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Active ultrasonic monitoring of high-pressure metamorphic reactions using a new generation of Griggs-type apparatus

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A new high pressure Griggs-type apparatus, equipped with ultrasonic transducers, was developed at the École Normale Supérieure (ENS, France). This press uses solid salt as confining medium and can reach 5 GPa confinement within a 20 mm borehole. Two piezoelectric transducers, with 5MHz center frequency, are installed above and below the sample, respectively in the deformation column and in the base plate. During the experiment, the top and bottom transducers are used as ultrasonic source and receiver, respectively, for pulse-through measurements. Full waveforms are digitized at 50MHz, and relative elastic waves travel times through the sample and part of the deformation column are calculated using cross-correlations.

In order to calibrate our acoustic system, an alumina dummy was used to estimate the sensitivity of the setup (i.e. the minimum travel time difference between two measurements) and the acoustic 'stiffness' of the apparatus (i.e. the relative change of travel time as a function of pressure, temperature and differential stress). We show that our resolution in relative travel time change is of the order of 10 ns, meaning that within a 7 mm long sample and given an average wave velocity of mineral assemblies of the order of 6-10 km/s, our theoretical resolution in velocity change in the sample is close to 1%.

The aim of a second set of experiments (still in progress) is to study the kinetics of the quartz-coesite reaction under non-hydrostatic conditions. At our (P,T) conditions, P-wave velocities in coesite are roughly 25 % higher than in (metastable) quartz. Experiments were performed on 10–20 μm quartz powder, at 800°C and confining pressures ranging from 1 to 3 GPa. During each experiment, the maximum principal stress, $\sigma 1$, was raised within the coesite field, at fixed $\sigma 3$ and temperature conditions. Stress and temperature were then kept constant during 2 hours. Microstructures and phases distribution were characterized post-mortem using EBSD mapping. Preliminary results reveal that coesite was only observed when both $\sigma 3$ and $\sigma 1$ were in the coesite field. In this case, using our ultrasonic monitoring, the reaction was detected by a clear change of P-wave velocity in the sample, as approximately 20% of the quartz transformed to coesite.

In the future, various stress, temperature and time conditions will be investigated to further our understanding of the thermodynamics of the quartz-to-coesite transformation under non-hydrostatic stress.