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Magmatic degassing at Brothers volcano, Kermadec arc: implications for submarine hydrothermal processes and SMS mineralisation

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Understanding how magmas release volatiles and metals into submarine hydrothermal systems is key to evaluating the formation of Cu–Au–rich seafloor massive sulfide (SMS) deposits, yet the processes governing this transfer remain poorly constrained. To address this, we studied the volatile contents (H_2O, CO_2, S, Cl), sulfur speciation, and trace element contents of glassy melt inclusions (MIs) in samples from Brothers submarine volcano in the Kermadec arc, where there is strong evidence for magmatic involvement in hydrothermal processes and Cu-Au-rich mineralisation. Primitive basaltic MIs from a nearby mafic ridge imply that the volatile contents and oxidation states (fO_2 ~ FMQ + 1.5) of parental Brothers melts are within the normal range for arc magmas, but they contain high concentrations of some chalcophile metals. Silicic (dacite/low-SiO_2 rhyolite) MIs from the main Brothers edifice record shallow (~1–3 km below sea floor) degassing of a S-bearing vapour phase under oxidising conditions (fO_2 ~FMQ + 2). These vapours are Cl- and metal-poor, but drive acid sulfate alteration and deliver trace metalloids, plus some Au and Cu. The silicic MIs contain some of the highest Cl contents (max = 6270 ppm) known for any subalkaline arc magmas. Chlorine contents increase systematically with differentiation, indicating a progression towards to brine saturation, which is reached only at late stages of crystallisation when the magma is no longer eruptible. Although shallow, late-stage brine exsolution is traditionally considered unfavourable for efficient metal extraction (as opposed to deeper and earlier degassing in subaerial porphyry systems), Brothers SMS deposits exhibit unusually high Cu and Au grades. This implies that significant quantities of metal are still able to be extracted by these late-exsolving brines, with very shallow magma storage allowing these dense fluids and their metals to be flushed directly into hydrothermal circulation cells. Our results highlight that high magmatic metal contents combined with shallow crustal magma storage may be critical controls on Cu–Au-rich SMS formation in submarine arcs, and that systems like Brothers share some common features with mineralised subaerial arc environments.