Experimental study of the effect of stress on α->β quartz transformation at lower continental crust pressure and temperature conditions

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Based on experimental observations, there have been claims that deviatoric stresses are responsible for triggering high pressure phase transitions below their equilibrium transition pressures. This implies that the phase assemblages observed in exhumed rocks may reflect stresses induced by tectonic overpressure rather than mere lithostatic pressure, thus resulting in overestimated maximum depths of burial. Despite the numerous studies that have addressed whether mean or principal stress may trigger polymorphic phase changes, the case is still not completely clear.

The aim of this study is therefore to investigate the role of deviatoric stress on phase transitions at high PT conditions. In this study, we investigated, The α-β transition of quartz, which is one of the most common mineral of the Earth's crust. This transition has a particular importance for the lower continental crust because of the significantly different elastic properties of the two polymorphs. The α-β quartz transition is also a good experimental candidate because of its displacive and quasi-instantaneous nature.

A series of experiments was performed with a new high pressure Griggs-type apparatus equipped with ultrasonic monitoring, at the ENS Paris. Cored rock samples of Arkansas Novaculite (mean grain size of 5.6 μm) were subjected to pressure and temperature conditions of 0.5-1.5 GPa and ~ 850°C. In all experiments, the mean stress was either equal to or higher than the confining pressure. The deviatoric stress was increased to cross the transition while keeping the temperature constant. Two P-wave transducers were used on top and bottom of the sample as transmitter and receiver to measure travel times across the assembly. The quartz α-β transition was directly observed by a time-shift of the p-wave arrival in the order of 10 ns.

The mechanical data show clearly that the phase transformation is controlled by mean stress. The quartz α-β transition induce a softening behavior on our sample because of difference of volume between quartz α and β.

According to thermodynamic models of elastic properties of α and β quartz, the variation of p wave velocity for the quartz α-β transition is in the order of 10% of magnitude. The active monitoring method allows us to calculate the variation of smaller than 5%. We can explain these small variations as a partial transformation because of stress heterogeneities since local stress at the scale of grains can be different than the macroscopic stress that we measure.