The importance of redox state, sulfur, and water content in the metallogeny of arc magmas

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Most arc magmas are generated by partial melting of hydrated asthenospheric mantle above subduction zones. The flux of volatiles (±melts) from the dehydrating seafloor-altered oceanic slab introduces water, sulfur, and other fluid-mobile components to the overlying mantle wedge. Increased deep ocean oxidation since the Neoproterozoic Oxygenation Event means that this volatile flux transmits the seafloor oxidation signature to the mantle wedge via components such as sulfate and ferric iron. The process is progressive over the life of an arc, such that it may take several millions of years for significant oxidation (and metasomatism) to build up in the mantle wedge and lithospheric magma column. Basaltic magmas from nascent island arcs have tholeiitic character and may not be significantly oxidized (FMQ~0). In more mature island or continental arcs, however, magmas are hydrous, more oxidized (FMQ~1-2), sulfate-rich, and calc-alkaline.

This difference in character fundamentally changes the metallogenic potential of arc magmas. While it has been shown that tholeiitic arc magmas can attain relatively high Cu contents, they will tend to lose metals during saturation in reduced sulfide melts/minerals; in nascent arcs, they also tend to erupt rather than forming shallow crustal plutons. Thus, such magmas have limited potential to form upper crustal porphyry-type magmatic-hydrothermal ore deposits. In contrast, later, more evolved calc-alkaline magmas have greater potential for shallow-crustal ore formation for the following reasons: (1) they have slightly higher oxidation states, close to the sulfide/sulfate transition (FMQ1-2), which reduces the tendency to saturate in sulfide phases and thereby leave metals in resite or deep crustal cumulates; (2) solubility of metals (Cu, Au) and S increases in such magmas with oxidation state over this range (FMQ1-2); (3) their high water content (>4 wt.%) means that these magmas will likely stall in the mid- to upper crust of mature island or continental arcs to form arc batholiths, where they will saturate with water and exsolve a magmatic-hydrothermal volatile phase. Efficient partitioning of metals (Cu, Mo, Au, etc.) dissolved at background magmatic levels into this hydrothermal fluid phase is the critical step in generating upper crustal magmatic-hydrothermal ore deposits such as porphyry Cu-Mo-Au and associated skarn and epithermal Cu-Au deposits.