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Sulfide liquid to crystal transition in Mid-Ocean Ridge Basalt magmas

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The segregation of sulfide from the Mid-Ocean Ridge Basalt (MORB) magma plays a critical role in distributing chalcophile metals in the oceanic crust, as MORB magma becomes sulfide-saturated early in its differentiation. Fe-rich sulfide liquid is widely considered the dominant phase in MORB systems. However, it remains unclear at what stage crystalline sulfide, specifically monosulfide solid solution (MSS), begins to crystallize and replaces sulfide liquid. This transition is important because upper crusts serve as the primary metal source for the seafloor massive sulfide (SMS) deposits, and the affinity of chalcophile metals differs between sulfide liquid and MSS. For example, Au strongly partitions into sulfide liquid but only weakly into MSS.

This study investigates the Cu-Ag systematics in MORB glasses, spanning a compositional range from basalt to dacite (MgO = 0.63–9.58 wt%), from the Australian-Antarctic Ridge and East Pacific Rise to constrain the timing of sulfide phase transition. Both Cu and Ag similarly partition into sulfide liquid; however, Cu is more compatible with MSS than Ag. Therefore, the Cu/Ag ratio serves as an effective proxy for the sulfide phase transition. The results show that Cu/Ag values remain constant during the early-stage differentiation but begin to decrease after ~5 wt% of MgO following sulfide saturation, indicating the sulfide phase transition in both ridge systems.

These findings have implications for the Ag and Au grades of SMS deposits at mid-ocean ridge and arc settings. The SMS deposits at fast-spreading centers generally exhibit lower Ag (64 g/t) and Au grades (0.31 g/t) than those at island arcs (Ag = 163 g/t; Au = 9.37 g/t). This may be attributed to early sulfide saturation and delayed sulfide liquid-MSS transition at MORB systems, which leads to significant Ag and Au depletion in the upper crustal basement. In contrast, the upper crustal basement of island arc systems may retain more Ag and Au due to either delayed sulfide saturation or early sulfide liquid – MSS transition during magma differentiation. These results provide new insights into the controls on Au distribution in submarine hydrothermal systems.