Geophysical Research Abstracts,
Vol. 11, EGU2009-1030-2, 2009
EGU General Assembly 2009

Fluid flow properties of Volterra Gypsum during experimental deformation at low strain rates monitored through simultaneous permeability measurement

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Understanding the evolution of fluid pathways in low permeability rocks during natural deformation is key in understanding rock deformation processes and rheology. Furthermore, it also has a direct application to studies concerning the migration of fluids in natural rock reservoirs (e.g. oil, CO_2), particularly under stress (tectonic or not). We use gypsum as an analogue rock material for low porosity materials but also to understand gypsum itself, as it can control the migration of fluids at shallow depths in the upper crust.

The starting material in the experiments is Volterra Gypsum, a very pure gypsum rock (>95 % gypsum), with low porosity (~0.5 %) and low permeability ($\sim 10^{-18}$ to 10^{-20} m^{-2}, depending on effective pressure). We measure permeability and pore volume change by using the pore pressure oscillation technique combined with pore volumometry. The technique involves applying a pore pressure sinusoidal wave in one end of the sample while monitoring the attenuation and phase shift of the wave at the other end, from which the permeability and storage capacity of the sample is calculated. The advantage over other techniques is that it allows continuous monitoring of permeability changes as other experimentally controlled parameters, for example effective pressure, differential stress and temperature, are varied.

We present experimental results that show consistent variations of permeability in Volterra gypsum with effective pressure and how the permeability evolves over time with differential stress at low strain rate during constant loading (at strain rate of approx. 10^{-6} s^{-1}), stress relaxation, and during cooling from 50 ºC to room temperature. Variations of permeability beyond one order of magnitude when samples are loaded hydrostatically and during non-hydrostatic loading reproduce previous experimental work. However, we also find smaller but consistent decreases of permeability, on the order of several times, when specimens relax over time from hydrostatic and non-hydrostatic load and also during cooling from low temperatures. It has been reported previously that gypsum deforms by diffusion creep at laboratory rates in powdered specimens. We suggest that the changes we report in the fluid flow properties of intact gypsum specimens when subject to small non-hydrostatic stresses may be related to the operation of diffusion creep.