Geophysical Research Abstracts
Vol. 18, EGU2016-14005, 2016
EGU General Assembly 2016

Influence of mechanical rock properties and fracture healing rate on crustal fluid flow dynamics

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Fluid flow in the Earth's crust is very slow over extended periods of time, during which it occurs within the connected pore space of rocks. If the fluid production rate exceeds a certain threshold, matrix permeability alone is insufficient to drain the fluid volume and fluid pressure builds up, thereby reducing the effective stress supported by the rock matrix. Hydraulic fractures form once the effective pressure exceeds the tensile strength of the rock matrix and act subsequently as highly effective fluid conduits. Once local fluid pressure is sufficiently low again, flow ceases and fractures begin to heal. Since fluid flow is controlled by the alternation of fracture permeability and matrix permeability, the flow rate in the system is strongly discontinuous and occurs in intermittent pulses. Resulting hydraulic fracture networks are largely self-organized: opening and subsequent healing of hydraulic fractures depends on the local fluid pressure and on the time-span between fluid pulses.

We simulate this process with a computer model and describe the resulting dynamics statistically. Special interest is given to a) the spatially and temporally discontinuous formation and closure of fractures and fracture networks and b) the total flow rate over time. The computer model consists of a crustal-scale dual-porosity setup. Control parameters are the pressure- and time-dependent fracture healing rate, and the strength and the permeability of the intact rock. Statistical analysis involves determination of the multifractal properties and of the power spectral density of the temporal development of the total drainage rate and hydraulic fractures.

References

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