003687	Brecciation of metased, fluids throughout matrix. Probably Feox veins. Porphyry adjacent to metased.Small clasts.	0.2	400.0
8	75003685	Porphyry seems to be overlying basement (now quartz rich metased, probably silstone in protolith).Brecciation observed with feox veins throughout. Matrix is fine grained and breccia clasts are <1/2cm rather angular to subangular	0.1	53.3
9	75003719	Contact quartz porphyry and quartz rich metased, brecciation distinct with feox veins throughout, breccia is very oxidised and comprises of both rock (predominantly metased)	0.1	181.5

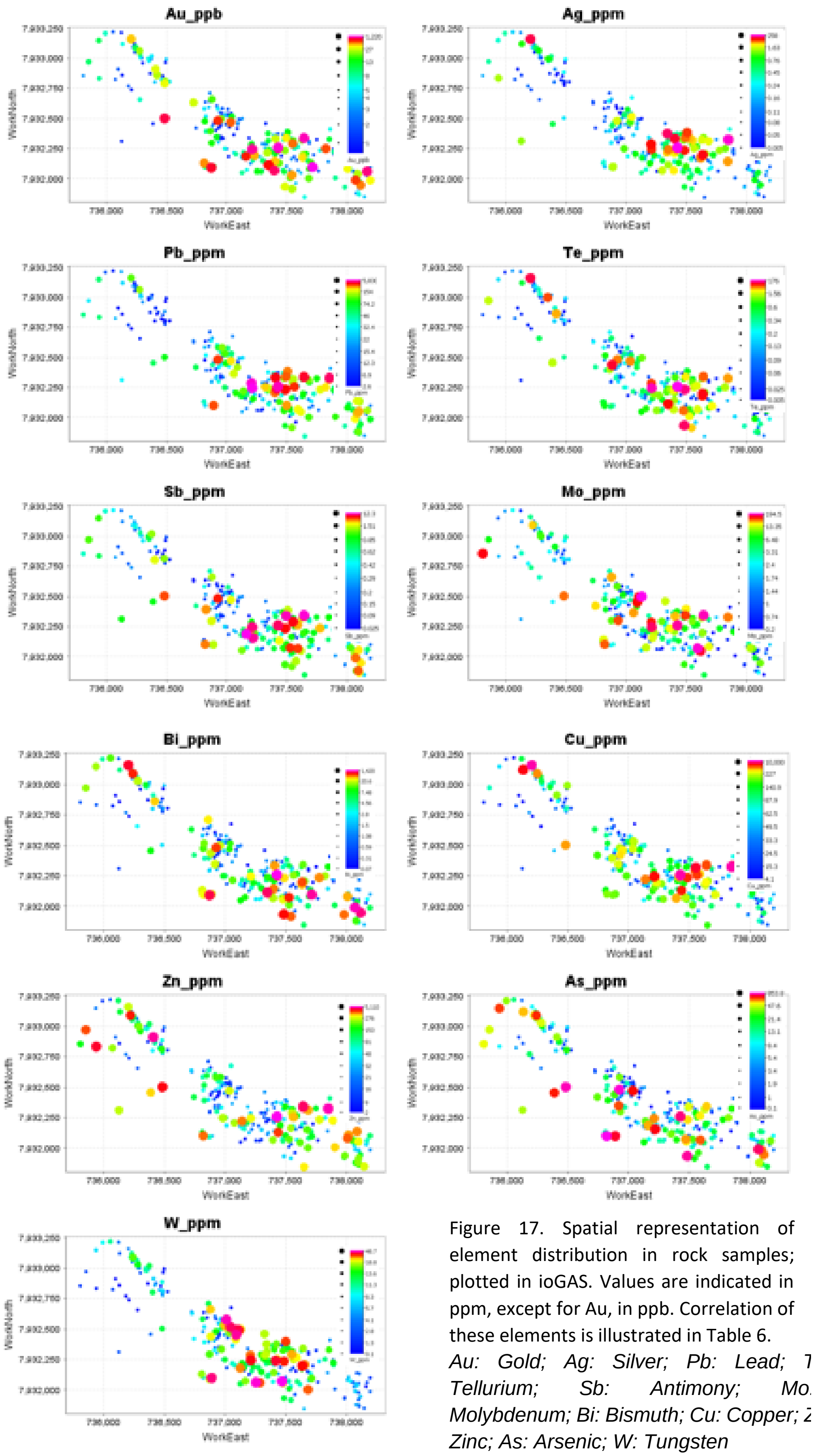
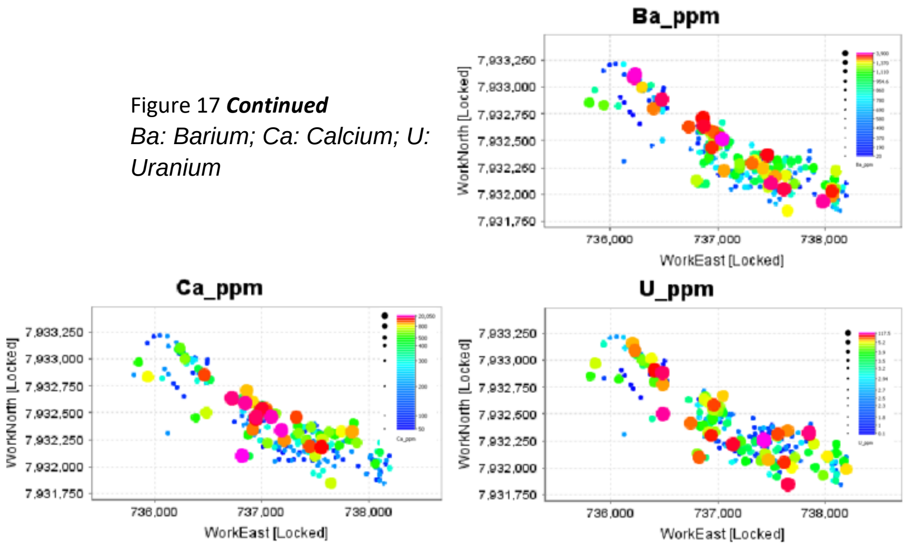


Figure 17. Spatial representation of element distribution in rock samples; plotted in ioGAS. Values are indicated in ppm, except for Au, in ppb. Correlation of these elements is illustrated in Table 6.

Au: Gold; Ag: Silver; Pb: Lead; T Tellurium; Sb: Antimony; Mo Molybdenum; Bi: Bismuth; Cu: Copper; Z Zinc; As: Arsenic; W: Tungsten

Figure 17 ***Continued***
Ba: Barium; Ca: Calcium; U: Uranium

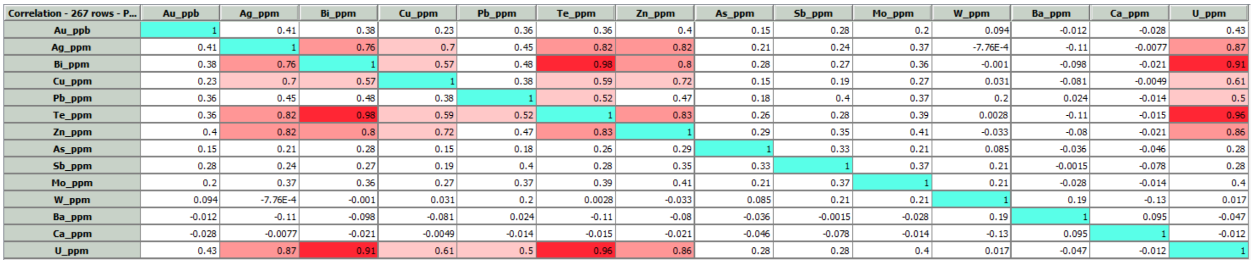


The element distribution in rocks, as represented in Figure 17, reveals:

- Au, ranging from 0.1 to 1220ppb, higher Au concentration are predominantly located in the core of the soil anomaly (Cu)and to its southern edge, extends slightly in SW direction.
- Ag, 0.005ppm – 258ppm, stronger values are predominantly concentrated within the core of the soil anomaly extending in an easterly direction. Slight anomaly detected to the north-west of Catalina
- Pb, 2.6 – 5830ppm, stronger values are concentrated within the core of the soil anomaly, and directly to its west. There is a general anomaly trending SE-NW crosscutting Catalina (values exceeding 75ppm)
- Te, 0.005 – 176ppm, slight anomaly SE-NW direction with higher values west and within the soil anomaly location.
- Sb, 0.025 – 12.3ppm, slight anomaly SE-NW direction with higher values west of the soil anomaly.
- Mo, 0.2 – 194.5ppm, anomalous trending E-W across Catalina and especially across the soil copper anomaly.
- Bi, 0.07 – 1420ppm, strongly anomalous in SE-NW direction with focus on the south of the copper soils (within).
- Cu, 4.1 to 10000+ppm, strongly anomalous, the copper anomaly is well contained within the core of the prospect, values are decreasing in an orderly manner away from the Cu-soil anomaly.
- Zn, 2 – 5110ppm, anomalous over most of the prospect area in SE-NW trending direction. Higher values are located around the copper soils.
- As, 0.1 – 853ppm, anomalous to the west and northwest of the copper soil anomaly.
- W, 0.1 – 48.7ppm, higher values are concentrated northwest to southwest of the copper soils.
- Ba, 20 – 3900 ppm, SE-NW anomaly trend over Catalina.
- Ca, 50 – 20050ppm, strong anomaly detected west of copper soils and directly south.
- U, 0.1 – 117.5ppm, SE-NW anomaly trend over Catalina, also around copper soils anomaly.

Summarized below is the correlation of elements, from the rock samples, as seen in Table 6. Elements are listed to represent correlation strength, from highest to lowest:

- Au correlates slightly with U, Ag, Zn, Bi, Te and Pb.
- Ag correlates well with U, Te, Zn, Bi, Cu and slightly with Pb, Au and to a lesser extent Mo.
- Bi correlates strongly with Te and U, and well with Zn, Ag, Cu; slightly with Pb, Au and to a lesser extent Mo.
- Cu correlates with Zn, Ag, U, Te, Bi and to a lesser extent Pb.
- Pb correlates with Te and U. Slightly with Bi, Zn, Ag and to a lesser extent Sb, Mo and Au.
- Te strongly correlates with Bi and U; well with Zn and Ag, and correlates with Cu, Pb
- Zn shows correlation with U, Te, Ag, Bi and Cu. Slightly observed with Pb, Mo, and Au.
- U shows strong correlation with Te and Bi, followed by Ag, Zn, Cu and Pb. Slight correlation is also observed with Au and Mo.
- As, Sb, Mo do not show any significant correlation, although a slight one can be established between them.
- W, Ba, Ca do not show any correlation



Correlation - 267 rows - P...	Au_ppb	Ag_ppm	Bi_ppm	Cu_ppm	Pb_ppm	Te_ppm	Zn_ppm	As_ppm	Sb_ppm	Mo_ppm	W_ppm	Ba_ppm	Ca_ppm	U_ppm
Au_ppb	1	0.41	0.38	0.23	0.36	0.36	0.4	0.15	0.28	0.2	0.094	-0.012	-0.028	0.43
Ag_ppm	0.41	1	0.76	0.7	0.45	0.82	0.82	0.21	0.24	0.37	-7.76E-4	-0.11	-0.0077	0.87
Bi_ppm	0.38	0.76	1	0.57	0.48	0.98	0.8	0.28	0.27	0.36	-0.001	-0.098	-0.021	0.91
Cu_ppm	0.23	0.7	0.57	1	0.38	0.59	0.72	0.15	0.19	0.27	0.031	-0.081	-0.0049	0.61
Pb_ppm	0.36	0.45	0.48	0.38	1	0.52	0.47	0.18	0.4	0.37	0.2	0.024	-0.014	0.5
Te_ppm	0.36	0.82	0.98	0.59	0.52	1	0.83	0.26	0.28	0.39	0.0028	-0.11	-0.015	0.96
Zn_ppm	0.4	0.82	0.8	0.72	0.47	0.83	1	0.29	0.35	0.41	-0.033	-0.08	-0.021	0.86
As_ppm	0.15	0.21	0.28	0.15	0.18	0.26	0.29	1	0.33	0.21	0.085	-0.036	-0.046	0.28
Sb_ppm	0.28	0.24	0.27	0.19	0.4	0.28	0.35	0.33	1	0.37	0.21	-0.0015	-0.078	0.28
Mo_ppm	0.2	0.37	0.36	0.27	0.37	0.39	0.41	0.21	0.37	1	0.21	-0.028	-0.014	0.4
W_ppm	0.094	-7.76E-4	-0.001	0.031	0.2	0.0028	-0.033	0.085	0.21	0.21	1	0.19	-0.13	0.017
Ba_ppm	-0.012	-0.11	-0.098	-0.081	0.024	-0.11	-0.08	-0.036	-0.0015	-0.028	0.19	1	0.095	-0.047
Ca_ppm	-0.028	-0.0077	-0.021	-0.0049	-0.014	-0.015	-0.021	-0.046	-0.078	-0.014	-0.13	0.095	1	-0.012
U_ppm	0.43	0.87	0.91	0.61	0.5	0.96	0.86	0.28	0.28	0.4	0.017	-0.047	-0.012	1

Table 6. Correlation of elements in the rock samples taken in Catalina. The order of redness, bright to faded or absent, indicate correlation strength between elements.

4.3 Field mapping

The mapping exercise allowed to highlight the lithologies listed in Figure 19. The metasediments dominate the basement rock of the area. Conglomerates and sandstones making up the more recent cover. Isolated quartz veins occur within the area, following a similar trend to the porphyritic intrusions mapped. Porphyritic intrusions tend to run SW-NE and NW-SE, two types of porphyry have been identified: quartz rich porphyry and feldspar rich ones. Phenocrysts are the distinguishing factor: the former is dominated by quartz while the latter is dominated by feldspar. Typically, the intrusions have a fine to medium grained matrix and seem rather felsic in composition.

Significant areas of brecciation occur near the boundary of the soil (Cu) anomaly as seen in Figure 19 & Figure 11. Brecciation mostly occur within metasediments and can be monomict or polymictic with different clasts orientation and shapes. In addition to lithologies, mineralisation of outcrops was noticed in the Catalina prospect (Figure 19). The two observed alteration are sericite and silicification, of which sericite is primarily significant and mostly associated with the intrusions (referred to as porphyry) and brecciated metasediments. The different lithologies mapped in the study area and field descriptions are summarized in section 4.4. Layers were grouped according to rock type variations for map readability purposes. The description provided in Figure 19 matches this approach and reflects field observations.

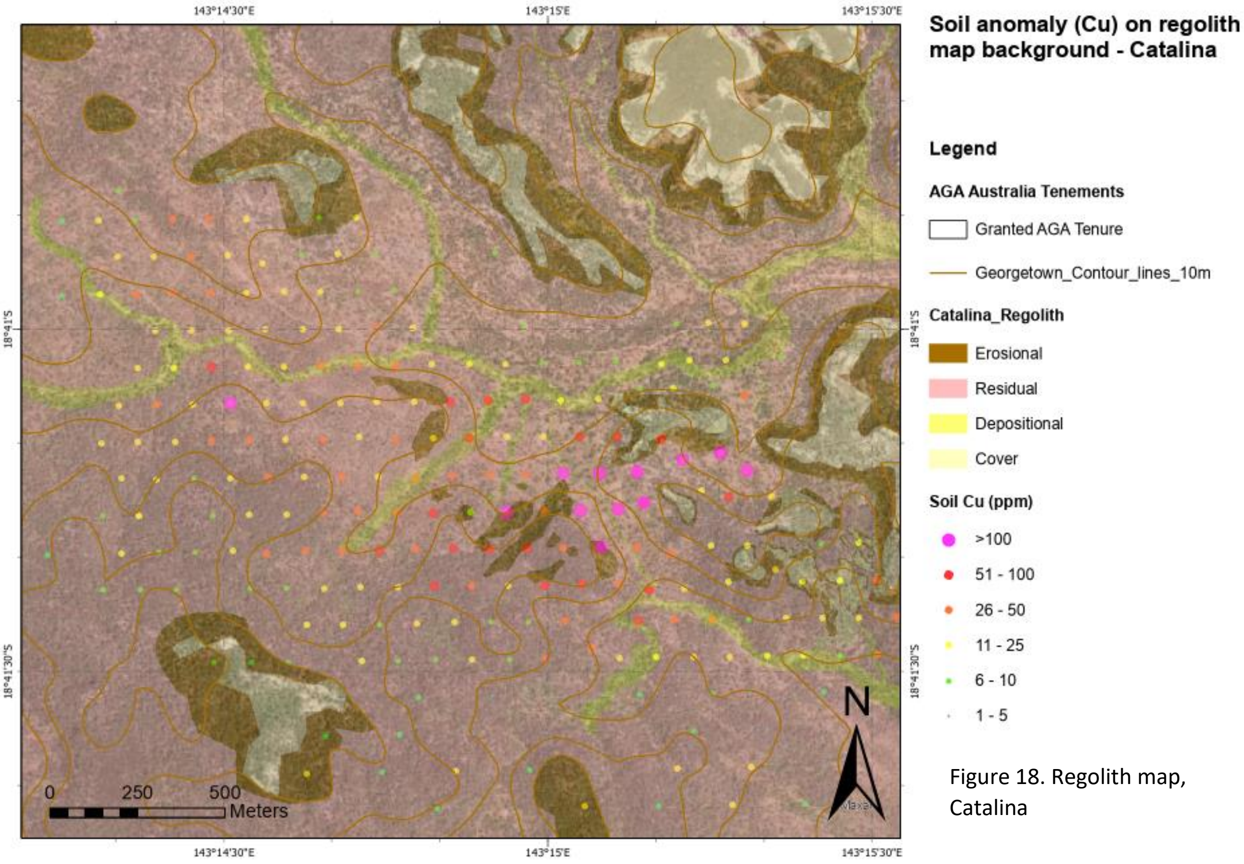


Figure 18. Regolith map, Catalina

The regolith map in figure 18 highlights areas of erosional, residual, and depositional regolith settings. Cover sequences dominate the most prominent outcropping rocks. The cover sequence is referred to as an assemblage of basinal sedimentary rocks, postdating the mineralisation age of the KIA. Residual regolith comprises a large section of the survey area, erosional settings are typically located on slopes (as indicated by contour lines) and around outcrops. Depositional regolith is associated with streams and floodplains. The soil geochemical anomaly is predominantly located in a residual setting.

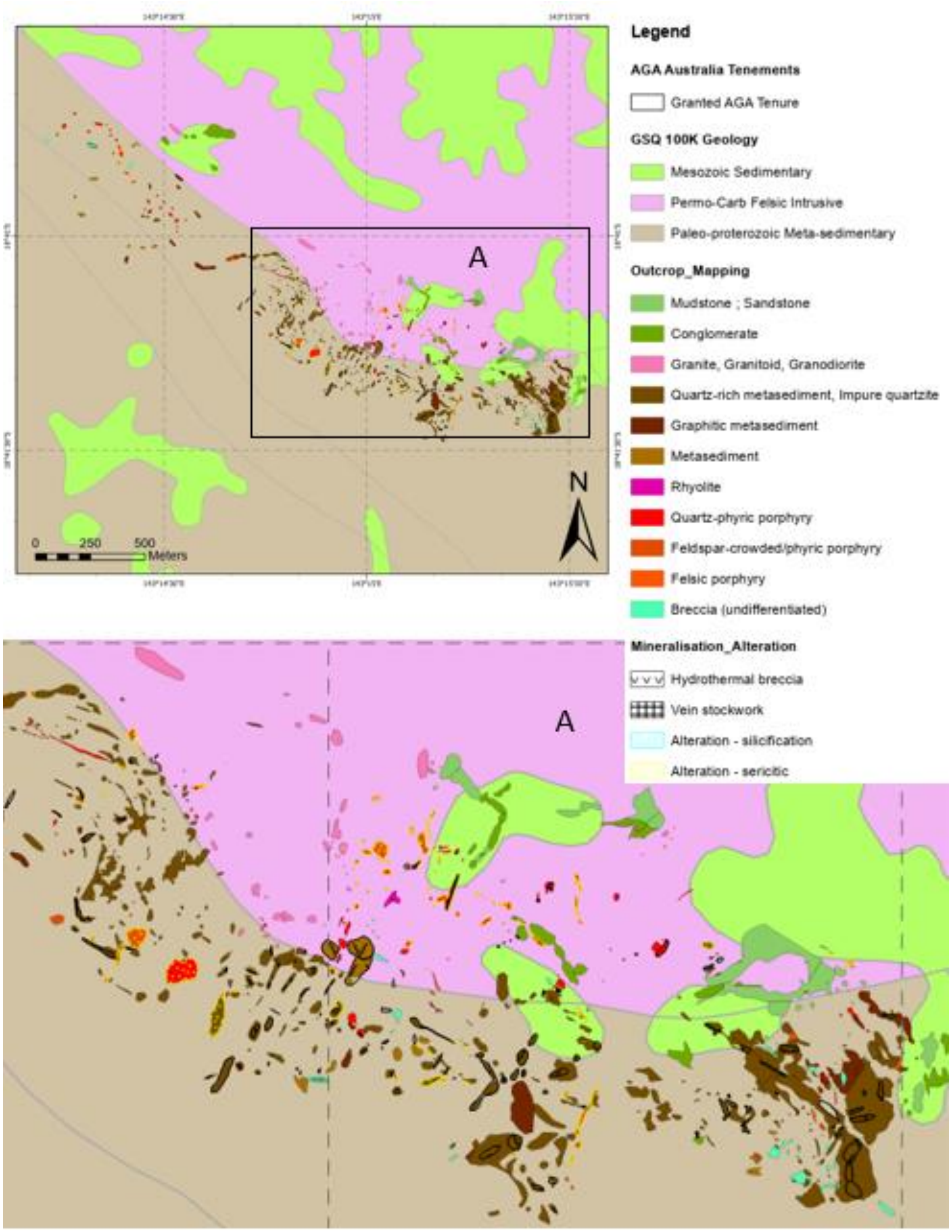


Figure 19. Mapped outcrops in the Catalina prospect overlying background 1:100 000 Geology map from Geoscience Australia. Box A helps to visualize the outcropping bedrocks closer to the geochemical anomaly

4.4 Rock description

Sedimentary units observed in the area are consist of sandstone, mudstone, and conglomerate. Sandstone makes up the primary sediment unit and is distinguished by its coarser grains. Conglomerates are typically composed of a medium to coarse grained matrix with rounded to sub-rounded clasts, and make up the cover of the area, thus of younger origin.
Granitic units comprise the Gongora batholith (granite), typically grey to pale grey with medium to coarse grained biotite (Figure 20.D). More plagioclase is noticed in some units and is referred to as granodiorite. Isolated occurrences of magnetite veinlets within granodiorite.

Metasedimentary units in the area can be subdivided in three groups:

- Graphitic metasediment (Figure 20.A): dark grey colored, fine-grained matrix.
- Metasediment (undifferentiated): light brown to grey fine-grained matrix. Occurrences of brecciation and iron oxide (hematite: red - brown streak; and limonite: yellow – brown streak)
- Quartz rich metasediments & impure quartzite: the former is of finer grained composition. The latter has quartz content in excess with granular texture. Some silicification occurrences usually associated with sulphides (pyrite mainly).

Intrusive units observed in Catalina are:

- Rhyolite: felsic intrusion, quartz, and feldspar (phenocrysts of quartz), light pink to brown in color with a fine to medium grained matrix.
- Quartz phyric porphyry (Figure 20.C) and feldspar phyric porphyry (Figure 20.B) are distinguished by their composition. Fine to medium grained matrix, the former has quartz phenocrysts, the latter feldspar ones and occurrences of biotite and hornblende.

Breccia (Figure 20.E) refers to a unit of mainly metasedimentary rocks displaying brecciation. Clasts embedded in the matrix are typically angular to sub angular ranging in size from a few mm up to 30cm.
Quartz veins are present in the area; however, their occurrences are sparse. Quartz veins are often of smokey quartz appearance and do not display any visible sulphides or specific textures.
Sericite alteration is distinguished in numerous felsic intrusive bodies within Catalina by the bleaching of the rock. It is also observed in brecciated metasediments.

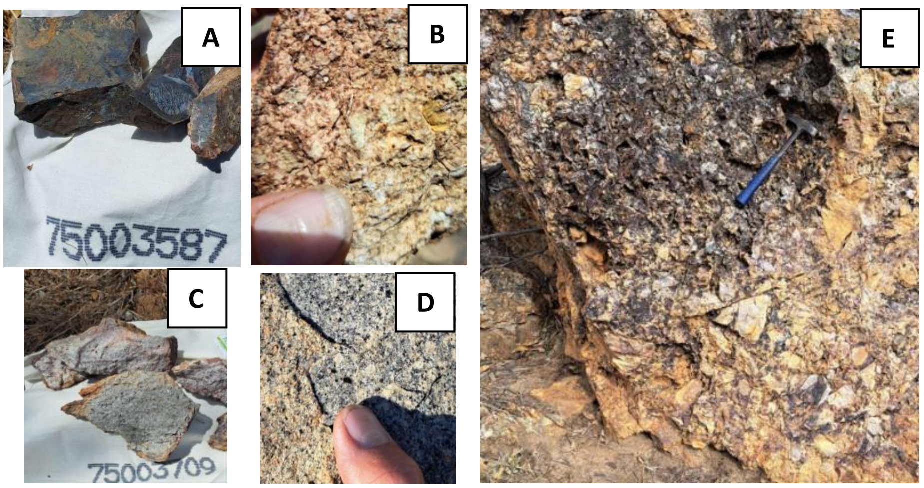


Figure 20. Rock description.

Sample A, B, C, D, E: description in text.

Chapter 5: Discussion

5.1 Geochemical data

Soil geochemistry shows strong anomalies of Au, Ag Bi, Te, Cu, Zn, Pb and Mo concentrated where the copper geochemical anomaly was first observed and Ca, U and Ba are anomalous around the edges of the latter. To the northwest, Au, As, Sb, Te are also strongly anomalous. Other elements tested (Au, Ag, Bi, Cu, Pb, Te, Zn, As, Sb, Mo, W, Ba, Ca, and U) are anomalous to a lesser extent over the broad area and the two anomalies described. Rock geochemistry indicates strong anomalies of Au, Ag, Bi, Cu, Pb, Te, Zn, Sb, Mo, and W concentrated where the copper geochemical anomaly was first observed. To the northwest, Ag, Bi, Cu, Te, Zn, and As are also strongly anomalous. Other elements detected (Au, Ag, Bi, Cu, Pb, Te, Zn, As, Sb, Mo, W, Ba, Ca, and U) are anomalous to a lesser extent over the broad area and the two anomalies described. Ca, U and Ba are strongly anomalous to the northwest and around the edges of the copper geochemical anomaly first detected in soils.

Geochemical anomalies are observed in both soil and rock samples and the datasets from these two sample types correlate well. The correlation coefficient tables for soils and rocks, as seen in Tables 4 and 6, illustrate well the relationships between the different metal enrichments in soils and rocks within the prospect area. Figures 13 and 17 represent the spatial distribution of these anomalies. In general, geochemical anomalies are amplified in rock geochemistry compared to soil. Differences between soil and rock geochemical anomalies can be partially explained by the regolith type as shown in Figure 18. The regolith distribution map shows that the regolith in the area is dominated by “residual type” which is the ideal type for soil geochemical surveys. In the NW part of the Catalina field area, however, the regolith style is more depositional and geochemical anomalies are not as well reflected in the soil samples from this area as within the rock geochemical data, especially the distribution of Cu, Bi and Te. To the SE of Catalina, the dominant regolith settings are depositional and erosional, and thus caution should be taken in interpreting this area. The area of interest is located at the center of Catalina, and both geochemical surveys highlight a polymetallic system.

5.2 Geochemical anomaly and local geology

As seen in Figure 19, the mapping exercise conducted in the study area indicates the different lithologies encountered within the prospect. The series of geochemical anomalies highlighted above are focused on areas of heavy brecciation and intrusive bodies (quartz porphyry and feldspar dominant porphyry) in a metasedimentary setting, itself bounded by the Gongora batholith. The distribution pattern of these lithologies is best illustrated surrounding the Catalina’s most centered anomaly (Copper soils). Brecciation appears restricted to the metasediments and to a lesser extent the porphyry intrusions surrounding that anomaly. This observation suggests rock types play an important role in the mineralisation distribution of the Catalina prospect, likely associated to the intrusive bodies.

Additionally, sericite alteration overlays a significant part of the Catalina area (Figure 21). The intensity of alteration decreases gradually outward from the center of the margins of the detected anomalies; and thus, correlates well with the geochemical anomalies observed.

In summary, mapping shows that the rock types occurring in the center of the geochemical anomalies in Catalina are those commonly found in IRGS; felsic intrusive bodies with heavy brecciation of metasedimentary country rock (Beams, 1995; Morison, 2007). Sericite alteration is also typical of in IRGS and is abundant in IRGS in North Queensland, in deposit types such as Mt Leyshon and Kidston (Beams, 1995; Morison, 2007).

5.3 Metal Zonation

Establishing a zonation pattern in the Catalina area is challenging due to the limited dataset and the mixed overlap between soil and rock geochemical data. Differences in the limits of detection for the analytical methods proved challenging in interpreting geochemical data to illustrate a zonation pattern.

The metal zonation represented in figure 21 is an interpretation of the results within the framework of a typical IRGS model. The process involved the following steps:

1) Figures 13 and 17 provide valuable information regarding the distribution of elements in Catalina, from which a raw zonation pattern can be drawn. This raw pattern confirms a clear polymetallic system (Au, Ag, Cu, Pb, Zn, As, Sb, Bi Te (Mo), refer to figure 21) spreading 1Km to the west, extending North-northwest, and slightly to the east from the center of the copper soil anomaly.

2) Tables 4 and 6 indicate the degree of correlation between elements, it is considered a good indicator of their association (Beams, 1995; Morison, 2007) and allows data to be filtered to constrain several metal zones. This is illustrated in Figure 21 and represented by metal zone crossovers such as Marginal U and Distal (Base metals: BM: Cu, Pb, Zn +/- Ag) and/or Marginal U and Proximal (BM); this is not the case however between Marginal U and Marginal Ca. Of interest is the center Cu, Bi, Te and peripheral Au, Ag, Zn, Pb, Mo, Cu, Te and Sb. As and (Au, As, Sb) are also present further west of the anomaly.

3) Beams (1995), Morison (2015 and 2023) propose an IRGS model, as seen in Table 1, where metal zones are classified as follow: Proximal (BM), Distal (BM), Distal (As) and Marginal (Ca, U, Hg, S, F, Ba, Se depending on and specific to a deposit).

Given the polymetallic nature of the system, metal zones that gradually decrease outward from their center, that can be separated as follow:

- Central zone: Proximal base metal (BM): Cu, Bi Te anomaly.

This central zone is defined by soil geochemistry of Cu > 50ppm, Bi > 1ppm, Te > 0.65ppm and rock geochemistry of Cu > 50ppm (with values exceeding 10000ppm), Bi > 2ppm (up to 1420ppm), and Te > 0.4ppm (up to176ppm). The geology of outcrops in this zone are dominated by porphyritic intrusions. All rocks in this zone show sericite alteration.

The proximal base metal zonation displays closed similarities to known deposits, such as Kidston: Cu (Au Bi Te) and Mt Leyshon: Cu Au Ag (Bi Te) as seen in Table 1. It could be argued the proximal (BM) zonation be defined as Cu (Zn) due to the evident correlation of these elements, their concentration and strong ppm values. However, Zn correlates best, in soil and rock geochemistry samples, with elements Ag, Cu, Bi, Te, U and Mo, Pb. As. Therefore Zn is preferred to be associated within the distal base metal zone (Table 4 and 6).

- Distal polymetallic base metal (BM) anomaly

This zone wraps around the central zone (Figure 21) and is defined by soil geochemistry of Zn > 20ppm, Au > 1ppb, Ag > 0.1ppm, Pb > 20ppm; Mo > 1ppm, Sb > 0.08 , Cu > 20ppm, Te > 0.06ppm, and Bi > 0.6ppm and rock geochemistry of Zn > 40ppm, Au > 4ppb, Ag > 0.56ppm, Pb > 30ppm, Mo > 2 ppm, Sb > 0.2ppm, Cu > 100ppm, Te > 0.05ppm, and Bi > 1ppm. The geology of outcrops in this zone are dominated by brecciated metasediments and porphyritic intrusions. Most rocks in this zone show sericite alteration.

The distal (BM) zonation is characterized by consistent high values of the following elements within the zone: AU (Au + Ag), BM (Cu + Pb + Zn), Mo, Cu, Bi, Te and Sb. It illustrates the continuation of the proximal (BM) zone, with slightly lower values of Cu, Bi and Te. Pb and Zn are consistent within this zone and share correlation with Cu. Mo does show slight correlation with Te, and to a lesser extent with Zn, Pb, Bi, Sb and Ag. Sb does not correlate clearly with other elements, although it can be associated (low correlation coefficient) to elements within the distal (BM) zone. When compared to the IRGS models summarized in Table 1, Catalina's distal base metal zone show similarities to known deposit types such as Mt Leyshon, Kidston and Goonumbla but does not fit a specific deposit type. Mt Leyshon's distal base metal zone is defined by Pb Zn Ag (Au, Bi); Kidston's is defined by Zn Cu Pb Bi Au. Elements such as Cu, Mo, Te and Sb are absent and thus differ from Catalina. Goonumbla model appears to fit best Catalina's distal base metal zone with differences being regarding the Bi and Sb elements.

- Distal As and Distal As, Sb, Au anomaly and anomaly

These zones are located respectively west and northwest of the central zone and is defined by soil geochemistry of As > 4ppm; Sb > 0.1ppm, As > 2ppm, and Au > 1ppb and rock geochemistry of As > 5ppm; Sb > 0.2ppm, As > 20ppm, and Au > 3ppb.

One zone is associated to As only, and one zone is associated to Au, As, Sb where weak correlation exists between As and Sb. Au is represented in this zone due to its enrichment in ppm/ppb. As indicated in Table 1, this association is common across IRGS.

- Marginal alteration zones

Marginal Ca is located at the boundary of the distal base metal zone to the northeast and trending west. It does not occur across the central zone and only slightly cross over the distal base metal zone. This anomaly is defined by soil geochemistry of Ca >> 500ppm and rock geochemistry of Ca > 300ppm. The geology of outcrops in this zone are dominated by Mesozoic sediments, granite, and metasediments to the west. Sericite alteration is sparse in this zone.

Marginal (Ca) does not correlate with any of the elements listed in other zones. This marginal occurrence is comparable to the Goonumbla and Mt Leyshon deposits.

Marginal U is located at the boundary of the central zone to the southwest and is trending east. It does slightly cross over the central zone and almost all the distal base metal zone to the southwest. This anomaly is defined by soil geochemistry of U > 1ppm and rock geochemistry of U > 3ppm. The geology of outcrops in this zone are dominated by metasediments, with some granite occurrences to the north. Sericite alteration is sparse in this zone.

Marginal (U) shows strong correlation with Bi, Te, Zn, Cu, Pb (in decreasing order) and can be correlated with the Kidston deposit style.

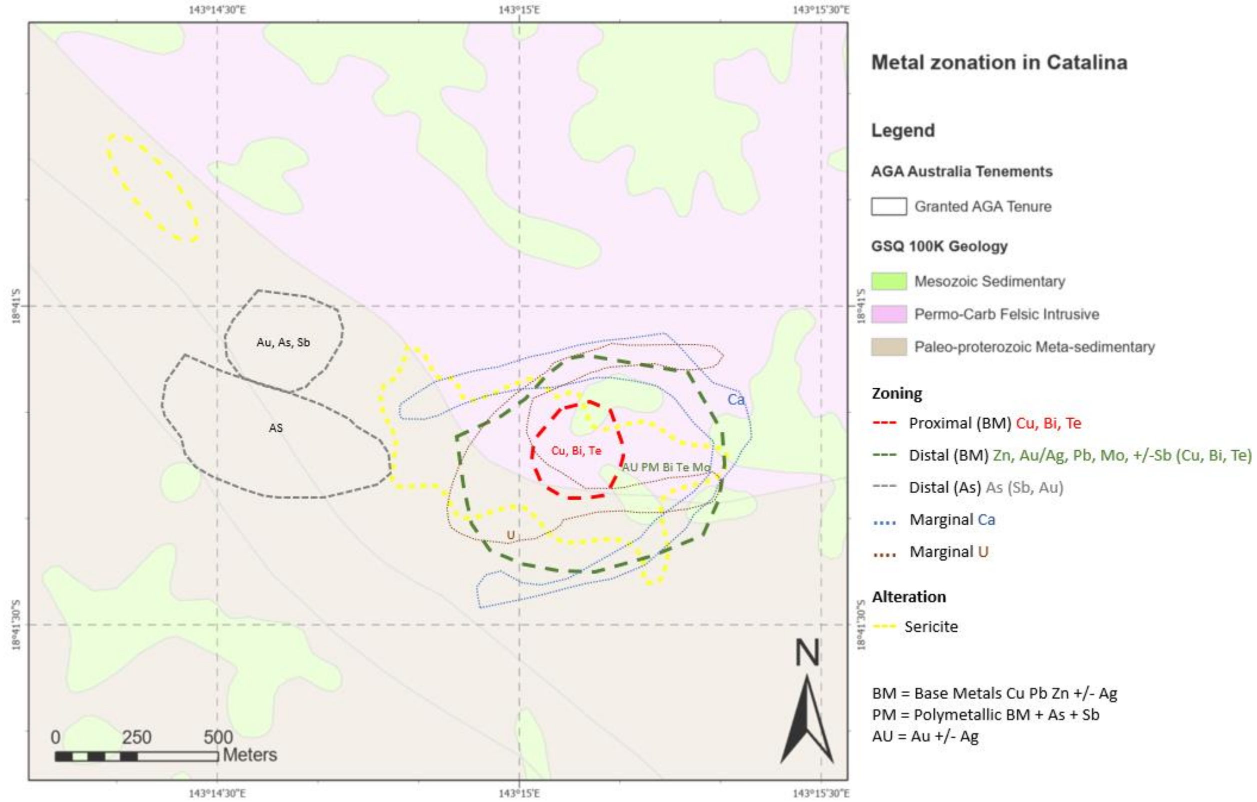


Figure 21. Metal Zonation and sericite alteration in Catalina.

In summary, differences arise when defined zones are compared with other deposit styles. The main discrepancy is the inability to define a core based on the geochemical data of the Catalina prospect. Many similarities with felsic to intermediate composition IRGS models are found and strongly support a similar setting in this area.

5.4 Reflection

Metal zonation in Catalina suggested a distribution of elements that can be associated with IRGS of different compositions. Morison & Beams (1995) and Morison (2017) attribute occurrences of Mo, Te and/or Bi, Te in an IRGS system as an indicator of intermediate to mafic system. Ba, however, is considered an indicator to felsic composition.

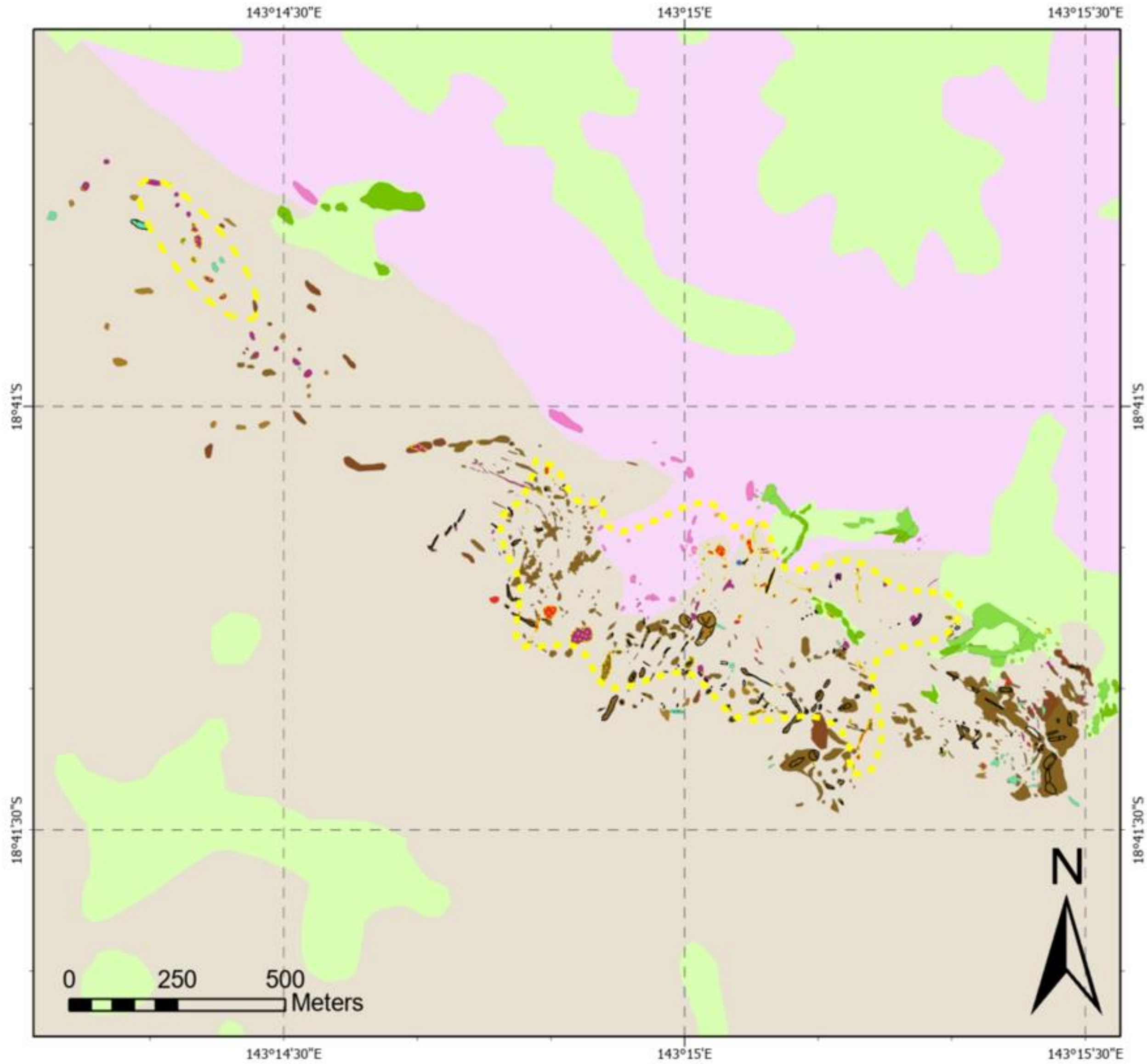
The following is observed in Catalina:

- Ba is significantly high (>1000ppm), especially in the mapped quartz phyric porphyry and felsic porphyry and is possibly representative of a felsic source. Felsic IRGS are commonly attributed to have AU PM Bi association (refer to *section 2.3.4*).
- Stronger geochemical anomalies of Bi, Te and Mo are associated with mapped feldspar crowded/phyric porphyry and possibly suggest a rather intermediate to mafic composition of the intrusive. IRGS model suggest the following element class: AU PM Bi Te (intermediate), AU PM Te Bi (intermediate to mafic), AU AS Bi Te +/-BM (mafic)

Dykes and sills features are commonly found and widespread over the Georgetown inlier (Beams, 1995; Budd, 2001; Morison, 2007; Morison, 2017; Morison et. al, 2019; Murgulov et. al, 2006)
Rhyolite intrusions have been observed near Agate Creek, Gilberton and many other areas in the Etheridge shire. Rhyolites are reported in many of Queensland's deposits including Kidston, Mt Leyshon and Mt Wright and is rather felsic in composition (Beams, 1995; Lisowiec et. al, 2007; Morison, 2007; Morison, 2017).

Rhyodacite, rock of intermediate composition, is found near the old Cumberland mine (located in proximity of the study area as seen in Figure 6) and is also associated with several major deposits in northeast Queensland such as Kidston and Mt Leyshon (Beams, 1995; Morison, 2017).

Figure 22 is proposed as an interpretation of the local geology based on geochemical data, mapping, and rock descriptions (refer to section 4.4). Quartz phyric porphyries and felsic porphyries are combined under a single layer: Rhyolite whereas Feldspar crowded/phyric porphyries are represented as Rhyodacite. The GSQ 100K Geology layer has also been reviewed and a more detailed layer created to highlight the setting.



Legend

AGA Australia Tenements

☐ Granted AGA Tenure

Reviewed_GSQ 100K Geology

🟩 Mesozoic Sedimentary

🟪 Permo-Carb Felsic Intrusive

🟫 Paleo-proterozoic Meta-sedimentary

Mineralisation_Alteration

▨ Hydrothermal breccia

--- Sericite

Reviewed_Outcrop_Mapping

🟩 Mudstone ; Sandstone

🟩 Conglomerate

🟪 Granite, Granitoid, Granodiorite

🟫 Quartz-rich metasediment, Impure quartzite

🟫 Graphitic metasediment

🟧 Metasediment

🟪 Rhyolite

🟩 Breccia (undifferentiated)

🟥 Rhyodacite

Figure 22.

Interpretation of the local geology in Catalina.

The yellow dotted outline represents the shape of sericite alteration halo as shown in figure 21.

Chapter 6: Conclusion

Since most regolith cover is residual, soil geochemical exploration is thought to be suitable in the Catalina prospect. The soil and rock sample geochemical anomalies support well one another and their correlation with mapping the local geology show characteristics of an altered intrusion related mineral system. Metal zonation established through such correlation demonstrates similarities to felsic and intermediate polymetallic IRGS. Limitations from surface geochemistry studies include the difficulty to characterize a metallic core. Ultimately, no deposit type can be matched with certainty to Catalina's geochemical anomalies.

Further exploration activities should be undertaken to constrain the mineralisation style:

- Lithogeochemistry samples of the intrusive bodies (quartz dominant porphyry and feldspar dominant porphyry) to understand their respective compositions and confirm or dismiss the rhyolite and rhyodacite occurrences. This could help differentiating between felsic and intermediate IRGS and be of benefit to define the core of the system.
- Geochronology samples of the intrusive bodies to date the mineralisation event that occurred in Catalina and relate it to the KIA.
- Drilling to understand vertical zonation of the system and characterize the type of mineralisation occurring at depth.

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