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Dehydration reactions and Vp/Vs ratio anomalies: Insights from experiments on gypsum

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The hydrous minerals contained within the subducted oceanic crust are thought to play a great role in subduction zones, in particular during their dehydration. Measuring the evolving mechanical and physical properties of rocks containing hydrous minerals during heating and phase changes at pressure is a challenging but necessary task to better constrain the subduction dynamics.

We performed dehydration experiments in a triaxial apparatus while measuring the evolution of P and S wave velocities and acoustic emission (AE) triggering. Natural gypsum polycrystal was used as an analogue to serpentinites.

During drained dehydration tests performed under isotropic pressure, P and S wave velocities reduced drastically (as much as approx. 50% in the low confining pressure case) at the onset of dehydration. Importantly, the Vp/Vs ratio also decreased. Shortly after the onset of decrease in P and S wave velocities, the dehydration reaction was also accompanied by bursts 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. In each experiments, the AE rate could be positively correlated to the reaction rate, inferred from pore volumetry. In such a way, the AE rate reached a peak when the reaction was the fastest. 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. In addition, the AE rate also increased with confinement, ie when a larger amount of compaction was observed.

A differential effective medium theory was used to model the evolution of elastic wave velocities during dehydration. The decrease in Poisson's ratio could be quantitatively explained by (1) the nucleation/growth of thin oblate spheroidal crakcs, and (2) the replacement of the soft gypsum matrix by a stiff bassanite matrix. Coupling this to Biot-Gassman equation, we can correct for some of the dispersion effects (mainly squirt flow) between the ultrasonic (MHz) and the seismic frequency (Hz) ranges. This extrapolation of our results point out that the signature of dehydration reactions in nature, in drained condition at least, might be a low Vp/Vs ratio. In subduction zones, anomalously high apparent Vp/Vs ratio could be due to anisotropy (Reynard et al., 2010).