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Distinctive Chemical Characteristics and Petrogenesis of Gold-Ore-Forming Arc Magmas

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Arc magmas that exsolve gold-ore-forming hydrothermal fluids are distinguished from infertile ordinary arc magmas by higher contents of lithophile elements that partition strongly into melt relative to residues during partial melting of mantle peridotite. Figure 1A shows published whole-rock analyses representing mafic-to-felsic differentiation series in Phanerozoic gold-ore-productive igneous complexes compared with differentiation series in large arc segments apparently barren of significant hydrothermal gold mineralisation. Due to relative enrichment in mantle-incompatible lithophile elements, gold-fertile magmas have steeper average slopes on mantle-normalised spidergrams (Fig. 1B). The slope can be represented by the ratio of a highly incompatible element on the left (e.g., Ba or Nb) to a less incompatible element farther to the right (e.g., Zr or Y), as illustrated in Figure 1A. Such plots can identify other gold-fertile igneous complexes and arc segments as exploration targets. Spidergram trends of metasomatically “refertilised” average subcontinental lithospheric mantle worldwide diverge leftward from the average asthenospheric mantle (NMORB source) in the same sense as the divergence between gold-fertile and gold-infertile mafic arc magmas in Figure 1B. This is evidence that melting of old metasomatic veins in lithospheric mantle is important in the petrogenesis of gold-ore-forming arc magmas. Published experimental data show that the wet solidus of peridotite is tens of degrees below the solidus temperatures of Fe-Ni(-Cu) monosulfide solid solution (mss) at upper mantle pressures. The experiments show that Au partitions preferentially into hydrous mafic silicate melts relative to mss-bearing restite during low-percentage melting of hydrated mantle peridotite at temperatures *below* the solidus of mantle mss. The partition coefficient of Au between crystalline mss and hydrous mafic silicate melt is ~60, so if the mass fraction of mss in peridotite is <1/60 (as is nearly always the case), then the Au content in hydrous mafic silicate melt is greater than in mss-bearing mantle restite. At temperatures *above* the sulphide solidus, Au partitions into sulphide melt relative to hydrous mafic silicate melt by an enrichment factor of about 10,000, so higher-temperature mafic silicate melts have very low Au content as they segregate from molten-sulphide-bearing mantle restite. Relatively Au-, Ba-, Nb-, and K-rich, near-solidus melts of asthenospheric mantle tend to freeze in transit through the cooler lithospheric mantle, producing a long-term accumulation of metasomatic veins and dikes in typical subcontinental lithospheric mantle. Metasomatic veins in lithospheric mantle have lower melting temperatures than their refractory peridotite matrix, so they can be selectively remelted in appropriate tectonic situations, producing magmas that are unusually fertile for magmatic-hydrothermal gold metallogeny.

Fig. 1(A) For unaltered or little-altered whole-rock analyses of samples from arc igneous complexes, ratios of a highly mantle-incompatible lithophile element to a moderately incompatible element are effective in discriminating magmas in barren arc segments (grey) from igneous complexes that produced major hydrothermal gold-rich deposits of varied types—porphyry, high-sulphidation to low-sulphidation epithermal, Tintina- and Carlin-types. (B) Relative abundances of incompatible lithophile elements in primitive arc magmas (6-12 wt % MgO) that are spatially and temporally closely associated with magmatic-hydrothermal gold mineralisation are compared to primitive magmas in unmineralised arc segments.