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Forming orogenic gold and base metal deposits via metamorphic devolatilization: Thermodynamic constraints

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Metamorphic devolatilization is a widely accepted model for the genesis of orogenic gold deposits and their base metal analogues. The latteroverall have lower economic significance compared to gold deposits. The devolatilization model of orogenic gold is challenged by alternative models involving non-metamorphic ore-fluids, such as exsolved magmatic gas, deeply circulated meteoric water, and mantle-derived fluids. The presence of orogenic-type base metal deposits also seems paradoxical, for base metals (e.g., Cu, Pb and Zn) are thought to complex with chlorine and therefore should be immobile in low-salinity metamorphic fluids. For better understanding of orogenic-type ore-forming process, fundamental knowledge of the chemical mechanism that governs metal extraction during devolatilization is required. To quantitatively constrain the mobility of Au and base metals during metamorphism, we simulated the dehydration process of an Au- and sulfide-bearing pelite within the Al–As–Au–Cl–Cu–Fe–H–K–Mg–Na–O–Pb–S–Si–Ti–Zn system. For the first time, we directly modeled the interaction between silicate solid solutions, sulfide minerals, native gold, and complex aqueous solution. The simulation shows that breakdown of chlorite across the greenschist-amphibolite facies boundary is the key reaction controlling the liberation of water, sulfur, gold and base metals from the source rock. Unlike previously predictions, negligible amounts of S and Au are released at the pyrite to pyrrhotite transition, because the excess sulfurbonds with Fe in silicate minerals and forms more pyrrhotite rather than being liberated into the fluid phase. Up to 2 ppb Au (as a proportion of bulk rock) can be stripped from the source rock by autogenous fluids upon the final decomposition of chlorite. Given that natural pelite has 3 ppb Au on average, metamorphic devolatilization is a highly efficient geological process that scavenges gold from large volumes of source rocks. This underpins the devolatilization model of orogenic gold deposits. In sulfur-rich metamorphic fluids, base metals are largely hydrosulfides (CuHS0, Pb(HS)20, Zn(HS)20) rather than chloride complexes. Trace amounts of base metals can be extracted during metamorphism. For an average pelite containing 45 ppm Cu, 20 ppm Pb, and 95 ppm Zn, small fractions of base metals (up to ~3% of the Cu, ~5% of the Pb, and ~2% of the Zn) will be mobilized upon chlorite decomposition. Mass balance calculation indicates that a medium-sized based metal deposit potentially forms accompanying the formation of a giant orogenic gold deposit.