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Experimental measurement of P-wave velocities across the α->β quartz at lower continental crust pressure and temperature conditions

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Polymorphic mineral phase transitions play an important role in the dynamics of the Earth's crust and mantle. The quartz α->β transition, one of the most common, is a displacive transition which has been studied for over a hundred year and has been detected up to 3 GPa by several experimental methods. In thermodynamics databases, the α->β phase transition of quartz is generally associated with a significant change in elastic properties, and a corresponding shift of seismic wave velocities. Several seismological studies have used the transition to estimate the temperature profile of the lower crust. However, the elastic properties of quartz at high-pressure and temperature remain poorly known, particularly within at β-quartz field. Indeed, because the transition is so called a lambda-transition, it is impossible to simply extrapolate room pressure measurements at high pressure and temperature.

Here, experiments were performed within a 3rd generation Griggs-type apparatus, equipped with active and passive acoustic monitoring (Moarefvand et al. 2021). In this set-up, two ultrasonic transducers (5-10 MHz) allow us to measure p-wave velocities at in-situ P-T conditions. Experiments were carried out on 10mm long cored rock samples of Arkansas Novaculite (grain size of 3-6 μm), under hydrostatic pressure conditions ranging from 0.5 to 1.25 GPa and temperatures from 200 to 900°C, i.e. effectively crossing the quartz α->β phase transition. The transition was directly observed as a minimum in p-wave velocities, preceded by an important softening of velocities as temperature was getting close to the transition temperature. However, the p-wave velocities measured beyond the transition, in the β-quartz field, were lower than that predicted by thermodynamic databases. Two additional experiments were carried out on Novaculite, at 0.5 and 0.8 GPa confining pressures, using the acoustic emission (AE) set-up, in order to investigate whether these low velocities could be related to damage (microcracking) triggered by the transition, but no significant peak of acoustic emission was observed near the transition temperature. Novaculite samples were then analyzed using Electron Back-Scatter Diffraction (EBSD) and a prevalence of Dauphiné twinning was observed on all the samples that underwent the transition at HP-HT.

Finally, four additional experiments were realized on quartz single-crystals to investigate the effect of grain boundaries and the evolution of anisotropy during the transition. Again, the velocities

observed in the β-quartz field, were lower than that predicted by thermodynamic databases. Microstructural analysis of these samples revealed the importance of cracking, in particular in the direction parallel to the c-axis.

Taken together, our results show that the velocity change due to the transition known at low pressure might be less important at higher pressure than that predicted by thermodynamic databases. If true, this important result needs to be confirmed using alternative methodologies, as it would imply that velocity changes related to the α->β quartz transition at lower crustal conditions might be lower than that observed by seismologists in thickened continental crust.

References:

Moarefvand, Arefeh, et al. "*A new generation Griggs apparatus with active acoustic monitoring.*"
Tectonophysics816 (2021): 229032.