Rock-matrix versus fracture-controlled fluid pathways in the extrusive layer of the oceanic crust

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Much of the hydrothermal circulation through the oceanic crust occurs within the upper layer of permeable basaltic lavas [1, 2]. Major faults are accepted channels of fluid flow in this setting but less is known about flow through the blocks of largely intact lavas that lie between major faults. The pervasive hydrothermal alteration of these blocks testifies to considerable fluid flux but realistic upscaled values of bulk porosity and permeability have been difficult to obtain. Here we examine axial lavas in the Semail ophiolite to estimate the porosity and permeability of sparsely fractured blocks displaying recharge alteration (chlorite-albite-quartz 'spilites') and discharge alteration (epidote + quartz + titanite ± Fe-oxide 'epidosites').

We use the simulation code FracMan [3] to combine upscaled measurements of rock-matrix porosity and permeability with mapped fracture distributions in order to construct dual-porosity flow models of the altered lavas. Fully discretised modelling allows us to simultaneously consider the rock-matrix and sparse fracture sets, and to obtain realistic bulk permeabilities.

These simulations reveal that hydrothermal fluids flow dominantly through the rock-matrix in distal zones and that the sparse fractures observed in the field are connected only by rock-matrix flow. High temperature epidotising fluids rise through the lavas without requiring a fracture network. Instead, these fluids enhance permeability by altering their wall rocks and thus self-propagate through the lava pile. The huge blocks of matrix-controlled flow in the upper oceanic crust compared to localised fault zones, may affect calibration of reactive-transport models that are used to describe processes such as hydrothermal circulation, formation of volcanogenic massive sulphide (VMS) deposits, and advective flux of heat through the oceanic lithosphere.

[1] Stein & Stein (1994) *Journal of Geophysical Research* **99**, 3018 –3095. [2] Fisher (2000) *Letters to Nature* **403**, 71–74. [3] Golder (2018) FracMan software, Golder Associates (UK), https://www.golder.com/fracman/