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Generation of porphyry copper deposits by gas-brine reaction in volcanic arcs

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Porphyry copper deposits (PCDs) are characterised by a close spatial and temporal association with small, hypabyssal intrusions of silicic magmas in volcanic arcs. PCD formation requires elevated chlorine and water to concentrate copper in magmatic hypersaline liquids (or brines), and elevated sulphur to precipitate copper-rich sulphides. These twin requirements are hard to reconcile with experimental and petrological evidence that voluminous chlorine-rich, hydrous silicic magmas, of the variety favourable to copper enrichment, lack sufficient sulphur to precipitate directly the requisite quantities of sulphides. These features are, however, consistent with observations of active volcanic arcs whereby PCDs can be viewed as roots of dome volcanoes above shallow reservoirs where silicic magmas accumulate over long time spans. During protracted periods of dormancy metal-enriched dense brines accumulate in and above the silicic reservoir through slow, low-pressure degassing. Meanwhile cogenetic volatile-rich mafic magmas and their exsolved, sulphur and CO_2-rich fluids accumulate in deeper reservoirs. Periodic destabilisation of these reservoirs leads to short-lived bursts of volcanism liberating sulphurous gases, which react with the shallow-stored brines to form copper-rich sulphides and acidic vapours.

We test this hypothesis with a novel set of “porphyry in a capsule” experiments designed to simulate low-pressure (1-2 kbar) interaction of basalt-derived, sulphur-rich gases with brine-saturated, copper-bearing, but sulphur-free, granite. Experiments were run at 720-850 ˚C in cold-seal apparatus with basaltic andesite, loaded with H_2O and S, situated below dacite, loaded with H_2O, Cl and Cu. At run conditions both compositions are substantially degassed and crystallized. S-rich gas from the basaltic andesite ascends to react with Cu-rich brines exsolved from the dacite, Our experiments reveal the direct precipitation of copper-sulphide minerals, in vugs and veins within the dacite, at magmatic temperatures and support previous suggestions of gas-brine interaction as a fundamental ore-forming process. The simultaneous production of acid (HCl) during sulphide precipitation drives mica-producing alteration reactions in brine-hosting granites and their wall-rocks that replicate observed associations of sulphides and mica-rich alteration haloes around PCDs**.**