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Water-rich magmas optimise volcanic chalcophile element outgassing fluxes.

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Volcanoes emit significant fluxes of chalcophile volatile metals in the form of gas and aerosols and play an important role in global geochemical cycling of these elements, which are nutrients and/or pollutants in the surface environment. Volcanoes in different tectonic settings emit characteristic assemblages of volatile metals; arc volcanoes outgas high fluxes of chalcophiles and specific metal assemblages that are linked to slab devolatilization and the high chlorine content of arc magmas. Volcanic gases derive from an exsolved magmatic volatile phase (MVP), representative of those involved in the formation of ore deposits. MVPs play a pivotal role in trace metal transport within arc magmatic systems by acting as the reservoir into which metals partition. Some trace metals are chloride-speciating and partition strongly into a chloride-bearing MVP. Here we ask: which factors are most important for maximising the metal content of the exsolved MVP and ultimately, the volcanic trace metal flux to the surface environment? Magmas with high water contents saturate in exsolved volatiles deep in the crust, promoting early and deep partitioning of trace metals into the MVP. Bulk chlorine contents of magmas likely influences the metal content of the exsolved MVP and is pressure-dependent: deeper fluids are expected to be more saline. We expect bulk magma water and chlorine content, as well as the depth of magma storage and fractionation, to be important factors in determining the mass flux and chalcophile metal composition of arc volcanic gases and aerosols.

We develop models based on five hypothetical arc magmatic systems with variable water and chlorine contents to describe the development of MVPs during isobaric fractionation and decompression. We model the behaviour of three theoretical trace metals with different speciation behaviours that partition between the melt and MVP. Chloride-speciating trace metal concentrations in the MVP are highest for saline, deep-stored magmas. Metal fluxes carried within MVPs (in kg per kg of magma) are maximised by shallow, isobaric fractionation of water-rich magmas. The exsolved MVP associated with decompression degassing, is analogous to that generated during volcanic eruptions. In this case syn-eruptive fluxes are maximised by decompression of volatile-rich magmas from mid-crustal reservoirs.