Alkalic porphyry and epithermal deposits - A view from outside the Macquarie Arc

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Abstract

Alkalic gold-(copper) deposits are of increasing economic significance and are an attractive exploration target. They include some of the world's highest grade and largest porphyry-related gold resources (e.g., Ridgeway: 73 Mt @ 1.76 g/t Au, 0.62 % Cu – 4.1 Moz Au, 0.45 Mt Cu; Ridgeway Deeps: 2.5 Moz Au, 0.28 Mt Cu; Cadia East: 18 Moz Au, 2.9 Mt Cu; Cadia Valley: 281Mt @ 0.64 g/t Au, 0.17% Cu - 5.9Moz Au, 0.48 Mt Cu http://www.newcrest.com.au; Galore Creek, BC: 516.7 Mt @ 0.37 g/t Au, 0.6 % Cu, 4.5 g/t Ag – 6.1 Moz Au, http://www.novagold.net), as well as some of the largest gold accumulations in epithermal settings (Ladolam, ~40 Moz Au; Porgera, ~22.9 Moz; Cripple Creek, ~26.7 Moz; and Emperor ~9.5 Moz).

The alkalic porphyry deposits of the Ordovician Macquarie Arc (Cadia, North Parkes) are NSW's premier gold and copper resources. In addition, Cowal is possibly an example of a deep-level alkalic low sulfidation epithermal gold deposit. A greater diversity of mineral occurrences have been recognized in alkalic provinces elsewhere, and so we review the characteristics and settings of some of the alkalic systems of British Columbia and Papua New Guinea below, in order to stimulate thinking regarding potential new styles of targets and implications for exploration within NSW's Macquarie Arc.

Alkalic Porphyry Deposits

The economic importance of the alkalic class of porphyry deposits to New South Wales is well established with the discovery and exploitation of the Cadia and North Parkes deposits. However, exploration for these targets is difficult because of their small footprint and alteration assemblages that are different in significant details from those characteristic of porphyry Cu deposits associated with subalkalic igneous complexes (Lang et al., 1994, 1995a,b). The alkalic group of porphyry systems are an eclectic group, and styles of mineralisation in the Jurassic oceanic island arc alkalic provinces of British Columbia differ considerably from those discovered so far in NSW.

Mt Polley has proven and probable reserves of 40.98 Mt @ 0.45% Cu, 0.32 g/t Au (0.42 Moz Au), measured and indicated resources (excluding pit reserves) of 79.24 Mt @ 0.35% Cu, 0.29 g/t Au – (0.51 Moz Au) and inferred resources of 27.17 Mt @ 0.30% Cu, 0.29 g/t Au (0.25 Moz Au; http://www.imperialmetals.com). Mineralisation is associated with a monzonitic intrusive complex that appears similar in texture to the Cadia Hill intrusive complex. However, mineralisation at Mt Polley differs markedly from Cadia in that it occurs as several ore zones localised within high-grade magmatic-hydrothermal breccia complexes. Significant breccia-hosted porphyry ore is yet to be discovered in the Macquarie Arc. Mt Polley demonstrates that these alkalic intrusive complexes can produce major mineralised breccia-hosted ore bodies.

Other alkalic porphyry deposits of British Columbia are associated with silica-undersaturated alkalic intrusions that are distinctive in that they lack quartz veins. At Galore Creek, Cu-Au ore occurs in several mineralised zones in association with garnet, anhydrite, orthoclase, biotite and magnetite. Mineralisation is partly hosted within an intrusive complex (monzonite, syenite) that contains approximately 12 discrete intrusive phases, however mineralisation is best developed in

the earliest phases and associated volcanic complex, which are pseudoleucite-bearing. The deposit is distinctive in that it contains abundant melanitic garnet as a vein and alteration mineral, and metal zonation is unusual, with a chalcopyrite core passing through a bornite zone to an outer pyrite zone.

The Lorraine prospect in British Columbia contains at least 32 Mt @ 0.66% Cu, 0.26 g/t Au (0.29 Moz Au; 1998 resource estimate – eastfieldgroup.com/eastfield/nr03-09-24.html. The Lorraine region contain some of the most unusual styles of alkalic intrusion-related mineralisation. The ore zones have characteristics that suggest their formation included magmatic-segregation and magmatic-hydrothermal processes, and elevated PGE contents are distinctive. The Lorraine deposits appear to represent the deepest known level of ore formation in the alkalic porphyry environment.

Mt Milligan is a volcanic-hosted alkalic porphyry system of British Columbia that contains measured and indicated resources of 408 Mt @ 0.18% Cu, 0.47 g/t Au (5.6 Moz Au; placerdome.com. Mineralisation occurs in several ore zones that have distinct Cu-Au ratios. Highest copper grades are associated with chalcopyrite-rich potassic alteration. The highest gold grades occur in the 66 zone, where pyrite is the dominant sulfide.

Mt Milligan and Lorraine are distinct from other alkalic systems in BC in that they formed at approximately 180 Ma during accretion of the oceanic arcs to the northern American continent (Fonseca, 2006). The other alkalic systems of BC formed between 210 and 200 Ma in oceanic island arc settings, demonstrating that it is possible for more that one period of alkalic porphyry mineralisation to occur in an alkalic mineral province.

Alkalic Epithermal Deposits

The alkalic epithermal systems have features similar to the “low sulfidation” family of calc-alkalic epithermal deposits. Discriminating features include the presence of roscoelite (e.g., Porgera, Emperor), and anhydrite (e.g., Lihir, Porgera), and negative sulfur isotopic compositions of sulfide minerals (e.g., Lihir). These features are indicative of oxidation states higher than expected for calc-alkalic LS systems, and potentially providing evidence of a greater magmatic contribution to the alkalic mineralising fluids. As with the calc-alkalic systems, alkalic epithermal deposits are best preserved in younger volcanic arcs, although the alkalic systems occur in association with alkalic igneous rocks, implicating anomalous tectonic processes in their formation.

Papua New Guinea is endowed with spectacular porphyry copper-gold and epithermal gold resources, some of which are alkalic in nature. The Ladolam gold deposit on Lihir Island has a resource of 421.8 Mt @ 2.95 g/t Au (40 Moz Au; http://www.lihir.com.pg) is an epithermal system that formed in the brecciated core of an alkalic volcano that was partly inundated by the ocean during sector collapse approximately 0.4 m.y. ago (Carman, 2003). It is the world’s largest known low sulfidation epithermal gold deposit. Lihir Island is part of the Tabar to Feni chain of Pleistocene alkalic volcanoes that formed on extensional structures that are arc-normal to New Ireland, but which have been reactivated in a back-arc setting during northwards-directed subduction of the Solomon Sea plate along the New Britain Trench (Carman, 2003). Early, pre-breccia mineralisation is of low-grade Cu-Au-Mo porphyry character, whereas high grade gold ores formed first during the transition from the porphyry to epithermal environments (e.g., breccia-hosted Minifie orebody), followed by the development of late quartz-calcite-adularia stockwork veins (Carman, 2003). Lihir is analogous in some ways to the deeper level breccia-hosted ores of Mt Polley.

Porgera occurs in the highlands of PNG, and as of June 2001, it had reserves and resources of 113 Mt @ 3.5 g/t Au, plus an additional 10.3 Moz Au produced since 1990 (total of 22.9 Moz Au; Ronacher et el., 2004). Porgera has a much larger vertical extent of mineralisation than Lihir and contained spectacular high-grade gold mineralisation associated with the Romane fault. Mineralisation occurred at depths greater than normal for epithermal systems (2 – 2.5 km; Ronacher et al., 2004). Ore formed during the intrusion of a series of alkalic intrusions into reduced carbonaceous wallrocks approximately 6 m.y. ago (Ronacher et al., 2002). Early carbonate-base metal sulfide veins are cross-cut by high grade quartz – roscoelite - pyrite gold veins. The early stage veins are comparable to the late-stage carbonate base metal veins that

occur in the North Parkes and Cadia porphyry systems, and are also comparable to the deep epithermal mineralisation that occurs at Cowal. There is no known analogue for the high grade Romane Fault-style mineralisation in NSW.

Conclusions

There is potential for discovery of a greater diversity of alkalic mineralisation styles in NSW, both of porphyry and epithermal character. Epithermal targets are problematic, in that the level of erosion in NSW is such that only deeper styles such as Porgera or Cowal are likely to be preserved. The diverse porphyry-related Cu-Au mineral occurrences of BC are potentially viable exploration targets in NSW, although it is not yet known if silica-undersaturated alkalic complexes formed in the Macquarie Arc.

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