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COMMENTS ON THE

CONTROLS TO Au-Ag MINERALISATION

AT THE TAHUEHUETO PROJECT,

DURANGO, MEXICO

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SUMMARY

The Tahuehueto Project represents a typical example of polymetallic Au-Ag mineralisation which displays pronounced telescoping as early high temperature mineralisation characterised by chalcopyrite-brown sphalerite, is overprinted by intermediate temperature pyrite-red to yellow sphalerite-galena with minor tetrahedrite, which is inturn further overprinted by two later epithermal end member assemblages characterised by either elevated Ag within freibergite (Ag-tetrahedrite) or high fineness (Ag-poor) visible Au. This telescoping may represent the progressive cooling of the hydrothermal system, although in some instances tectonic unroofing of the cover rocks may also result in a decrease in overburden and progressive deposition of higher crustal level, lower temperature mineral assemblages. The progressive rise in Au-Ag grades in the later higher crustal level assemblages without significant base metals, is a most important element of this telescoping. Continued prospecting should be mindful that porphyry and sheeted vein wall rock porphyry mineralisation could occur at deepest levels, as evident from sericite and increased potassic alteration along with tourmaline-bearing magmatic hydrothermal breccias and shingle style collapse breccias at the deepest levels of exposure. At Creston the fault appears to ‘grow’ with younger breccias on the footwall, which therefore warrants prospecting to deeper level.

Controls to low sulphidation epithermal Au-Ag mineralisation at Tahuehueto are similar to those recognised elsewhere in low sulphidation epithermal deposits as:

- Competent host rocks, here as the Kfeldspar altered andesite porphyry are required for the formation of fractures to host mineralisation. An incompetent conglomerate may act as a cap to mineralisation.
- Structural control comprises the NE corridor of fractures interpreted as normal faults which might host better (wider and higher Au-Ag) veins in steeper dipping portions and, by a component of left lateral (sinistral) strike-slip movement, form NNE dilatant flexures, splays and tension veins as settings of ore shoot formation. Continued prospecting should be mindful that these mineralised tension veins may be oriented at a low angel to the drilling direction.
- The variable styles of low sulphidation mineralisation described above influence base and precious metal grades and distribution, with a progressive change with time and decreasing crustal level from Cu with minor Au, to Pb-Zn with moderate Au and Ag, to the two epithermal Au-Ag rich end members described above. Prospecting lower temperature portions of the hydrothermal system, at the upper portions, in dilatant structures and at the margins, therefore remains important.
- Mechanisms of Au-Ag deposition influence precious metal grades with increases Au-Ag grades by: cooling or the ore fluid, mixing of ore fluids with oxygenated ground waters evidenced by hypogene haematite, mixing of the ore fluid with bicarbonate waters evidenced by MnO or Mn carbonate, while best Au-Ag grades result form the mixing of ore fluids with collapsing acid sulphate low pH waters evidenced by hypogene kaolin within the ore assemblage. Acid caps provide vectors to settings of buried higher grade polymetallic Au-Ag mineralisation.
- Supergene enrichment has remobilised metals in order to leach Ag, Zn and Cu in the oxide zone and deposit Ag and Cu overprinting sulphides below the base of oxidation, while enriched Au occurs at upper portion of the base of oxidation.

Some vectors arising from an analysis of the controls to mineralisation could aid continued prospecting.

Introduction

At the request of Hall Stewart 3.5 days were spent in a review of the geology and exploration at the Tahuehueto Project, Durango, Mexico. Lectures were presented on site to discuss some of the geological concepts used in this evaluation. The assistance is gratefully acknowledged during this work of Hall Stewart, Ralph Shearing, Art Freeze, Gerardo Villalobos, Ernesto Serrand, Antonio Zavala and Ricardo Cruz. This brief review may not have considered all aspects of the Tahuehueto project, and so some of the interpretations made herein could be open to further consideration if a more complete examination were to be made of the expanding database.

Mineralisation at Tahuehueto is classified as of an epithermal low sulphidation polymetallic Ag-Au style (Corbett, 2007 and references therein) and so Au and Ag are accompanied by Cu, Pb and Zn mineralisation. At Tahuehueto exposure in the vertical relief of over 1 km (photo 1) aids in the analysis of polyphasal mineralisation which is zoned in time and space.

Comparisons with other polymetallic Ag-Au occurrences suggest (Corbett, 2007) several controls for Tahuehueto low sulphidation Au deposits can be defined as:

- Host rock lithology,
- Structure,
- Style of Ag-Au mineralisation,
- Mechanism of Au deposition,
- Supergene Au-Ag enrichment,
- Dilution.

The geology and exploration potential of Tahuehueto may be considered in relation to these controls and best (often wider and higher Au-Ag grade vein) mineralisation is recognised where as many as possible of these controls coincide.

Host rock lithology

Tahuehueto contains a rock package similar to other districts in the Sierra Madre Occidental comprising two principle rock sequences described as the Upper Volcanics developed as cliff forming prominent ignimbrites unconformably overlain on the Lower Volcanics which include upper conglomerate, andesite, andesite breccia, crystal and lapilli tuff, as well as volcaniclastic rocks. Several intrusive rock types recognised include:

- The fresh El Reyo granodiorite which was not inspected,
- The interpreted feldspar porphyry dyke which locally hosts the El Creston mineralisation and displays generally strong chlorite (propylitic) alteration and weak pink Kfeldspar (potassic) alteration,
- The quartz-feldspar porphyry which crops out at the El Burro workings and displays strong Kfeldspar development indicative of potassic alteration (photo 2).

The importance of a related buried intrusion source for dykes, alteration and mineralisation is discussed below.

<u>Competent host rocks</u> are required for the development of low sulphidation epithermal veins and breccias, although silicification during early alteration and mineralisation may

create host rock competency utilised by later mineralising events. Most veins at El Creston occur in a brittle feldspar porphyry (andesite) interpreted as a dyke, which has fractured well as a vein host. The footwall andesite breccia is less well mineralised and drill holes examined do not transgress the upper contact of the feldspar porphyry, because of topographic constraints on the drill sites. Similar feldspar porphyry is reported to host vein mineralisation at the Santiago veins (H. Stewart, pers. commun.) and so this interpreted dyke unit may be sufficiently extensive to occur in multiple settings, where it not only provides a good host for mineralisation, but there could be a causal relationship between magmatism and mineralisation (below).

The conglomerate rocks in the upper portion of El Creston are not expected to have fractured to host veins and so may represent an aquitard restricting vertical vein formation.

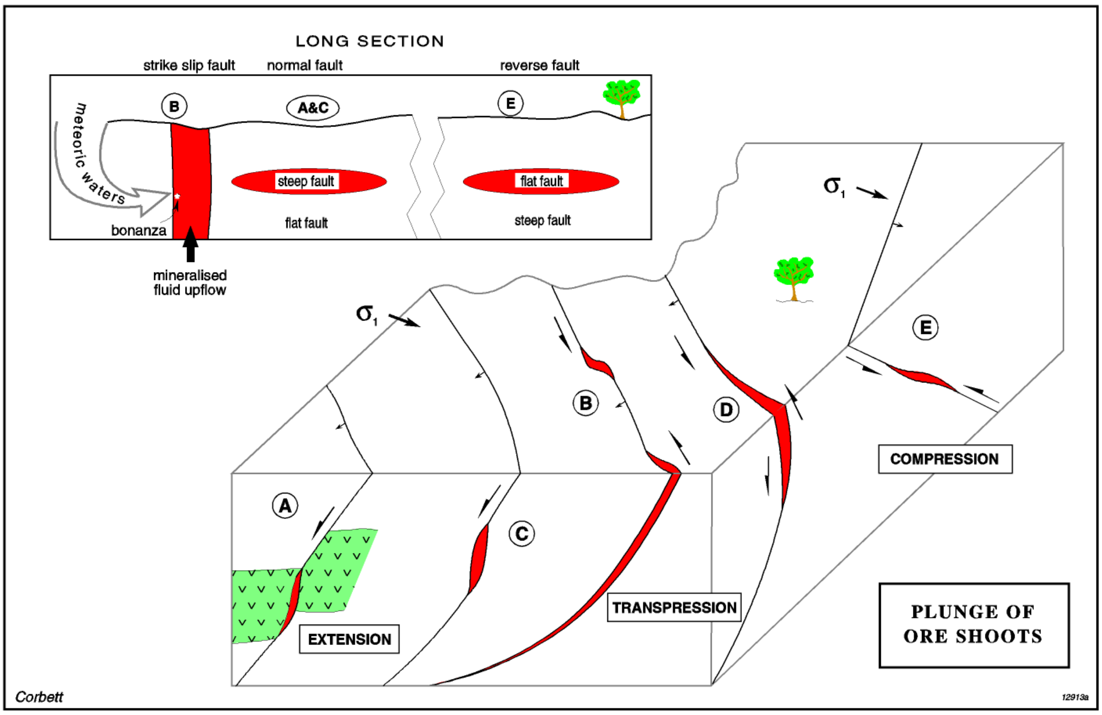

Figure 1. Varying structural controls to ore shoot formation in low sulphidation Au-Ag deposits.

Structure

Not only are most low sulphidation polymetallic Ag-Au veins structurally controlled, but in many vein systems much of the mineralisation is confined to ore shoots which host better mineralisation (as higher Ag-Au grades and wider veins) commonly developed within dilational structures. The kinematic end members and resultant ore shoots in most low sulphidation polymetallic Ag-Au systems (figure 1) include:

- Strike-slip deformation (transpression) evidenced by flat pitching slickensides on fault faces yields steep plunging ore shoots in the plane of the fault, generally developed in fault flexures or jogs containing tension veins,
- Normal (including listric) fault (extensional) deformation evidenced by steep plunging slickensides on fault faces yields flat plunging ore shoots generally in

steeper dipping portions of more moderately dipping (including listric) faults or at the intersection with hanging wall splays,

- Reverse faults evidenced by flat pitching slickensides provide flat ore shoots developed in flatter dipping fault portions, but these are not common.

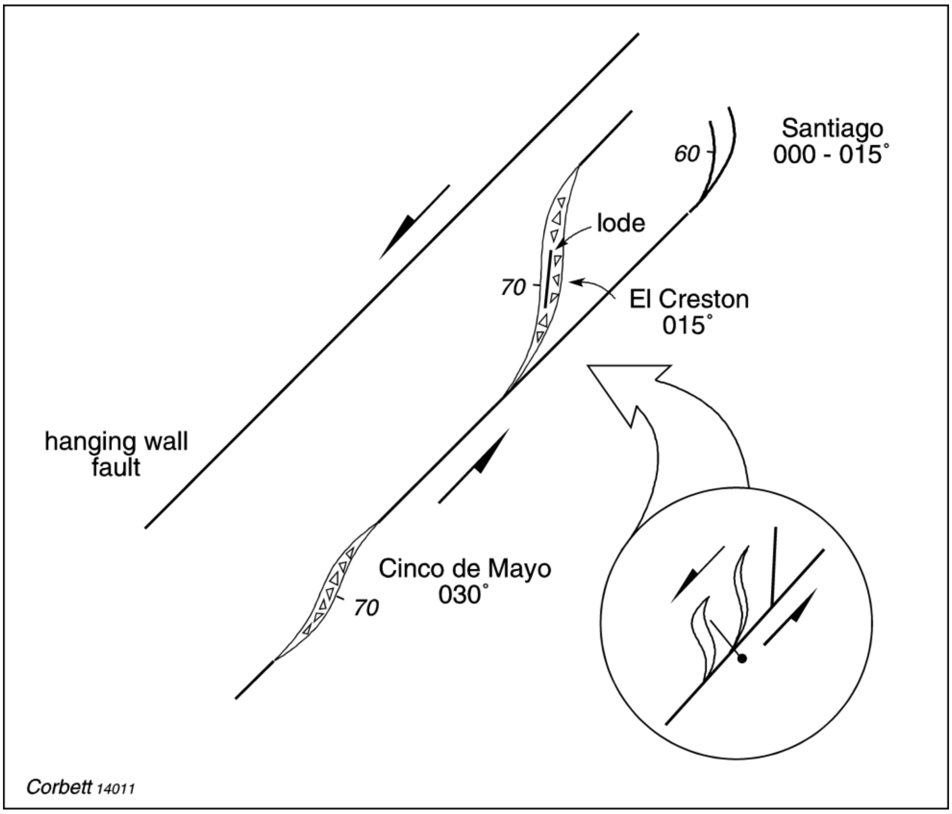

Figure 2. Structural elements present at Tahuehueto and illustration of the manner in which, during increased deformation, tension fractures initiated at 45^{o} to the controlling structures become reoriented and mineralised to occur a very high angles to the controlling (NE) structures and hence at a low angle to the drill core axis.

A NE trending corridor of many parallel throughgoing steep east dipping fractures and faults, traced for about 3 km from Santiago in the NE to Cerro de Mayo in the SW represents the main control to mineralisation at Tahuehueto.

NNE trending subsidiary structures which host mineralisation are less continuous and commonly display more open vein textures typical of a dilational setting.

Most slickensides recognised in this brief review of the Tahuehueto project dip steeply, indicative of normal fault activation in an extensional setting, consistent with other polymetallic Ag-Au deposits in the Sierra Madre that this author has visited. However, as also consistent with these other mineralised vein systems, better ore zones at El Creston occur in more northerly (mostly NNE trending) trending vein portions. The main El Creston is interpreted as a tension vein developed by a component of sinistral (left lateral) strike slip movement on the corridor of NE fractures (figure 2). Similarly, the mine workings in level 10 display a change in direction where mineralisation is localised in a NNE trending flexure in a throughgoing NE fault. The lode here is much wider and contains numerous open spaces, some lined with coarse crystalline quartz.

Thus, it is interpreted that in an environment of overall listric fault related extension, a transient component of left lateral (sinistral) strike-slip movement, has localised ore shoots within NNE trending portions of the general NE fractures which also host mineralisation in steep dipping portions (figure 2). Continued exploration should be mindful that:

- Tension veins and flexures which host better mineralisation become progressively reoriented as they are more dilated and mineralised so that the best mineralised veins (DDH07-111) often occur at high angels to the controlling structures which represent the overall structural grain of mineralisation, and hence parallel to the drilling direction (figure 2; Corbett and Leach, 1998),
- The corridor of NE structures might become less well mineralised in settings of flatter dips.

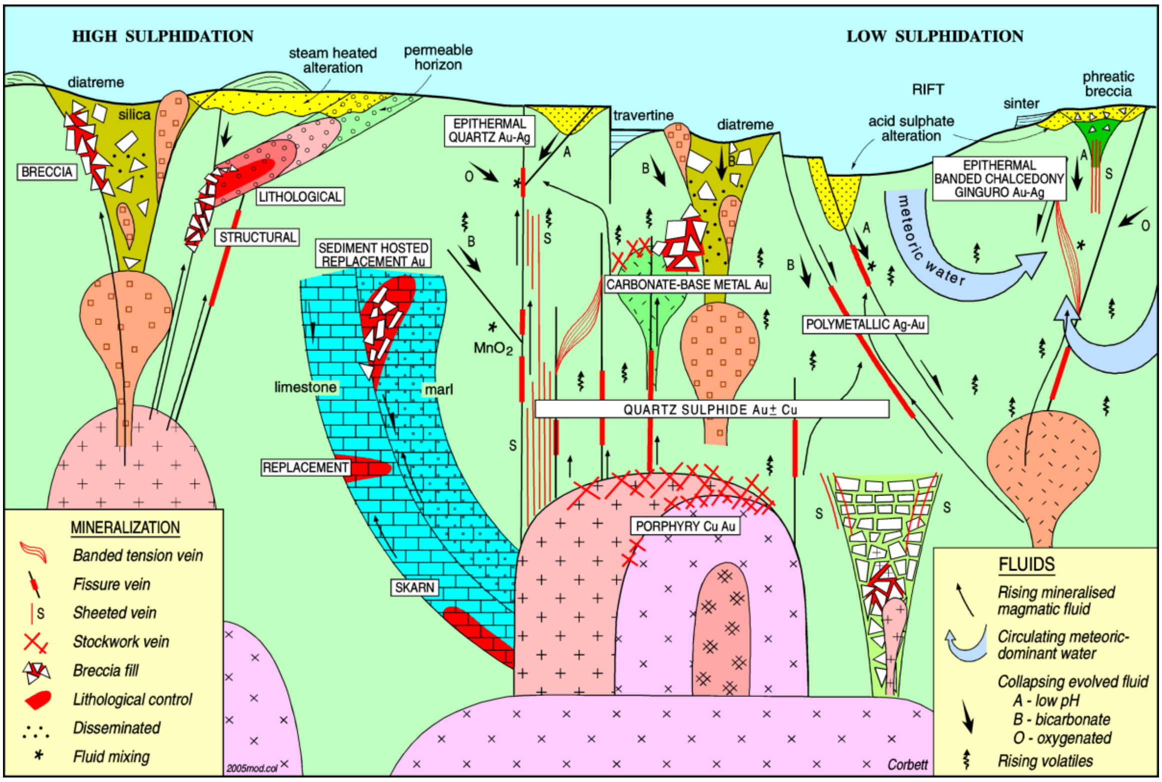

Figure 3. Model for the varying styles of Au-Ag mineralisation encountered in magmatic arc ore systems.

Style of mineralisation

Mineralisation at Tahuehueto is classified as of the intrusion related epithermal low sulphidation polymetallic Ag-Au style (Corbett, 2002, 2004, 2005, 2007; figure 3) and so Au and Ag are accompanied by Cu, Pb and Zn mineralisation. Polymetallic Ag-Au mineralisation displays pronounced zonation in time and space with considerable variation between deposits according to the crustal level of formation. The Tahuehueto project is characterised by a pronounced multiplicity in hydrothermal events, in which zonation typical of this style of mineralisation (figure 4) is discernible over the roughly 1 km of vertical exposure.

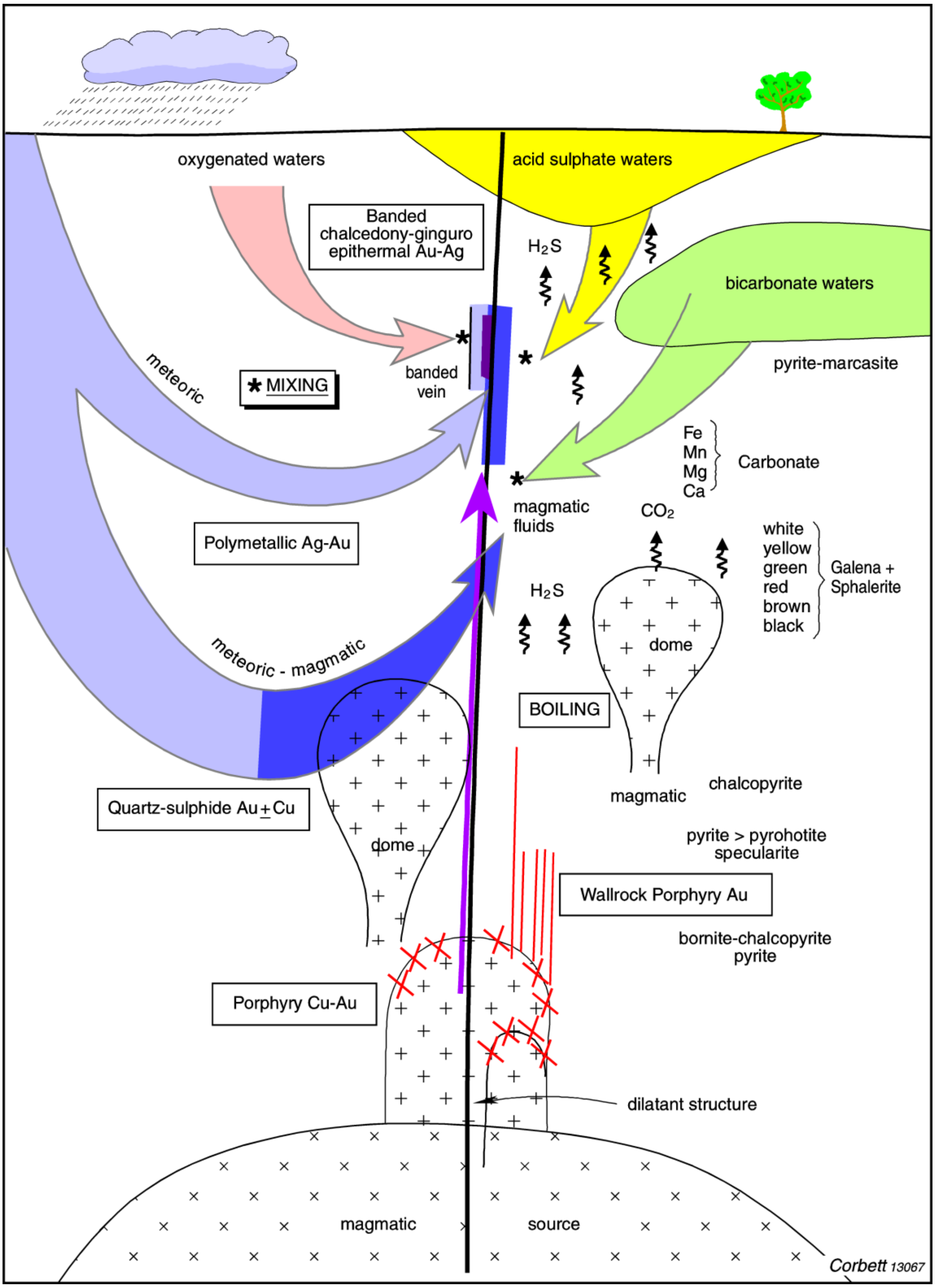

Figure 4. Vertical zonation in low sulphidation polymetallic Au-Ag deposits.

Styles of mineralisation identified at Tahuehueto during this review include:

- Initial pervasive propylitic-potassic alteration with local specular haematite has developed as an intrusion-related alteration product, described in detail below.
- Early chalcopyrite-pyrite mineralisation (photo 3), locally with quartz-barite, which has been deposited early at Tahuehueto is equated to the quartz-sulphide Au + Cu end member (in the classification of Corbett and Leach 1998) and typically forms early and at deeper crustal levels in polymetallic Ag-Au vein

systems (Corbett, 2007). As evident in the specimen in photo 3, pyrite-chalcopyrite mineralisation is expected to contain low to moderate grade Au-Ag (1.68 g/t Au, 160 g/t Ag), but is generally not a major contributor to the overall metal budget.

- Polymetallic Ag-Au mineralisation comprising pyrite-galena-sphalerite ± chalcopyrite ± Ag sulposalts ± barite represents the volumetrically most apparent mineralisation and displays pronounced vertical variation discerned as changes in the sphalerite colour from dark Fe-rich high temperature sphalerite formed early and at depth (photo 4) varying vertically and later from brown to red, and the most common yellow sphalerite (photo 5), then the less common white sphalerite as the Fe-poor low temperature end member, which typically develops at higher crustal levels and is clearly later stage at Tahuehueto. Much of this mineralisation occurs as sulphide lodes (photo 4) or breccia infill (photos 5 & 6). Bulk lower grade ore occurs as fine grained Au and Ag sulphosalts deposited within base metal sulphides as part of the main polymetallic mineralisation, rising to higher grade Ag with increased base metal contents (DDH07-85, 81.5m, 4.6g/t Au, 621g/t Ag, 3.15& Cu, 2.36% Pb & 12% Zn; photo 4). Importantly, these ores evolve to ore with a more epithermal character and locally higher Au-Ag grades at later stages where base metal sulphides are overprinted by Ag tetrahedrite (DDH07-111, 88m, 0.74g/t Au, 19.9g/t Ag, 0.07% Cu, 1.4% Pb & 5.3% Zn; photo 5 and DDH07-111, 80m, 1.2 g/t Au, 207.3g/t Ag, 1.33% Cu, 23.7% Pb & 4.61% Zn; photo 6).
- Highest Ag-Au grades locally occur in the absence of Cu-Pb-Zn in ores described as the epithermal end member of polymetallic Ag-Au mineralisation which is strongly structurally controlled and occurs as several variants.
    - In individual hand specimens where galena occurs with lower temperature yellow sphalerite, massive freibergite (Ag tetrahedrite) may be deposited after the base metal sulphides as part of a continuous paragenetic sequence (photo 6).
    - Freibergite also occurs within quartz in the absence of earlier sulphides, but locally with barite is an important contributor to the development of bonanza Ag grades (DDH 101, 125m; 4.06 g/t Au, 686 g/t Ag, 0.04% Cu, 0.62% Pb, 0.87% Zn; photo 7). In the oxide zone tetrahedrite is apparent as a black sulphide rimmed by secondary Cu (photo 8).
    - High grade Ag may occur as freibergite with celadonite in combination with white sphalerite, dark chlorite commonly with later stage opal-chalcedony (DDH 113, 42.5m; 35.1g/t Au, 480.2g/t Ag, 0.03% Cu, 0.47% Pb & 0.87% Zn; photo 9 and DDH 63, 170.4m, 14.45g/t Au, 41.9g/t Ag, 0.30% Cu, 0.83% Pb & 1.52& Zn; photo 10). The Ag-rich mineralisation may appear as simply fine black material within cedadonite-opal.
    - Semi-massive to banded chlorite locally occurs with celadonite-pyrite-opal and displays elevated Au with significantly lower Au:Ag ratios. (DDH113, 45m, 16.0g/t Au, 30.30g/t Ag, 0% Cu, 0.1% Pb & 0.24% Zn; photo 12; DDH113, 47.5m, 13.1g/t Au, 12g/t Ag, 0% Cu, 0.1% Pb & 0.2% Zn; photo 13). Banded opal-chlorite is well developed in DDH07-81, although supergene enrichment (below) may have remobilised Au and Ag within the mineralised zone (photo 14). Note also the late stage chlorite deposition in photo 6. This variant represents a transition to a chlorite dominant high Au fineness style of mineralisation probably dominated by electrum rather than freibergite and is therefore related the epithermal quartz Au-Ag end member of intrusion related low sulphidation

mineralisation (in the classification of Corbett and Leach, 1998), as recognised elsewhere in the Pacific rim (Porgera).

- Au-rich high fineness mineralisation recognised in DDH11, 107m (photo 15) in the footwall of the main mineralised zone comprises very yellow high fineness (low Ag) Au within sphalerite, calcite and pyrite adjacent to and within a shear. This mineralisation is correlated with the low sulphidation epithermal quartz Au-Ag style (in the classification of Corbett and Leach, 1998; figure 3) typically developed as a fluid evolution of quartz-sulphide ores (Pound Mountain). In this specimen it is interpreted to overprint the polymetallic sphalerite, pyrite, calcite etc, and to have been localised by a shear with additional pink secondary Kfeldspar (possibly adularia) alteration (photo 16).
- Hypogene haematite occurs with banded quartz as an epithermal assemblage which accounts for elevated Au grades overprinting earlier sulphide rich mineralisation (described below).

Aspects of a paragenetic sequence are discernible at Tahuehueto, although complicated by the presence of numerous overprinting events of alteration mineralisation. There is an overall progression to lower temperature polymetallic mineral assemblages with time as described above. Sulphides grade from early chalcopyrite rich, through progressively more pale sphalerite which overprints earlier dark sphalerite, and then later stage tetrahedtrite, while the gangue becomes enriched in low temperature opal and calcite in the later stages. Other variations are apparent between prospects at varying topographic levels such that deeper level projects such as Cinco de Mayo which contains higher temperature minerals and low temperature minerals dominate at the Santiago prospect (described below). Hypogene kaolin locally overprints earlier Kfeldspar and sericite as well as sulphides and is inturn overprinted by very last stage calcite (photo 17), although brecciation and silicification continued after calcite deposition.

Mechanism of Au deposition

More efficient mechanisms of Au deposition account for the development of elevated Au grades in polymetallic Ag-Au deposits (Corbett, 2007) and are discernible at Tahuehueto as:

- Cooling of magmatically derived ore fluids transported rapidly to elevated crustal settings including with local interaction with wall rocks or deep circulating ground waters is interpreted to account for much of the metal deposition at Tahuehueto. The presence of late stage opal in association with particularly the more epithermal higher Au and Ag grade mineralisation (above) supports the low temperature for mineralisation deposition (photos 6, 9, 10 & 11).
- Boiling is not considered an important mechanism of ore minerals.
- Hypogene haematite noted within late stage banded quartz (photos 4 & 21) is typical of oxidising conditions resulting from the mixing of ore fluids with shallow meteoric waters, which destabilise the complexes carrying Au and accounts for the deposition of elevated Au grades (Corbett and Leach, 1998). At the Topia deposit 25 km south of Tahuehueto, Locke et al (1998) describe oxidising conditions above the flat dipping ore zone and non-oxidising below, consistent with the deposition of precious metals by the mixing of rising ore fluids with collapsing oxidising ground waters. Hypogene haematite also occurs in the outcropping Santiago veins.

- Bicarbonate waters, common in the upper portions of many polymetallic Au-Ag deposits, may mix with rising ore fluids and result in the deposition of elevated Au grades, evidenced by mixed Fe-Mn-Mg-Ca carbonates within the ore assemblage, Mn carbonate in particular (Corbett and Leach, 1998; Corbett, 2007). Rhodochrosite is noted immediately above (DDH07-111, 78.4m; photo 18) and within a high grade Au intercept may be associated with a mixing mechanism of Au deposition (DDH07-111 78.8-79.3m, 110.4g/t Au, 579.7g/t Ag, 6.07%Cu, 16% Pb, 2.63% Zn; photo 19), although the elevated Ag here may lie within the abundant galena. Elsewhere MnO recognised in the mine workings is indicative of this mechanism of Au-Ag deposition, and MnO-$MnCO_3$ are noted in association with mineralised intervals in DDH's 07-85, 07-113.
- Kaolin noted in drill core, cut by later calcite as a demonstration of a hypogene character, has been deposited by collapsing low pH waters, which could also mix with ore fluids and result in the deposition of elevated Au grades. As with the weakly acidic bicarbonate waters, to low pH waters oxidise and so destabilise the complexes carrying Au and result in Au-Ag deposition. In other low sulphidation epithermal systems this mixing reaction accounts for the development of highest precious metal grades. An example of this reaction is recognised in DDH 06-63, 163.8-164.59 metres where a quartz breccia with white sphalerite and tetrahedrite is cut by banded chalcedony containing celadonite-kaolin infill and displays elevated precious metal grades of: 32.83 g/t Au, 72.4 g/t Ag, 0.35% Cu, 2.2% Pb, 2.2% Zn. Kaolin occurs above the high grade Au intercept of 28.63 g/t Au recognised at DDH07-111, 107m (photos 15-16) and may have been involved in the deposition of this mineralisation. Continued exploration should be mindful of the importance of acid sulphate caps as evidence of collapsing low pH waters which facilitated the development of high Au grade mineralisation.

Supergene enrichment

As typical of the upper oxidised portions of most epithermal low sulphidation polymetallic deposits some metal remobilisation is recognised at Tahuehueto. Although also discernible in the mine workings, supergene effects are most easily analysed in the assay data for drill hole DDH 07-81 from the upper portion of El Creston. The transition from oxidised to fresh sulphides occurs at about 37 metres down hole. Above this point low Ag:Au ratios and low Zn contents are indicative of supergene leaching of Ag and Zn in the oxidised zone. Au concentrates at the base of oxidation (average 11.71 g/t Au for 34.95-38m), while Ag and Cu, overprint existing sulphides below the base of oxidation and so are enriched. Ag increases dramatically from averages of 39.1 g/t for 34.95-37m to 270 g/t for 37-40.05m. Consequently, some supergene Au and Ag enrichment can be anticipated at slightly different levels during continued exploration at Tahuehueto.

Dilution

Many low sulphidation Au-Ag deposits are characterised by the interaction of a variety of hydrothermal fluids to form banded veins (Corbett, 2007; figure 5). While the collapsing near surficial oxygenated, bicarbonate and low pH waters are described above, rising hydrothermal fluids include:

- Shallow circulating meteoric waters which deposit clean barren quartz,

- Mixed meteoric-magamatic waters derived from the contact of deep circulating meteoric waters with intrusion source rocks for metals which deposit low grade Au-Ag mineralisation, and
- Magmatic derived fluids which deposit most Au-Ag mineralisation in association with sulphides.

In some systems mineralised veins may be diluted by addition of excessive late stage clean quartz deposited from meteoric waters (photo 14) or calcite from neutral bicarbonate waters (photo 17). Although present the effects of dilution at Tahuehueto are not presently pronounced, but continued exploration should be aware of this possibility.

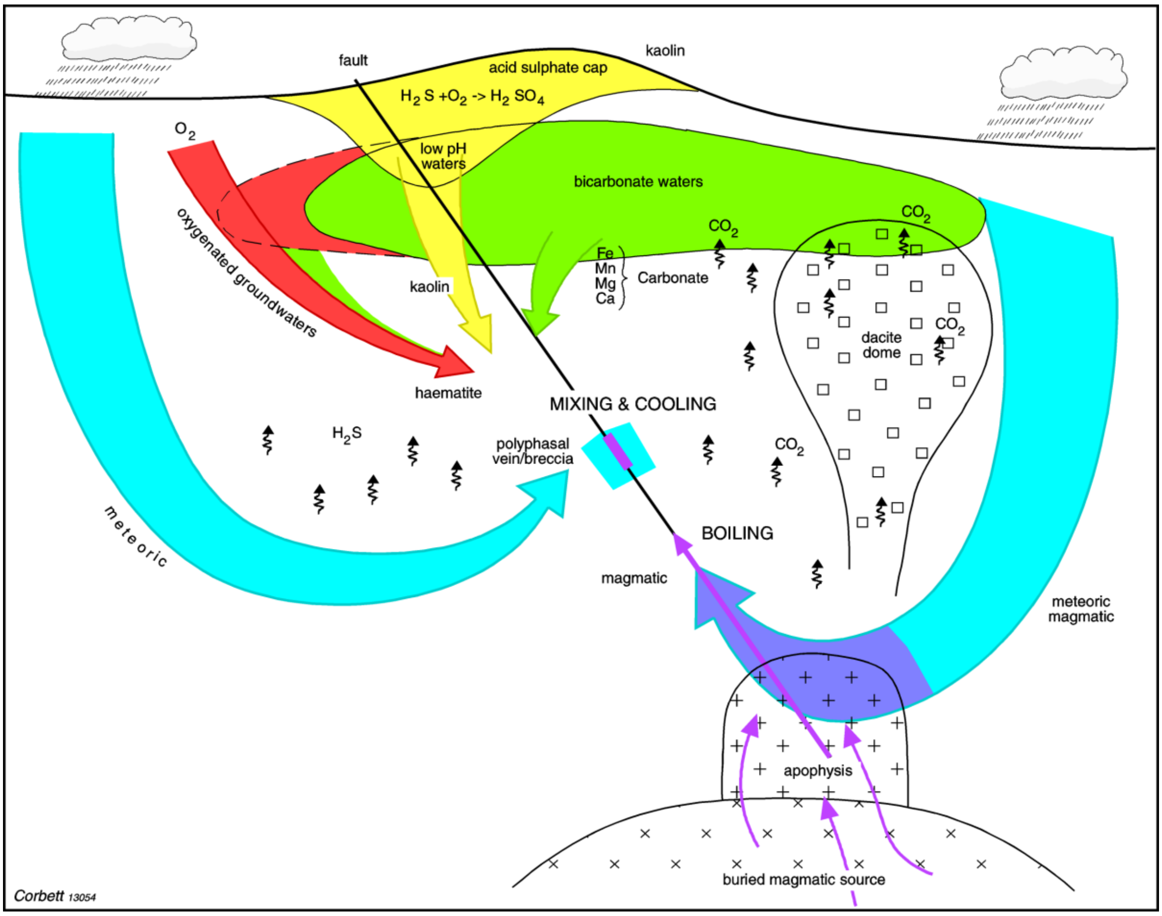

Figure 5. Styles of hydrothermal fluids discernible in low sulphidation epithermal Au-Ag deposits.

Hydrothermal alteration

Hydrothermal alteration, typically within the wall rocks is zoned according to crustal levels and laterally within low sulphidation deposits and may be used to vector towards mineralised veins (Corbett and Leach, 1998).

Hydrothermal alteration at Tahuehueto displays characteristics of alteration grading from higher crustal level epithermal to underlying porphyry conditions at deeper levels of exposure, along with a late stage pronounced collapse of near surficial low pH waters, which is locally associated with high grade Au-Ag mineralisation. Wall rock alteration occurs primarily as chlorite-carbonate ± pyrite ± specularite propylitic alteration varying to rare vein selvage epidote, indicative of locally higher temperature conditions. At deepest levels (DDH 85) magnetite is recognised within the propylitic alteration, while a magmatic hydrothermal breccia also contains disseminated tourmaline (photo 22). Potassic alteration occurs as Kfeldspar flooding of many dykes (photo 2), well developed as vein selvages and at deeper levels (DDH 85) Kfeldspar alteration of magmatic hydrothermal breccia clasts or wall rocks (photo 22). In the El Creston adit levels and much of the drill core, primary feldspar is replaced by retrograde illite which varies to sericite in outcrops close to Cinco de Mayo and in the lower portions of DDH 85 (photo 24). This argillic alteration, which is accompanied by disseminated pyrite, overprints the chloritic propylitic alteration as typical of most low sulphidation vein systems and displays variation in crystalline from higher level less crystalline illite to deeper more crystalline sericite. The illite should grade to less crystalline (illite and illite-smectite) forms in more distal settings to the vein in lower temperature settings, and this zonation can be used to prospect for vein systems within higher temperature alteration (Corbett and Leach, 1998). As typical of near porphyry environments, in the deepest drill hole (DDH07-85) Kfeldspar is overprinted by sericite (photo23), also apparent in outcrop near the El Burro mine workings.

Celadonite (a laminated hydrous Fe, Mg, K silicate of the mica group) alteration is present in association with the epithermal Ag mineralisation (photos 9-11) at Tahuehueto and common as a wall rock alteration mineral in many other polymetallic Ag-Au low sulphidation epithermal deposits, commonly in association with later stage higher Au-Ag mineralisation. Continued exploration should be mindful that wall rock celadonite alteration provides a vector towards mineralised veins.

Kaolin recognised in many drill holes is interpreted to have been deposited from low pH waters collapsing from a now eroded near surficial acid cap and where cut by later calcite veins can be demonstrated to be of hypogene origin. Kaolin overprinting the shingle breccias present in a deeper level drill hole (DDH07-81, 71m; photo 24) is indicative of collapse of near surficial waters to a very deep level (in the order of 1 km) in the hydrothermal system no doubt aided by open space breccias and dilatant veins. This telescoping of low temperature high crustal level alteration upon deeper level features is recognised in analogous geothermal systems as a result of fluid draw down as the buried intrusion heat source cools (Corbett and Leach, 1998). Continued mineralisation during uplift and erosion may also account for telescoped mineralisation of this nature.

Buried porphyry

Low sulphidation epithermal polymetallic Au-Ag deposits are interpreted to have been derived from porphyry intrusion source rocks at depth, and locally occur marginal to porphyry Cu-Au systems (Bajo de la Alumbrera, Argentina). Although not currently regarded as a high priority target, the increase in alteration temperature at deeper levels in the Tahuehueto hydrothermal system (above) provides evidence of a porphyry intrusion at depth. In surface exposures at lower topographic levels and hence deeper levels in the hydrothermal system, illite changes to sericite and Kfeldspar becomes more abundant within the dykes at El Burro (photo 2) than at El Creston. Similarly, in DDH 85 one of the deeper drill holes, a magmatic hydrothermal breccia contains potassic alteration within rucked up clasts (from 82.8m) in a chlorite-magnetite-tourmaline propylitic altered matrix (photo 22). Shingle breccias (DDH07-85, 69-77m; photo 24) which are normally associated with intrusion-related collapse (Corbett and Leach, 1998), also provide evidence of a closer association with an intrusion at deeper levels within the Tahuehueto hydrothermal system. Tourmaline recognised in the magmatic hydrothermal breccias is an important associate with magmatic source rocks. Wall rocks display sericite alteration (photo 23) and the magmatic hydrothermal breccia exhibits higher temperature magnetite-bearing propylitic alteration than recognised at upper levels of El Creston.

Continued exploration at Tahuehueto should be aware of the potential for the development of a porphyry Cu-Au or wall rock porphyry Au-Cu target at deeper levels in the Tahuehueto hydrothermal system and regionally. Sheeted (parallel) porphyry B style veins with centrally terminated comb quartz with central sulphides commonly occur as wall rock porphyry mineralisation overlying mineralised porphyry intrusions in dilational structural settings.

At Topia 25 km south of Tahuehueto, Locke et al (1998) suggest that granodiorite magmatism and mineralisation occurred about 43-46 m.y. and that ignimbrite eruption began at 37.9 m.y., which is significantly older that this authors understanding of the ignimbrite flare up in this region as about 30 m.y. Nevertheless, the model proposed herein is that mineralisation is related to a buried porphyry Cu-Au style intrusion source and that some of the altered dykes recognised in outcrop might be derived from such an intrusion so that there could also be a relationship between the magmatism responsible for ignimbrite deposition and mineralisation, as speculated for elsewhere in the Sierra Madre. At Tahuehueto veins partly penetrate the overlying ignimbrite, consistent with a speculated similar age.

Breccias

Breccias are an integral part of the Tahuehueto hydrothermal system and display several genetic styles:

Fluidised breccias are typically characterised as mediums of ore fluid introduction in which there is discernible transport of the sulphide matrix while the clasts display significantly less transport (Corbett and Leach, 1998; photo 25). Many of sulphide lodes are brecciated and display sulphide transport textures and so could be included in this category (photo 26). However, mineralised fluidised breccias at Tahuehueto are transitional to the milled breccias in that generally angular moderately transported sulphide clasts are present (photo 27).

Milled breccias are those in which the clasts have undergone significant working while being transported from deeper to elevated crustal settings. These breccias typically contain rounded clasts in a matrix of milled rock flour which has undergone hydrothermal alteration (silicification at Tahuehueto). Banded breccia in fill is consistent with the polyphasal activation of these breccias (photo 30). At Tahuehueto the milled breccia display polyphasal activity and commonly contain rucked up mineralised sulphide clasts which have been transported from deeper levels in the breccias (photos 28-31). The footwall of El Creston contains a polyphasal milled breccia in which low temperature quartz is indicative of an elevated crustal level or late stage of formation (photos 29 & 30). The late stage of formation is further supported by the presence of angular clasts of calcite which normally occurs as the last vein event (photo 32). These breccias commonly contain sedimentary structures formed at a subsurface setting in originally open faults and provide another indication of the dilational nature of the Creton Fault footwall at the time of breccia formation (photo 31). These structures are only preserved because this breccia is a late stage of hydrothermal activity which has not been rebrecciated, and represent part of the manner in which the Creston fault is 'growing'in the footwall, as recognised by this author in other Mexican polymetallic Au-Ag vein systems.

Expansion breccias are breccias in which the clasts have been moved apart and then in-filled with hydrothermal minerals such as carbonate or quartz resulting in a mosaic or jigsaw pattern (photo 33). These are typical in dilational structural settings such as at Tahuehueto.

Magmatic hydrothermal breccias typically occur in near porphyry environments and contain clasts of porphyry intrusions and alteration in a milled matrix, each with hydrothermal alteration typical of near porphyry environments. The magmatic hydrothermal breccia cut by DDH07-85 (85m, photo 22) contains rucked up Kfeldsapr altered clasts in a chlorite-magnetite-pyrite altered matrix with local fine tourmaline rosettes, indicative of an intrusion association. These breccias form by magmatic volatiles venting explosively from intrusion source rocks at depth and often precede mineralisation (Kidston in Corbett and Leach, 1998).

Shingle breccias are defined as having elongate parallel shingle like clasts and are considered (Corbett and Leach, 1998) to have formed by collapse following the explosive escape of volatiles from an underlying magma chamber. In the tourmaline Cu-Au deposits of Chile-Peru and elsewhere brecciation is followed by emplacement of mineralised sulphides. Therefore these breccias in DDH07-85 (71m, photo 24) are indicative of a setting which is expected to lie above an intrusion.

Comments on specific prospects

Cinco de Mayo occurs as the deepest crustal level investigated in this review, by inspection of the adit and DDH 85, where alteration and breccias (below) are indicative of a buried porphyry. Mineralisation examined in a NE trending lode exposed in underground workings and DDH 85 is dominated by higher temperature polymetallic chalcopyrite-brown sphalerite grading to yellow sphalerite and locally contains an epithermal overprint characterised by banded comb to chalcedonic quartz with hypogene haematite with which higher grade Au is interpreted to be associated (4.6g/t Au, 621g/t Ag, 3.15& Cu, 2.36% Pb & 12% Zn; photos 20 & 21). Whereas most Au-Ag occurs in association with base metal sulphides, Au is locally elevated (10 m @ 29.87 g/t Au) without an accompanying rise in base metal sulphides. The hypogene haematite mineralisation is well developed within floating clast breccias comprising banded quartz deposited in open space, typical of active fault structures (photo 20).

El Creston represents the main ore system which has been subject to most exploration to date. Here, a roughly NNE trending zone developed with an angular relationship to the controlling NE trending structural corridor is dominated by brittle feldspar porphyry into which has been emplaced overprinting events of quartz-sulphide brecciation and associated quartz veins (figure 2). Varying styles of mineralisation described above include polymetallic sulphide lodes with significant Au-Ag credits (photo 4), and higher precious metal grade, either Ag (photo 7) or Au (photo 15) rich epithermal mineralisation. While individual paragenetic sequences are difficult to define in conditions of strong overprinting, there is a broad trend from earliest chalcopyrite-pyrite, locally with red-yellow sphalerite-galena, to generally more yellow sphalerite-galena-pyrite with lesser tetrahedrite and later stage pyrite-yellow to white sphalerite with more abundant Ag tetrahedirte and local later stage kaolin (photo 17). Calcite is common as a late stage overprint and post-dates kaolin. Relatively deep oxidation described below is responsible for Au, Ag, Cu and Zn mobilisation and local concentration in association with the base of oxidation.

In many instances milled breccias contain clasts of earlier locally higher temperature polymetallic vein material rucked up from deeper levels in the system and polyphasal breccias are common, but most polyphasal breccias display a gradation from higher temperature to lower temperature assemblages. Similarly, the same structures may be utilised by higher temperature polymetallic and then later lower temperature epithermal mineralisation with more elevated Au-Ag grades. At DDH 111, 79m a massive high temperature polymetallic lode containing abundant chalcopyrite is cut by later locally banded bluish crystalline quartz-chlorite, interpreted as lower temperature mineralisation which accounts for the elevated Au-Ag in this interval (DDH 111, 78.8-79.3m, 110.4 g/t Au, 579.7 g/t Ag, 6.07% Cu, 16% pb, 2.62% Zn), while the adjacent assay interval of the same polymetallic lode is noticeably Au-poor (79.3-80.8m, 1.2 g/t Au, 207.3 g/t Ag, 1.3%Cu, 20.7%Pb, 4.61% Zn; photo 6). Elevated Ag is interpreted to occur within galena.

The footwall of El Creston (DDH 111, 113) is dominated by a strongly polyphasal late stage low temperature very dilatant breccia characterised by a variety of clasts including polymetallic mineralisation in-filled with locally well banded green chalcedony, indicative of the low temperature character. The presence of angular clasts of calcite, which is normally post-mineral, further suggests this breccia is late stage. Subsurface sedimentary structures demonstrate the dilational character in fault structures, preserved in only the late stage events in the footwall. This author has recognised other polymetallic vein systems 'growing' in the footwall in a manner similar to El Creston. It sould be considered during continued exploration whether such a late stage breccia, which is poorly mineralised at the current level lower temperature portion of the vertical body investigated by drilling to date, grades to a higher temperature better mineralised portion at depth.

The Catorce target between El Creston and Cinco de Mayo was briefly examined as DDH 101, much of which bores down a mineralised zone. Several possibilities including a change in strike or dip of the mineralised structure as a flexure or development of a tension vein at a high angel to the controlling structural corridor and hence parallel to the drill direction, could account for the parallelism of the mineralisation to the drill core axis, and this relationship is recognised in many ore shoots in epithermal deposits (figure 2). This situation is common in low sulphidation epithermal veins where high grade mineralisation may occur within tension veins which become progressively reoriented to high angles to the controlling structures and hence sub parallel to the drilling direction during mineralisation (figure 2). Continued evaluation of this target should seek to determine whether this high grade vein occurs within an ore shoot, which might host wider and higher precious metal grade mineralisation. Such a feature could comprise a high priority target. While much of the mineralised intercepted examined in DDH 101 is oxidised and so is dominated by remnant chalcedony to saccharoidal silica with minor adularia and coarse bladed barite within open space quartz, the fresh parts contain white to yellow sphalerite within the quartz and locally abundant ferberite, the Ag tetrahedrite, which accounts for the elevated Ag contents with low base metal sulphides (DDH 07-101, 125m; 4.06 g/t Au, 686 g/t Ag, 0.04% Cu, 0.62% Pb, 0.87% Zn; photo 7). Catorse warrants further consideration for the identification of high Ag grade epithermal mineralisation within a dilational structural setting.

The Santiago area occurs at the highest elevation visited, some 3 km NE of Cinco de Mayo. In outcrop crystalline and chalcedonic quartz veins are consistent with the pronounced overprinting relationships recognised elsewhere at Tahuehueto and hypogene haematite in the chalcedony vein is indicative of the lower temperature epithermal mineralisation with possible entry of collapsed oxygenated ground waters. Drill hole 06-63 bored in this area contains well developed polymetallic and epithermal mineralisation. At 159 metres a drill core parallel fluidised breccia characterised by introduced and milled pyrite, lesser base metal sulphides and broken off local wall rock clasts, is cut by a later open crystalline quartz vein. While some Au-Ag may occur with sulphides, the elevated Au no doubt occurs within the epithermal quartz vein (159.7-160.3m 10.17 g/t Au, 115.4 g/t Ag, 0.31% Cu. 1.44% Pb, 0.87% Zn; photo 25), typical of formation at a higher crustal level lower temperature portion of a polymetallic Au-Ag system . For much of the mineralised interval in drill hole 06-63 (160-170.69 metres, although the drill hole ends in mineralisation) polymetallic breccias are dominated by chalcedony to saccharoidal quartz, varying to crystalline quartz fill of open space and grades to very finely banded opal (photo 10). Elsewhere (166-168m; photo 34), massive chalcopyrite with yellow sphalerite grades rapidly to white sphalerite in hand specimen, which is the dominant sphalerite throughout, commonly in association with tetrahedrite. The progression in silica and sphalerite types, easily observable in single hand specimens, is indicative of rapid cooling of an originally hot ore fluid which is conducive to the development of higher Au-Ag epithermal mineralisation (photo 34). The highest Au assay (163.8-164.59; 32.83 g/t Au, 72.4 g/t Ag, 0.35% Cu, 2.2% Pb, 2.2% Zn) occurs in a quartz breccia with white sphalerite and tetrahedrite cut by banded chalcedony and also containing celadonite-kaolin infill, all indicative of low temperature epithermal mineralisation, similar to the specimen in photo 26.

Further exploration should trace the Santiago vein to depth.

Conclusions

Tahuehueto displays many features typical of epithermal low sulphidation polymetallic Au-Ag mineralisation including pronounced telescoping of lower temperature mineralisation and alteration on much higher temperature deeper crustal level features. Porphyry manifestations include higher temperature propylitic-potassic alteration at deeper levels along with tourmaline bearing magmatic hydrothermal and shingle style collapse breccias. Earlier higher temperature mineralisation with chalcopyrite and brown sphalerite is overprinted by lower temperature more Zn-rich red, then yellow, then white lower temperature sphalerite, the latter in combination with more abundant Ag tetrahedrite, freibergite. Lower temperature epithermal mineralisation occurs as freibergite, the Ag rich tetrahedrite, and also high fineness free Au each overprinting earlier polymetallic mineral assemblages.

One of the outstanding features of the Tahuehueto polymetallic vein mineralisation is the great number of hydrothermal events grading from early high temperature polymetallic and local porphyry associations with higher Cu grades to later stage more epithermal mineralisation with elevated Au-Ag, all telescoped within the same structure. The Creston structure appears to be growing on the footwall side such that breccias there display lowest temperatures of formation. These might therefore be mineralised at deeper levels.

The controls to mineralisation recognised in other low sulphidation epithermal deposits are also discernible at Tahuehueto as:

- More competent host rocks, such as the porphyry dykes, fracture well to host better vein mineralisation, which only partly penetrates the overlying less competent ignimbrite and essentially terminates upward at the incompetent conglomerate base to the ignimbrite.
- As typical of most low sulphidation vein systems both normal and strike-slip fault movement are evident. The normal fault control for mineralisation provides for better mineralisation within steeper dipping fault portions, which may include hanging wall spays. As a result of a component of left lateral (sinistral) movement on the NE trending structural corridor which hosts mineralisation, more dilatant NNE portions of the of the host structures (flexures) or tension veins and splays contain better (wider and higher grade) mineralisation as possible ore shoots.
- Higher precious metal grades occur in the later stage epithermal end member of the polymetallic mineralisation, characterised by more abundant freibergite and locally quite yellow high fineness (low Ag) free Au.
- Improved mechanisms of precious metal deposition account for higher precious metal grades, vary from cooling of the ore fluid to mixing with oxidising ground waters. Best Au-Ag grades accompany hypogene kaolin as evidence of the mixing or ore fluids with collapsing low pH waters.
- Metal redistribution is recognised in the supergene environment as the removal of Ag Zn and Cu in oxidised ores, deposition of Au within FeO at the base of oxidation and Ag and Cu overprinting existing sulphides immediately below the base of oxidation.

Increased porphyry manifestations recognised at deeper levels in the hydrothermal system, as more sericite and Kfeldspar alteration as well as tourmaline-bearing magmatic hydrothermal and shingle collapse breccias, suggest that continued exploration should be mindful of the possibility that porphyry Cu-Au and sheeted wall rock Au-Cu porphyry quartz-sulphide vein mineralisation could occur in the district, at low elevations.

Recommendations

Elevated precious metal grades occur in the later stage epithermal mineralisation as two end members, one Ag-rich with freibergite and one Ag-poor with high fineness free Au, each of which overprint the main polymetallic mineralisation as lower temperature mineralisation. This mineralisation is likely to be well developed within the structurally controlled ore shoots and also possibly at the cooler margins of the hydrothermal system. Each of these settings should be carefully prospected.

Drilling is encouraged to greater depths, as well as along strike, as the low temperature breccias on the footwall side of the main Creston structure may host additional mineralisation at depth as part of the extensive telescoping at Tahuehueto.

Regional prospecting should pay careful attention to any acid sulphate caps evidenced by kaolin-alunite alteration as the near surficial low pH fluids responsible for the development of this alteration result in the development of very high grade Au-Ag mineralisation by the mixing with rising ore fluids. Here hypogene kaolin is discernible in the ore assemblage, typically late in the paragenetic sequence.

Continued drill testing should be mindful that better (wider and higher Au-Ag grade) mineralisation occurs within NNE-NS flexures, splay faults and tension veins developed at an angle to the NE structural corridor which hosts mineralisation and so these better mineralised portions may lie at a very low angle to the core axis.

Continued exploration at lower topographic levels close to the existing focus of drill testing and more regionally should be mindful of the possibility of the identification of porphyry Cu-Au and wall rock sheeted quartz-sulphide vein porphyry mineralisation. Care should be taken that sheeted veins are tested at optimum angles to the drill core axis.

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Photo 1. View of the Tahuehueto project showing the upper ignimbrites and the Creston discernible as a pale ridge in the centre of the photo.

Photo 2. Burro prospect Kfeldspar altered quartz feldspar porphyry dyke.

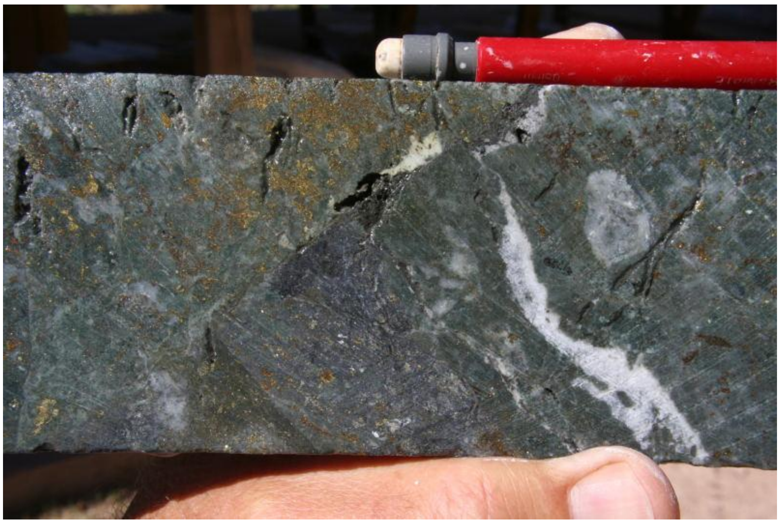

Photo 3. DDH07-111, 75.4m - Milled breccia with chalcopyrite flooding (1.68g/t Au, 160g/t Ag, 3.3% Cu, 0.16% Pb & 2.48% Zn).

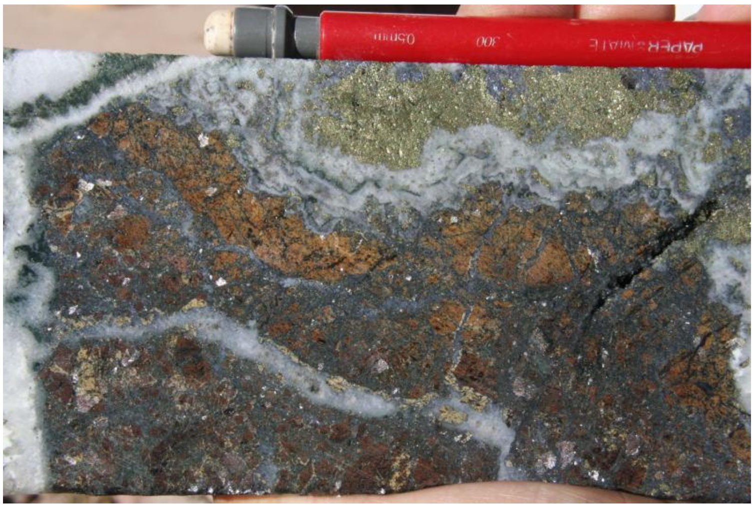

Photo 4. DDH07-85, 81.5m - High temperature polymetallic mineralisation characterised by brown sphalerite which is overprinted by epithermal banded quartz-hypogene haematite (4.6g/t Au, 621g/t Ag, 3.15& Cu, 2.36% Pb & 12% Zn).

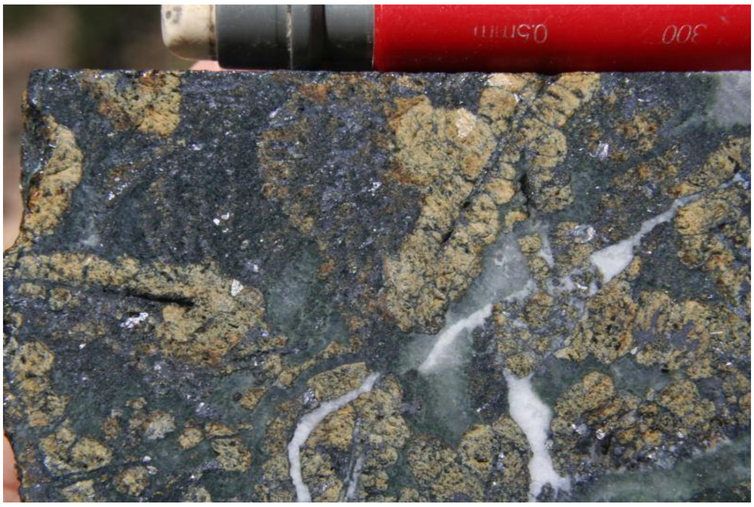

Photo 5. DDH07-111, 88m - Polymetallic vein dominated by yellow sphalerite and galena with later stage tetrahedrite (0.74g/t Au, 19.9g/t Ag, 0.07% Cu, 1.4% Pb & 5.3% Zn).

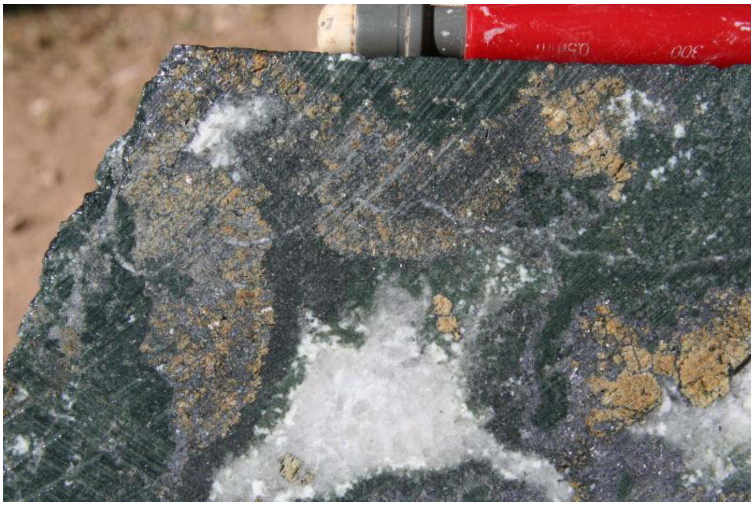

Photo 6. DDH07-111, 80m - Gradation from yellow sphalerite-galena to tetrahedrite then chlorite to quartz epithermal alteration (1.2 g/t Au, 207.3g/t Ag, 1.33% Cu, 23.7% Pb & 4.61% Zn).

Photo 7. DDH07-101, 125m - Breccia comprising quartz and freibergite, the Ag tetrahedrite (3.8 g/t Au, 626 g/t Ag, 0.03% Cu, 0.4% Pb & 0.43% Zn).

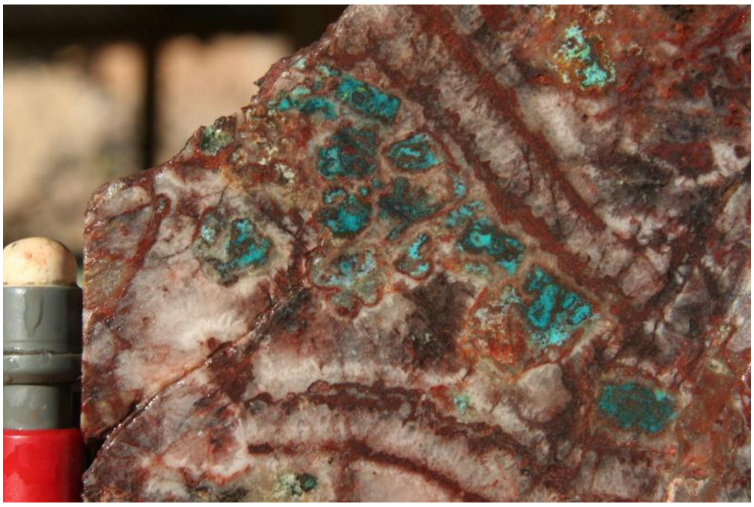

Photo 8. DDH05-20, 265 feet (80.79m) – Secondary Cu in oxidised material as an indication of original tetrahedrite content (1.14g/t Au, 273g/t Ag, 0.06% Cu, 0.45% Pb & 1.77% Zn).

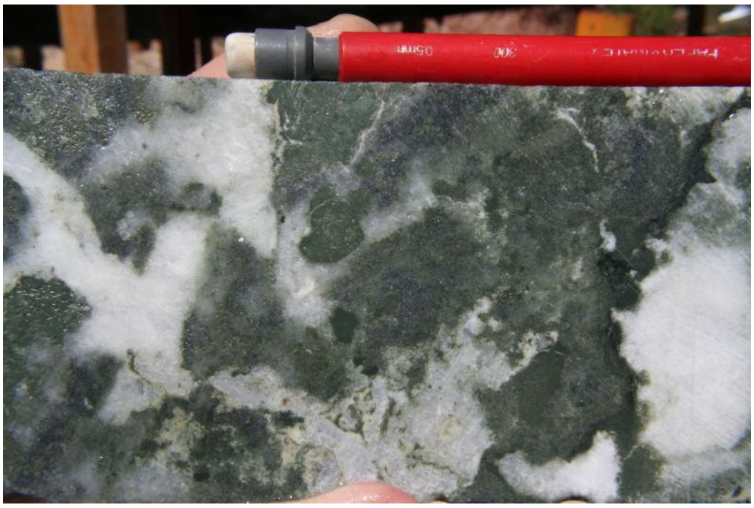

Photo 19. DDH07-113, 42.5m Celadonite and quartz-black silica which contains high grade Ag (35.1g/t Au, 480.2g/t Ag, 0.03% Cu, 0.47% Pb & 0.87% Zn).

Photo 10. DDH06-63, 170.4m - Caladonite with chalcedony-opal from a relatively high grade Ag interval (14.45g/t Au, 41.9g/t Ag, 0.30% Cu, 0.83% Pb & 1.52% Zn).

Photo 11. DDH07-111, 94m - Opal bubbles formed as part of the chlorite-celadonite-opal-Ag event (1.35g/t Au, 23.1g/t Ag, 0.17% Cu, 0.785% Pb & 1.01% Zn).

Photo 12. DDH07-113, 45m - Massive chlorite chalcedony breccia (16.0g/t Au, 30.30g/t Ag, 0% Cu, 0.1% Pb & 0.24% Zn).

Photo 13. DDH07-113, 47.5m - Banded opal within chlorite-celadonite-silica-pyrite alteration (13.1g/t Au, 12g/t Ag, 0% Cu, 0.1% Pb & 0.2% Zn).

Photo 14. DDH07-81, 37m - Banded opal-chlorite assumed to be associated with elevated hypogene Au-Ag now effected by supergene processes and cut by later stage interpreted barren clean quartz (14.6g/t Au, 353g/t Ag, 0.1% Cu, 0.66% Pb, 2.86% Zn).

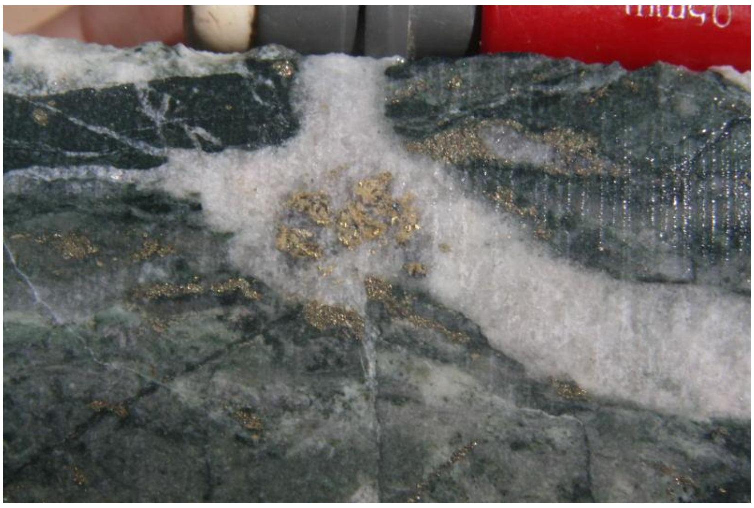

Photo 15. DDH07-111, 107m - Free gold within competent yellow sphalerite extending into the adjacent calcite and interpreted to be related to a late stage shear (28.63g/t Au, 6.2g/t Ag, 0% Cu, 0.08% Pb & 0.2% Zn).

Photo 16. DDH07-111 107m - Shear interpreted to host later stage free Au with possible pink Kfeldspar (adularia) altered andesite dyke clasts (28.63g/t Au, 6.2g/t Ag, 0% Cu, 0.08% Pb & 0.2% Zn).

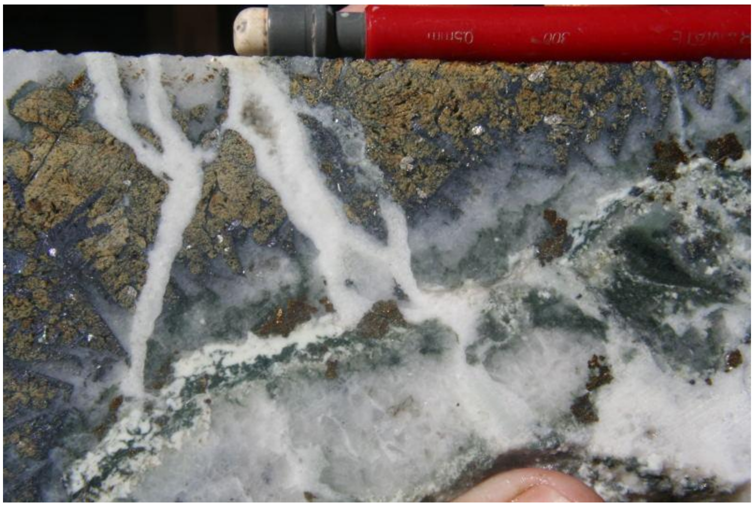

Photo 17. DDH07-111, 89.2m - Quartz-kaolin-sulphide (yellow sphalerite-galena-pyrite) vein in which calcite cuts kaolin demonstrating a hypogene origin of the kaolin.

Photo 18. DDH07-111, 78.4m - Pink rhodochrosite recognised immediately a high grade Au drill intercept (photo 19) as evidence of the mixing of ore fluids with bicarbonate waters as a mechanism of Au deposition.

Photo 19. DDH07-111 78.8-79.3m – Massive sulphide lode which elsewhere contains late stage carbonate here with a more cross cutting aspect. The high Ag man occur within the abundant galena (110.4g/t Au, 579.7g/t Ag, 6.07%Cu, 16% Pb, 2.63% Zn).

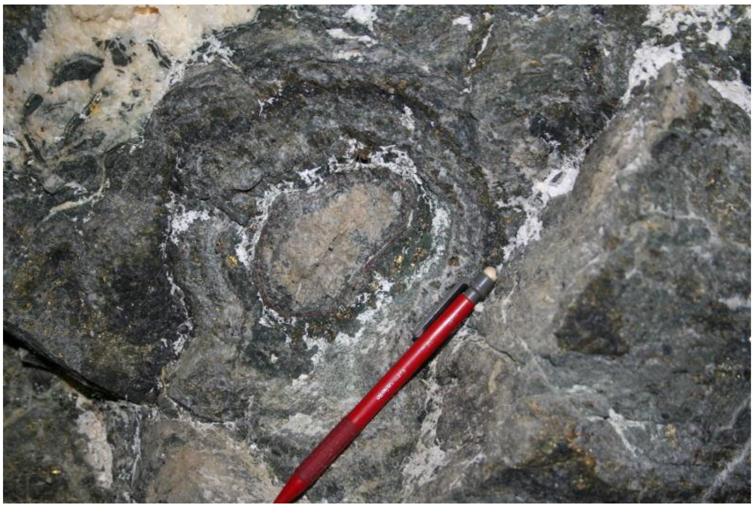

Photo 20. Cinco de Mayo floating clast breccia comprising milled wall rock clasts rimmed by banded silica-sulphides.

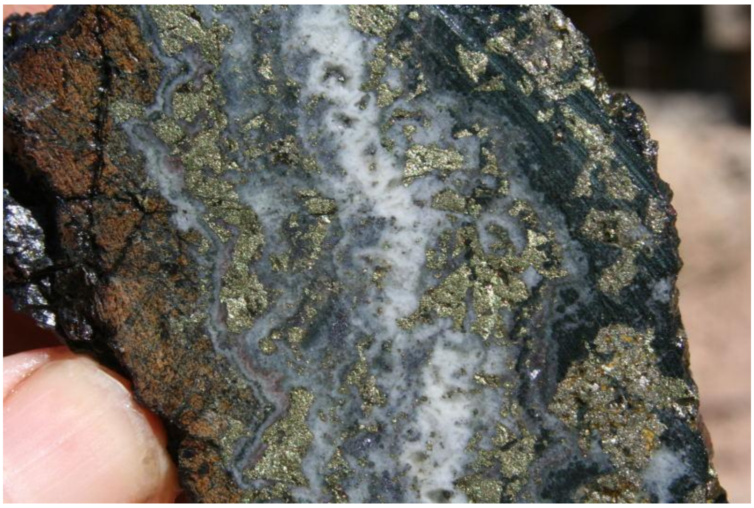

Photo 21. Cinco de Mayo mineralisation varying from left to right as red-brown sphalerite, finely banded quartz-hypogene haematite quartz-pyrite fill breccia and massive chlorite-specular haematite.

Photo 22. DDH07-85, 85.6m - Magmatic hydrothermal breccia with Kfeldspar alteration of clasts and chlorite-magnetite propylitic alteration of matrix with minor tourmaline.

Photo 23. DDH07-85, 89.5m - Relict Kfeldspar alteration overprinted by silica-sericite-pyrite (phyllic) alteration.

Photo 24. DDH07-81, 71m - Shingle breccia with sericite-silica-pyrite clast alteration and later kaolin infill.

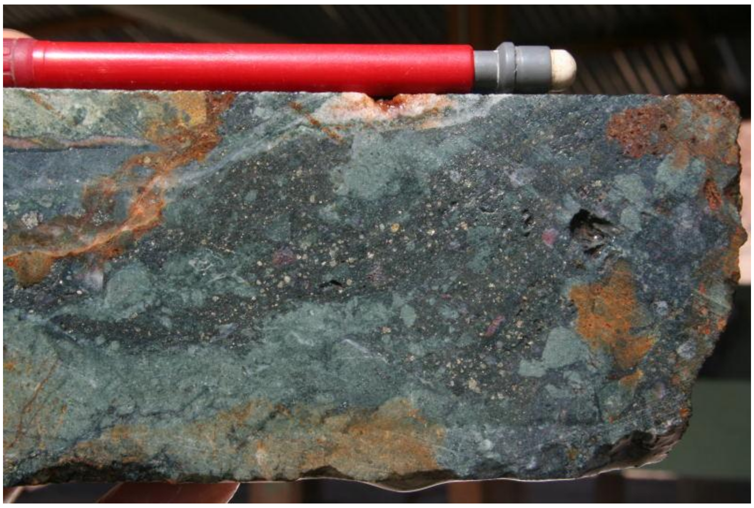

Photo 25. DDH06-63, 159.4m – Core parallel fluidised breccia with rucked up sulphide clasts (10.17g/t Au, 115.5g/t Ag, 0.31% Cu, 1.44% Pb, 0.87% Zn).

Photo 26. DDH07-113, 61.5m - Massive sulphide breccia.

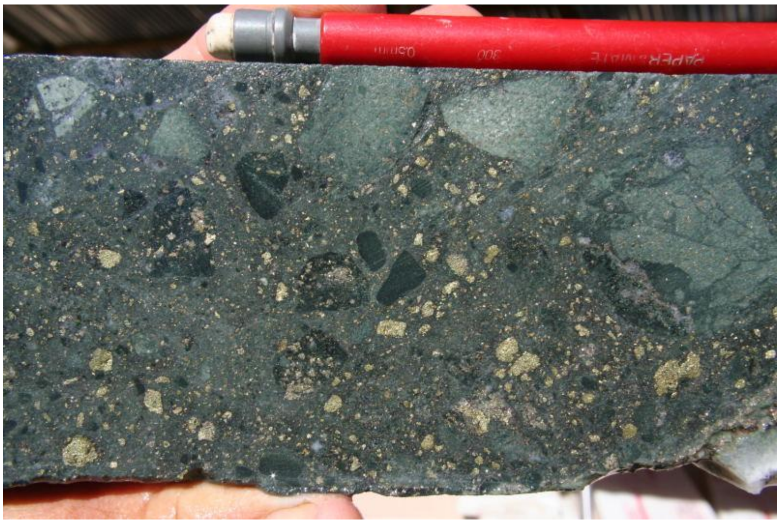

Photo 27. DDH06-63, 169.2m – Milled breccia with sulphide clasts indicative of a very active fault controlled hydrothermal system with substantial clast transport.

Photo 28. DDH07-121, 233.2m - Milled breccia with rucked up mineralised clasts

Photo 29. DDH07-111, 92.8m - Several overprinting breccia events.

Photo 30. DDH07-111, 99.8m - Low temperature floating clast footwall breccia with rucked up clasts and banded polyphasal low temperature quartz infill.

Photo 31. DDH07-113, 76m - Bedded sedimentary structure in footwall breccia

Photo 32. DDH07-113, 74.5m - Footwall breccia showing clast of calcite which is normally very late along with many other rock types.

Photo 33. DDH07-111, 78.2 - Carbonate filled expansion breccia characterised by a movement apart of clasts and later infill.

Photo 34. DDH06-63, 167.4m – Progression from high temperature chalcopyrite to lower temperature banded chalcedony-chlorite (2.77g/t Au, 322g/t Ag, 4.93% Cu, 1.16% Pb, 1.53% Zn).