Tracking the link between epidosites and volcanogenic massive sulfide (VMS) deposits in the Semail ophiolite, Oman*

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Volcanogenic massive sulfide (VMS) deposits in mafic volcanic rocks are associated with extensive zones of sub-seafloor hydrothermal alteration. Published models of hydrothermal convection suggest a strict spatial relationship between VMS deposits on the seafloor and deep, underlying, high-temperature hydrothermal reaction zones identified by epidote-rich rocks ("epidosites"). If the models are valid, then the field occurrence of epidosites may be a useful indicator in VMS exploration. Previous studies in the Oman ophiolite have suggested that epidosites in the sheeted dike complex may be related to specific VMS deposits up-section. However, these epidosites are rare and extremely small, and no systematic link to VMS deposits is apparent at the regional scale, despite favorable outcrop conditions. In contrast, the overlying basalt pillow lavas contain abundant epidosites, in some cases very near to VMS deposits. We are evaluating the significance of these high-level epidosites for VMS mineralization.

We have mapped a ~1 km² epidosite in the distal footwall of a VMS deposit in northern Oman, which is hosted by MORB-type pillow basalts of the lowermost (Geotimes) extrusive unit. The epidosite consists exclusively of epidote–quartz and laterally grades into and overprints lavas affected by regional chlorite–albite alteration. The dramatic mineralogical changes during epidotization are reflected by substantial changes in rock composition. Compared to the chlorite–albite altered pillows, the epidosites are enriched in Ca and Si and depleted in Na, Mg, Fe, and notably Cu and Zn. Even the nominally immobile elements V and Ti are somewhat depleted. Whole-rock $^{87}\text{Sr}/^{86}\text{Sr}_{\text{init}}$ values reveal that the hydrothermal fluid that caused epidotization was rock-buffered rather than seawater dominated, indicating a long history of fluid-rock interaction within the oceanic crust. Whole-rock and mineral $^{18}\text{O}$ values yield alteration temperatures of approximately 250 °C. Waters in equilibrium with quartz at these temperatures have $^{18}\text{O}_{\text{SMOW}} \approx 2.5$. Thus, similarly to the strontium isotope data, oxygen isotopes show no simple seawater-derived fluid path.

Cross-cutting relations indicate that, despite the close proximity of the epidosites to the VMS deposit, the alteration is in fact younger than the sulfide mounds: both the associated umbers and the overlying massive lava flows are epidotized. Moreover, the epidotized zone contains numerous dikes that fed the supra-subduction-zone pillow basalts higher up in the extrusive sequence (Alley unit). The fact that the earliest Alley dikes are epidotized whereas the later Alley dikes are not demonstrates that the alteration occurred during Alley volcanism — long after the VMS deposit had been deposited on the Geotimes paleo-seafloor.
We propose that the epidotes within the extrusive sequence represent hydrothermal upflow zones that developed at higher crustal levels than the sheeted dike complex. This upward telescoping of the convection system was presumably due to heat accumulation attending eruption of the thick layer of Alley-type lavas over the MORB (Geotimes) seafloor. The Cu and Zn depletion of the epidotes suggests they could have been source rocks for VMS deposits in the Alley unit, but a direct link has yet to be proven.