Unlocking the Full Potential of Metal Leaching in the Oceanic Crust: Assessing Permeability and Fluid Flow

Alannah C. Brett (Brett-Adams), Larryn W. Diamond
University of Bern, Bern, Switzerland

The distribution of permeability in the upper oceanic crust controls the extent to which hydrothermal solutions can leach Cu and transport it to form sea-floor volcanogenic massive sulphide (VMS) deposits. The prevailing view in the literature is that the volcanic crust is a fractured aquifer through which seawater circulates dominantly along extensional faults and fracture networks. However, this is at odds with evidence in VMS-rich ophiolites, where hydrothermal alteration is penetrative within the entire rock matrix rather than confined to fracture walls. The relative hydraulic roles of fracture networks versus the rock matrix are unclear, raising the question of how much source rock is actually accessible for metal leaching in VMS systems. To clarify this ambiguity, we have quantified the distribution of permeability in MORB-type lavas in the Semail ophiolite, which are considered to be source rocks for the known VMS deposits. We measured permeabilities of the intensely altered rock matrix (greenschist-facies chl+alb±act spilite) and upscaled the results to outcrop scale. Mapping of hydrothermal veins as proxies of syn-alteration fractures revealed high fracture intensities in km-spaced subvertical fault-damage zones, but low fracture intensities and connectivities in intervening fault-distal blocks. Using *DfnWorks* software, we upscaled the fractures numerically as discrete fracture networks to model fault-distal lava blocks of 0.5 × 0.5 × 0.5 km. Hydraulic simulations using *PFLOTRAN* confirm and constrain the expected high permeability of fault-damage zones, whereas in the fault-distal blocks, the sparse and poorly connected fracture networks are found to have only the same permeability as the rock matrix. These results imply that the entire volume of lavas in the upper oceanic crust is accessible for leaching of VMS metals during hydrothermal circulation, while steep, km-spaced fault zones provide the essential focusing for hydrothermal discharge and localisation of VMS deposits.