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Elastic wave velocity and acoustic emission monitoring during Gypsum dehydration under triaxial stress conditions

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Two experiments were performed in order to study contemporaneously the evolution of P and S elastic wave velocities and acoustic emission (AE) triggering during the dehydration of natural Gypsum polycrystal samples coming from Volterra, Italy. During these experiments, the temperature was slowly raised at 0.15 degrees C per minute under quasi-hydrostatic stress (15 and 55 MPa respectively) in drained (10MPa constant pore pressure) conditions.

We observed a linear decrease of both P and S wave velocities during heating. At the onset of dehydration, both P and S wave velocities reduced drastically (as much as approx. 50% in the low confining pressure case). Importantly, the Vp/Vs ratio also decreased. Shortly after the onset of decrease in P and S wave velocities, the dehydration reaction was accompanied by a large number of AEs. Time serie locations of the AEs show that they initiated from the pore pressure port, ie from where the pore fluid could easily be drained, and then slowly migrated within the sample. The AE rate could be directly correlated to the reaction extent, inferred from pore volumometry. In such a way, the AE rate was larger at higher confinement, ie when a larger amount of compaction was observed. Focal mechanism analysis of the largest AEs showed they had a large volumetric component in compaction, confirming that AEs were indeed related to pore closure and/or collapse.

Additional dehydration experiments performed within an environmental scanning electron microscope under low vacuum highlight that, in drained conditions at least, the reaction seems to take place in two phases. First, cracks are being opened along cleavage planes within a single gypsum crystal, which allows for the fluid to escape. Second, the solid volume shrinks and pore collapse can occur. Such a scenario is also consistent with our in-situ analysis under pressure.

Finally, we use a differential effective medium theory approach for oblate spheroidal inclusions and a mix of gypsum and anhydrite randomly oriented crystals to extract the crack density and the crack population average aspect ratio from our elastic wave velocity measurements. Using these, we can then correct for at least some of the frequency dispersion effects between the ultrasonic (MHz) and the seismic frequency (Hz) ranges. Even doing so, we highlight, that, under low confining pressures at least, the effect of low aspect ratio crack nucleation/propagation during dehydration reaction dominates the "high fluid pressure" effect. Our results thus seem to point out that the signature of dehydration reactions in nature, should, in fact, possibly be that of a low Vp/Vs ratio, contrarily to what has been instinctively assumed until now.