Reduced I-type magmatism and porphyry Cu-Au mineralization in the west Central Cascades, WA: The ca. 37 Ma North Fork Deposit

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The ca. 37 Ma North Fork deposit (80.4 million tonnes @ 0.44% Cu and 0.1 gram/tonne Au), in the west Central Cascades Range, Washington, is the oldest porphyry Cu-Au deposit in a belt that extends northward into the Coast Mountains of southern British Columbia. In contrast to most porphyry Cu-(Mo-Au) deposits, which are genetically associated with intermediate to felsic, calc-alkaline, I-type magmas that crystallized at oxygen fugacities (fO_2's) ranging between the NNO and HM buffers, the magmas associated with the North Fork deposit are reduced I-types. Quartz monzodiorite and mafic latite porphyry crystallized at fO_2's ranging from the quartz-fayalite-magnetite (QFM) oxygen buffer to QFM+1 and andesites crystallized at fO_2's approximating QFM-1. The magmatic-hydrothermal fluids responsible for the Cu-Au mineralization also record low fO_2's as manifested by veins containing abundant hypogene pyrrhotite but lacking hematite and sulfate minerals. Another major difference between the North Fork deposit and typical porphyry Cu-Au deposits is the thermally prograding nature of the hydrothermal system, from lower temperature Early-stage potassic alteration through to Main-stage sodic-calcic alteration. The prograde evolution and change from potassic to sodic-calcic alteration can be attributed to later batches of magma, with higher Na and Ca activities, exsolving fluids (i.e., becoming fluid saturated) at higher temperatures than earlier batches of magma that exsolved the fluids responsible for potassic alteration. This recognition of reduced porphyry Cu-Au mineralization and related arc magmatism at ca. 37 Ma, highlights the prospectivity of the Mount Persis andesites and raises the possibility that Late Eocene porphyry Cu-Au mineralization may be far more common in the west Central Cascades than has been previously predicted.

New model for the Butte Cu-Mo porphyry and polymetallic vein deposits, and the hosting Boulder batholith, SW Montana, USA

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Recent U-Pb and Re-Os dating of magmatic phases in the Boulder batholith (80-75 Ma) provides insight into the regional geologic and metallogenic history. The well-known Butte deposit contains the youngest magmatic phases in the Boulder batholith (66-60 Ma), with mineralization occurring within a 3 m.y. window (66-63 Ma). In particular, Butte, estimated to have formed at >9 km depth and often divided into pre-Main (porphyry Cu-Mo) and Main (polymetallic Cu-Ag veins) stage mineralization, may provide an analog for the unseen roots of much shallower (2-3 km depth) systems observed in exposed Chilean porphyry Cu-Mo systems (e.g. El Teniente). The tectonic regime for the two localities is markedly different. Nevertheless, both regimes contain an older porphyry-style mineralization catastrophically breached by centrally located polymetallic assemblages emplaced during dramatic change from confined porphyry-style stockwork mineralization to brittle open-space conditions (i.e. rapid uplift). Thus, the high-grade polymetallic veins at Butte may be reminescent of the unexplored lineage feeding late-venting giant breccia pipes in Chilean porphyry deposits (e.g. Braden breccia pipe, >1.2 km diameter, piercing El Teniente).

The Boulder batholith was constructed from ~5 m.y. of incremental melt accumulation that we relate to middle crustal metamorphism. We suggest that the Boulder batholith is a higher level continuum of widespread magmatic exposures to the west, including deeper level equivalents manifested in the Idaho batholith. During Eocene time (~50-45 Ma), the intervening Bitterroot mylonite zone juxtaposed different crustal levels displaying high grade metamorphism-magmatism. Small polymetallic vein deposits occur near the interface irregularly dividing the metamorphic-magmatic batholith from middle Proterozoic metasedimentary host rocks. Molybdenite-bearing leucocratic pegmatites yield ages similar to hosting leucocratic phases of the Boulder batholith. Low Re concentrations in dated molybdenite in both the batholith and the Butte deposit attest to crustal melting without input from the mantle. Thus, the Cu-Mo porphyry deposit at Butte lacks subduction-related Re concentrations seen in large, high-grade Andean porphyry Cu-Mo systems.