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Numerical fluid flow modelling in the context of CO_2 sequestration on mid-ocean ridge flanks

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The majority of Earth's basaltic volcanism occurs at mid-ocean ridges, where new ocean floor is created. Especially young oceanic crust, which is highly porous and permeable, is subject to regional off-axis hydrothermal circulation, which extracts large amounts of heat and impacts global water and chemical fluxes between the ocean and the lithosphere. Generally, seawater recharge and hydrothermal fluid discharge happen where the basaltic crust is exposed to the seafloor. This mode of circulation is usually referred to as outcrop-to-outcrop flow. Basaltic aquifers, overlain by impermeable sedimentary layers, can sustain outcrop-to-outcrop flow over distances of several 10s of kilometers. Basaltic rock formations are also explored for their potential to store injected CO_2 with the added benefit that carbonation reactions promote the safe long-term storage. In this context, it is uncertain whether natural hydrothermal flow between outcropping seamounts compromises a long-term storage or whether it will help to continuously expose injected CO_2 to fresh reactive basaltic rock.

Numerical fluid flow modelling on different scales is a powerful tool to understand the relations between off-axis hydrothermal circulation and CO_2 storage. On the one hand, coupled heat transfer and fluid flow modelling of regional ridge flank flow can be performed at the kilometer scale and compared with heat flow observations. By using such regional models, we find that outcrop-to-outcrop flow arises if the permeability of the basaltic aquifer is larger 10^{-13} m^2. This regional crustal permeability primarily controls the flow velocity and discharge mass fluxes. In the presence of outcrop-to-outcrop flow, the permeability and geometric shape of the outcrops further determine the direction of the flow. Secondly, the flow rates and fluid temperatures in the aquifer are influenced by the thickness of the sediment and the distance between the outcrops, respectively. These results based on regional models help to constrain flow patterns through the basaltic crust from seafloor observations, e. g. heat flow measurements in the sediment. Understanding these regional flow patterns is a compelling necessity in the context of CO_2 sequestration on mid-ocean ridge flanks.

On the other hand, in-situ carbon mineralization in porous basaltic crust can modify crustal permeabilities on local and regional scales, and thus influence regional circulation patterns. In this

regard, we use pore scale numerical fluid flow simulations based on core samples in combination with laboratory experiments to parameterize the permeability evolution during carbonization reactions. Results of pore-scale modelling can be incorporated into the regional flow models to further enhance understanding of the interplay between off-axis hydrothermal circulation and carbon sequestration in mid-ocean ridge basalts.