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Tectono-Magmatic Precursors for Porphyry Cu-(Mo-Au) Deposit Formation

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Abstract

Porphyry Cu-(Mo-Au) deposits are relatively rare but reproducible products of subduction-related magmatism. No unique processes appear to be required for their formation, although additive combinations of common tectono-magmatic processes, or optimization of these processes, can affect the grade and size as well as the location of the resulting deposits. These various contributing processes are reviewed, from partial melting in the mantle wedge overlying the subducting plate, through processes of magma interaction with the lithosphere, to mechanisms for magma emplacement and volatile exsolution in the upper crust. Specific ore-forming processes, such as magmatic-hydrothermal fluid evolution, are not discussed.

Hot, hydrous, relatively oxidized, sulfur-rich mafic magmas (predominantly basalts) generated in the metasomatized mantle wedge above a subducting oceanic slab rise buoyantly to the base of the overlying crust where they stall due to density contrasts. Because these magmas are oxidized, sulfur is dominantly present as sulfate, and chalcophile elements such as Cu and Au are incompatible (i.e., they are retained in the melt). As these magmas begin to crystallize they release heat which causes partial melting of crustal rocks. Mixing between crustal- and mantle-derived magmas yields evolved (andesitic to dacitic), volatile-rich, metalliferous, hybrid magmas, which are of sufficiently low density to rise through the crust. Magma ascent is driven primarily by buoyancy forces and is dominantly a fracture-controlled phenomenon. As such, crustal stress and strain patterns play an important role in guiding the ascent of magma from the lower crust. In particular, translithospheric, orogen-parallel, strike-slip structures serve as a primary control on magma emplacement in many volcanic arcs worldwide. A feedback mechanism operates, whereby preexisting faults facilitate magma ascent, the heat from which further weakens the crust and focuses strain. Certain structural geometries, such as fault jogs, step-overs, and fault intersections, offer low-stress extensional volumes during transpressional strain. Such sites represent vertical conduits of relatively high permeability, up which magmas will preferentially ascend. Large upper crustal plutonic complexes may therefore be localized within these structural settings. Having delivered a sufficient volume of evolved, fertile arc magma to a focused position in the upper crust, magmatic fractionation, recharge, and volatile exsolution lead to the development of ore-forming magmatic-hydrothermal systems. To a first approximation, the size of the resulting deposit will be limited by the magma volume delivered to the upper crustal magma chamber. System-specific details such as magmatic-hydrothermal evolution, the nature of the country rocks, and subsequent erosional and weathering history will ultimately control the value of the deposit, but these factors fall outside the scope of this paper.

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