Geophysical Research Abstracts
Vol. 17, EGU2015-7448-1, 2015
EGU General Assembly 2015

A numerical model for dynamic crustal-scale fluid flow

Till Sachau (1), Paul Bons (1), Enrique Gomez-Rivas (2), and Daniel Koehn (3)

(1) Department of Geosciences, Eberhard Karls University, Tübingen, Germany (till.sachau@uni-tuebingen.de), (2) Department of Geology and Petroleum Geology, University of Aberdeen, Scotland, (3) School of Geographical & Earth Sciences, University of Glasgow, Scotland

Fluid flow in the crust is often envisaged and modeled as continuous, yet minimal flow, which occurs over large geological times. This is a suitable approximation for flow as long as it is solely controlled by the matrix permeability of rocks, which in turn is controlled by viscous compaction of the pore space. However, strong evidence (hydrothermal veins and ore deposits) exists that a significant part of fluid flow in the crust occurs strongly localized in both space and time, controlled by the opening and sealing of hydrofractures. We developed, tested and applied a novel computer code, which considers this dynamic behavior and couples it with steady, Darcian flow controlled by the matrix permeability. In this dual-porosity model, fractures open depending on the fluid pressure relative to the solid pressure. Fractures form when matrix permeability is insufficient to accommodate fluid flow resulting from compaction, decompression (Staude et al. 2009) or metamorphic dehydration reactions (Weisheit et al. 2013). Open fractures can close when the contained fluid either seeps into the matrix or escapes by fracture propagation: mobile hydrofractures (Bons, 2001). In the model, closing and sealing of fractures is controlled by a time-dependent viscous law, which is based on the effective stress and on either Newtonian or non-Newtonian viscosity.

Our simulations indicate that the bulk of crustal fluid flow in the middle to lower upper crust is intermittent, highly self-organized, and occurs as mobile hydrofractures. This is due to the low matrix porosity and permeability, combined with a low matrix viscosity and, hence, fast sealing of fractures. Stable fracture networks, generated by fluid overpressure, are restricted to the uppermost crust. Semi-stable fracture networks can develop in an intermediate zone, if a critical overpressure is reached. Flow rates in mobile hydrofractures exceed those in the matrix porosity and fracture networks by orders of magnitude. Hydrothermal fluids from the lower region can thus ascend rapidly, retaining their heat and dissolved metals content, to the transition zone where hydrothermal ore deposits form, due to thermal and chemical equilibration with the host rock.

References

Bons, P.D. 2001. The formation of large quartz veins by rapid ascent of fluids in mobile hydrofractures. Tectonophysics 336, 1-17.

Staude, S., Bons, P.D., Markl, G. 2009. Hydrothermal vein formation by extension-driven dewatering of the middle crust: An example from SW Germany. Earth and Planetary Science Letters 286, 387-39.

Weisheit, A., Bons, P.D., Elburg, M.A. 2013. Long-lived crustal-scale fluid-flow: The hydrothermal mega-breccia of Hidden Valley, Mt. Painter Inlier, South Australia. International Journal of Earth Sciences 102, 1219-1236.