CONTRASTS BETWEEN SOUTHWEST AND EAST PACIFIC MESO- TO EPITHERMAL GOLD DEPOSITS

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INTRODUCTION

Prior to 1980, when the rise in the price of gold prompted a dramatic increase in gold exploration, Pacific rim geological research and exploration focused upon the search for porphyry Cu-Mo-Au deposits. At this time many workers described all deposits outside the porphyry environment as epithermal. The increased data acquisition during the gold boom of the 1980-90's has facilitated a more detailed classification of magmatic arc gold deposits (Corbett and Leach, 1998) and it is interesting to contrast southwest and East Pacific gold deposits.

A classification of Pacific rim deposit styles derived mainly from studies in the Southwest Pacific rim is based on crustal levels varying with decreasing depth from porphyry, to mesothermal and epithermal; and on fluid chemistry as low or high sulfidation, distinguished by characteristic alteration and ore mineralogy (White and Hedenquist, 1995; Corbett and Leach, 1998).

High sulfidation Au-Ag-Cu

In simple terms, high sulfidation systems develop where, in the absence of significant wall rock reaction, ascending magmatic derived volatiles (SO_2 dominant) condense and evolve into a fluid which then dissociates at shallow levels to form hot acidic fluids. The initial volatile-rich acidic fluid is progressively cooled and neutralised by rock reaction, commonly facilitated by fluid flow within breccias (Lepanto, Philippines; Wafi, Papua New Guinea; Yanacocha) or other permeable host rocks (Pierina; La Coipa, Chile) or dilatant fracture systems (Peak Hill, Eastern Australia; Mt Kasi, Fiji; El Indio, Chile) to form a characteristic zoned alteration which grades from cores to margins as: vughy (residual) quartz, quartz-alunite, quartz-pyrophyllite/kaolinite and illite/sericite-quartz(Corbett and Leach, 1998; Sillitoe, 1999). Gold $\pm$ silver $\pm$ copper mineralization is generally related to later liquid-rich fluid overprint varying from epithermal levels (Peak Hill, Eastern Australia: Yanacocha), to near porphyry (Monwya, Myanmar; Tampakan, Philippines) environments. Higher temperature (with andalusite or corundum) advanced argillic alteration close to porphyry systems may be barren (Horse-Ivaal, Papua New Guinea; Lookout Rocks, New Zealand). Mineralization is associated with pyrite and the copper sulfides varying from enargite at intermediate levels, the lower temperature polymorph luzonite in elevated settings, covellite and/or chalcocite at deeper levels, and more peripheral tennantite. Barite is a common accessory.

Many Southwest and East Pacific rim high sulfidation systems are associated with domes (Mt Kasi, La Coipa) and diatreme/flow dome complexes (Lepanto, Wafi, Yanacocha; Veladero, Argentina) and so the identification of these is an important exploration tool. Brecciated host rocks at the margins of diatremes may be important ore hosts (Lepanto, Wafi). Eastern Pacific high sulfidation systems may be silver rich (La Coipa and Pascua in Chile) whereas those in the Southwest Pacific contain no silver, with the exception of the Wetar (Indonesia), possible exhalative, system. This metal budget may be a function of the greater influence of continental crust in the Andes compared to the oceanic island arcs of the Southwest Pacific. Steam heated alteration caps formed in the vadose zones of high sulfidation systems and comprising opal, powdery alunite, kaolin, sulfur with anomalous mercury but no precious metals, tend to be only well preserved in the arid conditions of the Andes (Pierina, Yanacocha) especially in of Chile-Argentina (La Coipa, Pascua-Lama).

Although high sulfidation systems terminate downwards, many Southwest Pacific rim high sulfidation systems display pronounced lateral fluid flow within permeable horizons (Nena, Papua New Guinea) at the intersection of breccia units (Lepanto) or within breccias (Mt Kasi). Lateral fluid flow is noted in some Andean systems (Pierina) and so interpretation of drilling at depth should be mindful that it is possible to drill under these ore zones. Hypogene oxidation interpreted (Veladero; Lewis, 2000: Pierina, Nobel et al., 1998) to account for elevated gold grades in many East Pacific rim high sulfidation systems is not documented from the Southwest Pacific.

Massive enargite-pyrite veins which are distinguished from classic high sulfidation systems by the lack of vughy silica (e.g., El Indio) occur in the root zones of some high sulfidation systems (Pierina, Volkert et al, 1998) locally overprint (Chuquicamata, Chile) or form peripheral to porphyry intrusions (Poposa, Argentina).

Low sulfidation Au-Ag

Low sulfidation systems are characterized by meteoric-rich (dilute), near neutral pH fluids, in which the magmatic fluid component has undergone significant dilution by mixing with ground waters. Differing styles of mineralization develop as these fluids ascend to higher crustal levels and mix with varying groundwaters (Leach and Corbett, 1995; Corbett and Leach, 1998).

Quartz-sulfide gold ± copper systems are common rimming porphyry intrusions (in the Andes well developed in the Copiapó Region, Chile) or exploiting pre-existing structures (in the Southwest Pacific Adelong, Eastern Australia; Jiang Cha Ling, China; Hamata and Bilimoia in Papua New Guinea) exhumed from deeper crustal levels. Mineral deposition by cooling and mixing with deep circulating ground waters produces veins comprising characteristic quartz and coarse euhedral pyrite. These display good metallurgy and may undergo weathering to produce supergene enrichment in tropical settings (Tawerie Ridge, Sangihe Is, Indonesia). Fine grained pyrite and arsenical pyrite in quenched ore systems may display difficult metallurgy (Kerimenge and Lihir in Papua New Guinea) and so systems formed in elevated crustal settings may display anomalous As. Although predominantly mined for gold, copper may be abundant at deeper levels (Mineral Hill, Eastern Australia) especially as these deposits are transitional to porphyry Cu-Au systems (Cadia, Eastern Australia). Gold mineralization in the Maricunga belt displays similarities to this style. High gold grades occur in dilatant flexures or jogs (Jaing Cha Ling; San Cristobal, Chile) or settings of overprinting carbonate-base metal alteration telescoped from higher levels (Lake Cowal and Kidston in Eastern Australia; San Cristobal).

In the Andes quartz-sulfide gold ± copper deposits are common as veins worked by small miners peripheral to porphyry intrusions. Larger systems in this region include San Cristóbal in Northern Chile (Egert and Kasaneva, 1995), associations with the Maricunga Belt porphyries, La Arena in Peru, and Vueltas del Rio, Honduras (Walford, 2000). Many of these oxidized ores are ideally suited to heap leach operations.

Carbonate-base metal gold systems (Leach and Corbett, 1994; Corbett and Leach, 1998) occur at higher crustal levels than quartz-sulfide gold ± copper systems, and comprise gangue of carbonate> quartz> pyrite> sphalerite> galena> chalcopyrite, typically as fracture/vein/breccias with commonly only minor quartz (Porgera, Mt Kare, Hidden Valley, Kerimenge, Wau, Woodlark Is in Papua New Guinea). Many are associated with domes (Bullawan, Philippines) and phreatomagmatic (diatreme) breccias (Kelian, Indonesia; Acupan, Philippines, Kerimenge, Wau). Others occur peripheral to, or telescoped upon, quartz-sulfide (Lake Cowal, Kidston) or porphyry (Copper Hill, Eastern Australia) systems, and gradations to higher level epithermal systems are common in poorly eroded terrains (Mt Kare, Porgera Zone VII). Structure and zonations in the ore and gangue mineralogy of carbonate-base metal systems can locally provide vectors towards higher gold grades (Kelian and Porgera in Corbett and Leach, 1998). Gold grades may be extremely spotty contributing towards difficulties in ore reserve determinations, and the presence of manganese wad in weathered exposures is indicative of this style of mineralization, particularly where telescoped to form higher grade portions of quartz-sulfide gold systems.

Carbonate-base metal gold systems are the dominant style of gold deposit in tertiary rocks of the Southwest Pacific rim and may therefore warrant further consideration in the East Pacific. Andean systems which display similarities to the carbonate-base metal gold style of the Southwest Pacific rim include Rio de Medio in the El Indio District and Faride in Northern Chile as described by Camus and Skewes (1991). The silver-rich polymetallic veins of Peru and Bolivia and Cu-Au veins of the Farallón Negro Region, Argentina (Sasso and Clarke, 1998) also show some similarities to this style.

Epithermal low sulfidation gold-silver deposits are subdivided (Corbett and Leach, 1998) into those within magmatic arcs which display an association with intrusion source rocks, termed epithermal quartz gold-silver style (Porgera Zone VII, Mt Kare; Emperor, Fiji; Thames, New Zealand) or those developed in back arc basins or rifts in association with veins of quartz, adularia and quartz pseudomorphing carbonate gangue minerals, termed adularia-sericite epithermal gold-silver style (Waihi and Golden Cross in New Zealand; Pajingo-Vera Nancy in Eastern Australia; Hishikari, Sado, Konamai in Japan) with transitional relationships between the two styles (Cracow, Eastern Australia; Tolukuma, Papua New Guinea). Adularia-sericite epithermal gold-silver locally overprints carbonate-base metal (Misima, Papua New Guinea; Karangahake, New Zealand) and quartz-sulfide gold styles (Rawas, Indonesia; Gulbadi at Tolukuma). Although traditional boiling models still hold for the deposition of gangue minerals, mixing with oxygenated or low pH groundwaters is also favored as a mechanism for the development of characteristic bonanza gold-silver grades (e.g., Hishikari, Porgera Zone VII; Corbett and Leach, 1998).

Bonanza gold veins in the El Indio District are classed as epithermal quartz gold-silver style. Although adularia-sericite epithermal gold-silver systems are best developed in back arc settings, the recognition in Northern Chile of the El Peñón vein system possibly of this style, heightens the possibility that like Tolukuma, Toka Tindung (Indonesia) and Cracow in the Southwest Pacific, this style of mineralization may develop in local extensional zones in magmatic arcs.

Although sediment hosted replacement deposits are best developed in the Carlin trend (Nevada) some examples are recognized in the Southwest Pacific (Mesel, Bau, Sepon). Similarly, sediment hosted replacement deposits are reported from localized settings of extension and favorable impure limestone host rocks in the Andes (Gemuts et al., 1996) and so represent a style of mineralization worthy of closer consideration where these conditions prevail.

Conclusion

High sulfidation systems are the major sources of gold mineralization in the Andes, whereas low sulfidation systems are more important in the Southwest Pacific. Factors which may contribute towards these differences include the hyper-aridity and rapid uplift which could restrict the influence of groundwaters in the Andean high sulfidation systems, whereas in some southwest Pacific systems the more abundant groundwaters have encouraged dilution of magmatic fluids to form low sulfidation fluids and also promote mineral deposition by fluid mixing. Low and high sulfidation systems may occur in proximity (Victoria, Lepanto, FSE) with the low sulfidation commonly forming after, and peripheral to, the high sulfidation mineralization (Link Zone at Wafi; Leach, 1999: El Indio). Recent discoveries (El Peñón) demonstrate that the evaluation of low sulfidation epithermal gold deposits should not be neglected.