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Forward geochemical modeling as guiding tool for the exploration of the Kama'ehuakanaloa hydrothermal vent field, Hawaii

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Geochemical modeling offers an effective way to guide decision-making during exploration of hydrothermal systems by enabling the forward mapping of rock alteration, fluid compositions and chemical energy driving microbial activity. As part of the SUBSEA project, we performed forward modeling to provide a guiding tool for the exploration of the Kama'ehuakanaloa (formerly Lō'ihi, Hawaii) hydrothermal vent field in 2018, where 20-50°C fluid vents show chemical compositions enriched in Si, CO_2, alkalinity, and Fe.

Our forward modeling includes >1000 reaction paths chosen to account for heterogeneous reactions conditions along the hydrothermal convection cell. High-temperature fluid-rock interactions at depth are followed by low-temperature basalt alteration as the hydrothermal fluid ascends to the seafloor. Both steps vary in terms of amount of reacting rock, gas inputs, and extent of mixing with seawater.

Information entropy applied to our library of predicted fluid compositions indicates that Si concentrations and pH are the most informative chemical parameters to measure on-board the ship to learn in real-time about subseafloor reaction conditions. The compositions of Kama'ehuakanaloa vent fluids require both subsurface equilibrium mixing between a ≥350 ºC hydrothermal fluid end-member and seawater and a further ~4% low-temperature basalt alteration as the fluid mixture rises to the seafloor. This low-temperature basalt alteration leads to the characteristic Fe enrichments of the vent fluids and large changes in chemical energy available for microbial communities. We hypothesize that low-temperature basalt alteration during an extended path of fluid upwelling through the subseafloor might arise as a direct consequence of the height and steep-sloped topography of Kama'ehuakanaloa seamount. This suggests that magmatically-active intraplate hotspots can contribute more substantially than previously recognized to the global ocean Fe cycle.

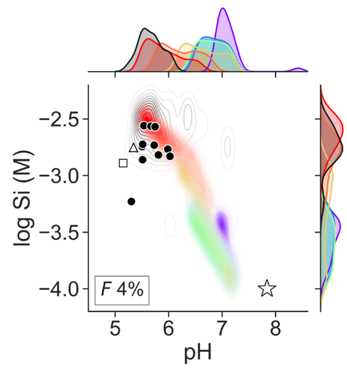

Figure 1. Modeled and measured Si concentrations as functions of pH values for 20-50° C vent fluids at Kama'ehuakanaloa considering a degree of low-temperature basalt alteration of 4% and temperature maximum ranging from 400° C (red) to 50° C (purple).