Geophysical Research Abstracts
Vol. 12, EGU2010-8287, 2010
EGU General Assembly 2010

Acoustic emissions monitoring and synchrotron X-ray diffraction analysis of mineral dehydrations at high pressures and temperatures

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We have monitored from in-situ X-ray diffraction coupled to Acoustic Emission (AE) imaging, the behavior of several materials under elevated pressures and temperatures (quartz, kaolinite, serpentinite). The samples were placed in a boron-epoxy assembly with an 8mm edge-length and loaded in the MAX80 cubic multi-anvil press installed on the German synchrotron (HASYLAB-DESY, Hamburg). AE were recorded using six piezoceramic transducers (2 MHz eigen frequency) glued on each of the six WC anvils. Full waveforms were acquired using an eight channel digital oscilloscope and a continuous acoustic recorder.

Our system was first tested using quartz beads (500µm) aggregates. During cold compression performed on these samples many acoustic events were recorded and located inside the samples. These are obviously related to the fragile fracturing of the quartz due to the porosity loss. During the heating cycles performed on the same samples, the acoustic activity progressively vanishes between 300 and 400°C indicating the transition to the ductile regime towards higher temperatures. Further experiments were performed by mixing 20wt% of kaolinite to the quartz. As a result, the amount of acoustic emissions recorded during cold compression is significantly reduced. This is thought to be a result of the ductile behaviour of kaolinite even at low temperatures. This assumption has been confirmed by performing experiments on pure kaolinite which did not produce acoustic emissions during cold compression nor during heating cycles up to 1000°C (i.e. beyond the kaolinite dehydration temperature). This set of experiments clearly established that no acoustic activity is produced by the assembly and that AEs produced by the samples are accurately located by the software.

The behaviour of serpentinite dehydration was then investigated under various pressure conditions (i.e. various volume changes), from ∼0.6 to ∼40kbars. These experiments were performed under deviatoric stress conditions by using Al_2O_3 waveguides. While clearly identified with the time resolved diffraction patterns, the dehydration process did not produce any AE, at least within the sensitivity and frequency ranges of our transducers. The microstructures observed on the recovered samples by SEM show features characteristic of fluid localisation and/or migration and highlight the fact that fractures were activated prior, during and after mineral dehydration.

These results tend to show that the relationship between mineral dehydration, acoustic emission production, earthquakes and fracturing are not as straightforward as one could expect under high pressure and temperature conditions.