Constraints on Ocean Floor Permeability From Hydrothermal Modelling

S. Titarenko[1], A. McCaig[1]

[1]School of Earth and Environment, University of Leeds, Leeds LS2 9JT UK

Abstract

The Atlantis massif is a domal seamount close to the mid-Atlantic Ridge at 30 °N. Water depths vary from 700m at the crest of the massif to >5000m in the adjacent ridge-transform intersection, a distance of about 10 km. Close to the crest of the Massif, the Lost City hydrothermal field (LCHF) has been active for at least 120,000 years, venting fluids with a temperature of 40-90 °C. 5 km north of Lost City, a temperature profile has been measured in IODP Hole 1309D, with a thermal gradient of ~100 °C/km down to 1415m depth. The gradient is linear below 750 metres, indicating conductive heat transfer, and slightly convex downwards at shallower depths suggesting slow downward flow of fluid. The Hole was drilled in a saddle with slightly higher topography to the north and the main massif to the south.

In a 2_D model along a north-south profile, we have successfully matched the thermal profile in the borehole using a basal heatflow of 0.22 W/m2, a constant temperature upper boundary condition, and a permeability of 3 e-14 m2 in a 750m thick layer mimicking the topography of the massif. Permeability below this level is 1 e-17 m2. Temperature dependent thermal conductivity and heat capacity for gabbroic rocks were used. The model was setup in COMSOL Multiphysics® using the Heat Transfer and CFD modules, and properties of pure water at a constant pressure of 50 MPa to suppress boiling. Fluid flows downwards at the borehole site and upwards in areas of higher topography, in a very stable regime.

Temperatures at the LCHF can be approximated over long time periods by increasing the permeability beneath the field to 10-14 to 10-15 m2 down to depths of 4-5 km below the crest of the Massif. This makes little difference to the thermal profile in the borehole.
Current work extends this modelling to 3-D, with high permeability beneath the LCHF confined to an E-W trending fault slot defined by microearthquakes. Preliminary results indicate that a somewhat higher basal heatflow will be required to match the borehole thermal profile.

Our results place tight constraints on the permeability of gabbroic rocks exhumed by faulting to the seafloor in the Atlantic. This has implications for potential fluid flow and heat redistribution in continental margins, and hence on hydrocarbon maturation.