

Understanding Cu-Au Metallogeny at Convergent Margins: Oxidation of the Sub-Arc Mantle and Genesis of Arc-Related Ore Deposits

Andrea Rielli* Andrew G. Tomkins

School of Earth, Atmosphere and Environment, Monash University, Melbourne, Victoria 3800, Australia

*E-mail, andrea.rielli@monash.edu

An essential ingredient in the genesis of magmatic-hydrothermal ore deposits in arc settings such as porphyry Cu-Au and epithermal Au is thought to be a relatively high oxygen fugacity (f_{O_2}) of the associated magma. The f_{O_2} in magmatic systems controls the speciation of sulfur: at $f_{O_2} > \text{FMQ} + 1.5$ sulfur is present mainly in its oxidized form, and is an order of magnitude more soluble in basaltic melt. This is important for at least two reasons: (1) if the sub-arc mantle is able to melt under oxidized conditions, the resulting magma would more readily dissolve metal-bearing sulfides, allowing for greater Au and Cu in that melt; and (2) in oxidized magmas S saturation cannot be achieved by crystal fractionation alone, so metals are likely to remain in the silicate phase and be available for the hydrothermal stage of the ore-forming process. Theory suggests that fluids liberated from the downgoing slab can oxidize the overlying mantle by introducing oxidized species as S^{6+} , C^{4+} and possibly Fe^{3+} , with apparent influence on the genesis of Cu-Au deposits. However, little is known about the transfer mechanisms of these elements from the slab to the mantle, if and how they modify the redox state of the mantle, and whether any oxidation potential is transferred to basaltic magmas upon melting of metasomatized domains.

To shed light on the role of subduction-related mantle metasomatism in the genesis of arc-related ore deposits, we studied orogenic peridotites from the Western Gneiss Region of Norway. These peridotites are considered portions of supra-subduction mantle that were chemically altered by slab-derived fluids at high to ultra-high pressure. Preliminary results suggest that dissolved sulfate and carbonate were added to the mantle and subsequently reduced to form sulfides and graphite, causing oxidation of the silicate bulk rock via an increase in $Fe^{3+}/\sum Fe$ of mantle Fe. In situ S isotope analyses of metasomatic sulfides by SHRIMP-SI and laser ablation-ICP-MS for PGE concentrations indicate that S was added by slab-derived fluids. Redox budget calculations show that even modest amounts of slab-derived sulfate would cause an increase of f_{O_2} , from depleted mantle values of $\text{FMQ} \sim -1$ to values $\text{FMQ} > +1.5$. Together these results suggest that S (and possibly C) cycling at subduction zones can increase the oxidation state of the sub-arc mantle via metasomatism promoted by slab fluids. This oxidation would greatly enhance the ability of arc magmas to dissolve and transport Cu and Au, increasing their potential for producing economic deposits if emplaced into the upper crust.