Hydrofractures and crustal-scale fluid flow

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Fluids can circulate in all levels of the crust, as veins, ore deposits and chemical alterations and isotopic shifts indicate. It is furthermore generally accepted that faults and fractures play a central role as preferred fluid conduits. Fluid flow is, however, not only passively reacting to the presence of faults and fractures, but actively play a role in their creation, (re-) activation and sealing by mineral precipitates. This means that the interaction between fluid flow and fracturing is a two-way process, which is further controlled by tectonic activity (stress field), fluid sources and fluxes, as well as the availability of alternative fluid conduits, such as matrix porosity. Here we explore the interaction between matrix permeability and dynamic fracturing on the spatial and temporal distribution of fluid flow for upward fluid fluxes. Envisaged fluid sources can be dehydration reactions, release of igneous fluids, or release of fluids due to decompression or heating.

Our 2D numerical cellular automaton-type simulations span the whole range from steady matrix-flow to highly dynamical flow through hydrofractures. Hydrofractures are initiated when matrix flow is insufficient to maintain fluid pressures below the failure threshold. When required fluid fluxes are high and/or matrix porosity low, flow is dominated by hydrofractures and the system exhibits self-organised critical phenomena. The size of fractures achieves a power-law distribution, as failure events may sometimes trigger avalanche-like amalgamation of hydrofractures. By far most hydrofracture events only lead to local fluid flow pulses within the source area. Conductive fracture networks do not develop if hydrofractures seal relatively quickly, which can be expected in deeper crustal levels. Only the larger events span the whole system and actually drain fluid from the system. We present the 10 square km hydrothermal Hidden Valley Mega-Breccia on the Paralana Fault System in South Australia as a possible example of large-scale fluid expulsion events. Although field evidence suggests that the breccia formed over a period of at least 150 Myrs, actual cumulative fluid duration may rather have been in the order of days only. This example illustrates the extreme dynamics that crustal-scale fluid flow in hydrofractures can achieve.