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Thermohaline multi-phase simulations of vent fluid salinity evolution following a diking event at East Pacific Rise

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Submarine hydrothermal systems sustain unique ecosystems, affect global-scale biogeochemical ocean cycles, and mobilize metals from the oceanic crust to form volcanogenic massive sulfide deposits. Quantifying these processes requires linking seafloor observations to physico-chemical processes at depth and this is where numerical models of hydrothermal circulation can be particularly useful. One region where sufficient data is available to establish such a link is the East Pacific Rise (EPR) at 9°N, where vent fluid salinity and temperature have been repeatedly measured over a long time period. Here, large salinity and temperature changes of vents at the axial graben have been correlated with diking events and extrusive lava flows. Salinity changes imply the phase separation of seawater into a high-salinity brine and a low-salinity vapor phase. The intrusion of a new dike is likely to result in a characteristic salinity signal over several years: first the low salinity vapor phase rises and later the brine phase appears along with a decreasing vent temperature. These short-term salinity variations are super-imposed on the background salinity signal, which is modulated by phase separation phenomena on top of the axial magma lens.

From these variations, numerical models can help to infer sub-surface properties and processes such as permeability, background flow rates, and brine retention as well as mobilization – if the employed model can resolve the complexity of phase separation. We here present a novel numerical model for saltwater hydrothermal systems, which uses the Finite Volume Method on unstructured meshes and the Newton-Raphson Method for solving the coupled equations. We use this new 2-D model to investigate a setup that mimics hydrothermal convection on top of the axial magma lens, which is then perturbed by a dike intrusion. In a comprehensive suite of model runs, we have identified the key controls on the time evolution of vent fluid salinity following the diking event. Based on these insights, we can reproduce time-series data from the EPR at 9°N and infer likely ranges of rock properties for the oceanic crust layer 2B.

Our work shows how useful data integration into numerical hydrothermal models is. Unfortunately, data collection like mapping of magmatic events, continuous measurements of hydrothermal vent fluids or crustal drilling are very expensive and technically challenging. Here global and transdisciplinary collaboration would be very useful for achieving data with maximal

benefit for all disciplines. Compared to the EPR the Mid-Atlantic Ridge shows a higher geological complexity, due to its lower spreading rate, and a higher diversity of vent fluid chemistry, but less continuous data is available, which hampers research using numerical models here for now. Therefore, numerical case studies at EPR serve as important validity checks for our numerical model and indicate where it has to be enhanced for quantifying processes related to hydrothermal systems at Mid-Atlantic Ridge.