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Permeability of fractured and jointed reservoirs

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The presence of fractures can greatly enhance the permeability of otherwise impervious units. For example, during the formation of columnar joints, the creation of an hexagonal network of mode-I tensile macro-fractures during cooling can force flow localisation and form permeability anisotropy in the direction parallel to the fracture planes. We have shown that the presence of a macro-fracture enhances the permeability of a suite of volcanic rocks with varying porosity (Lamur et al., 2017). Importantly, we derived an expression for the permeability of a fractured system as a function of 1) the intact rock permeability; 2) the fracture density; 3) the average fracture geometry (length and width).

Here, we summarise this approach, and further show the results of a new experiments that investigate columnar jointing. First, we measured the permeability of an intact sample of basalt from Seljavellir (Iceland) at 10-18 m2 using the steady state method. We then determined its thermal characteristics (solidus temperature, coefficient of expansion) to compute the fracture geometry with temperature and coupled the results to a new type of experiments aiming to constrain the temperature at which cooling macro-fractures would form. We found that, for this basalt, columnar joints would form purely elastically, between 890 and 840 °C during cooling (90 to 150 °C below the solidus temperature). We then compute the permeability evolution of columnar jointing reservoirs (with different column widths). The permeability before this temperature window is set to that of the intact basalt, which upon cooling, becomes fractured and fracture width increases non-linearly, controlling the permeability of the reservoir.

The model developed here, provides first order approximation of permeability evolution in fractured and jointing reservoirs and shows that fracture spacing greatly impacts the overall permeability of the system.

Lamur, A., Kendrick, J., Eggertsson, G., Wall, R., Ashworth, J., and Lavallée, Y., 2017, The permeability of fractured rocks in pressurised volcanic and geothermal systems: Scientific Reports, v. 7, no. 1, p. 6173.