Alpha-Beta quartz transition in the lower continental crust: perspective from diffraction and acoustic data at high P-T conditions

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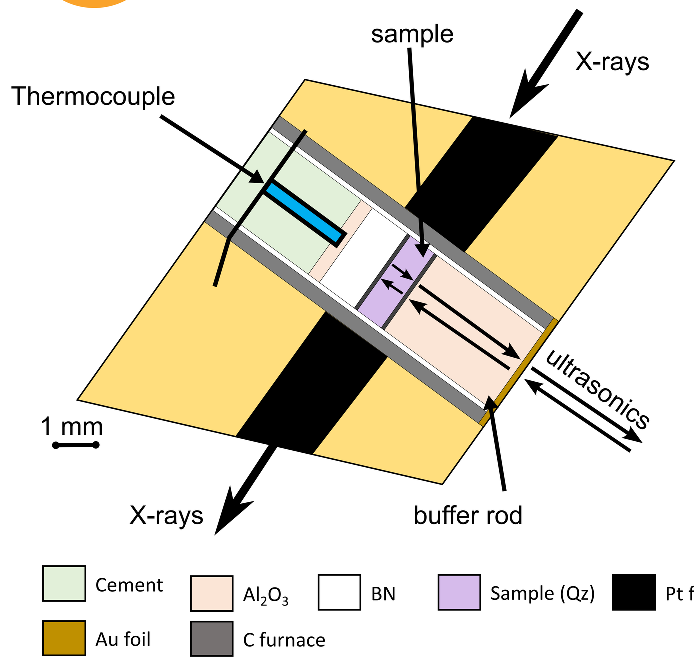
BACKGROUND

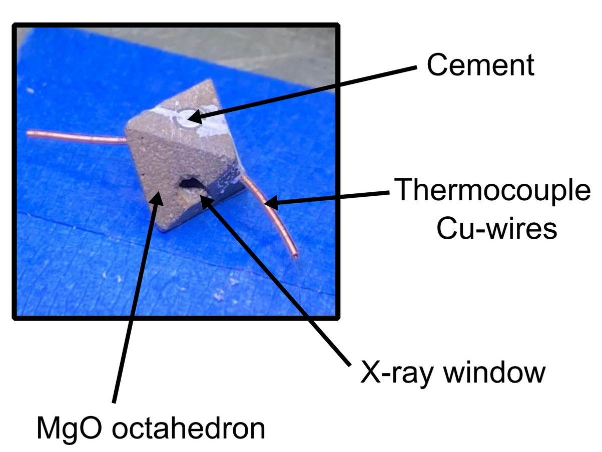
Quartz is a common constituent of most rocks in the Earth's continental crust an it undergoes the **α-β transition** at deep crustal conditions. The transition is well-known at ambient pressures, but only few works report its behaviour at high pressures. Thermodynamic databases (Abers and Hacker, 2016) predict a dramatic increase in V_p in the high T field with depth, which results in the attribution of high velocities zones in seismic tomography data to this transition. Here, we performed high pressure and temperature experiments using a multi-anvil press. Quartz lattice parameters were obtained using **synchrotron X-ray radiation** (ESRF) while simultaneously measuring acoustic velocities using **ultrasonic pulse-echo travel times**.

METHODS

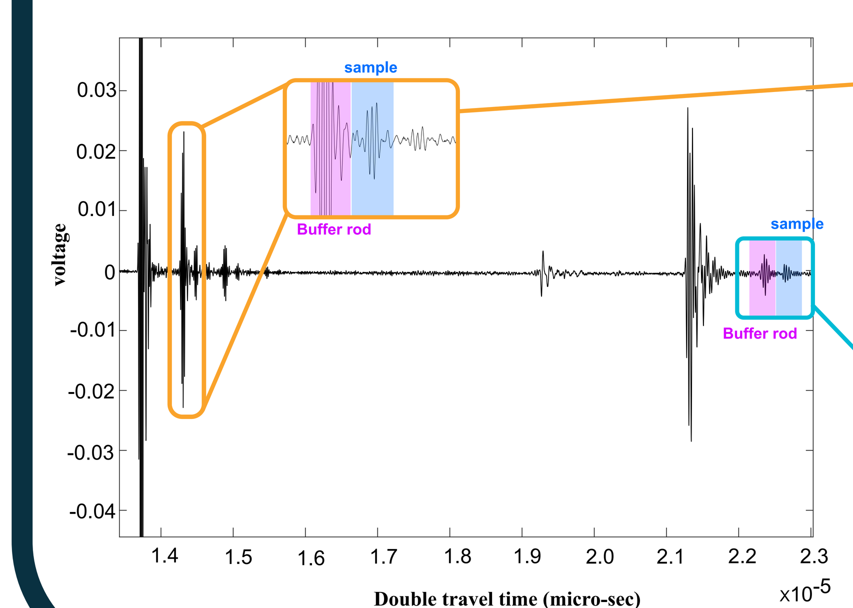
Experiments have been conducted at the Large Volume Press at the ID06 beamline (ESRF).

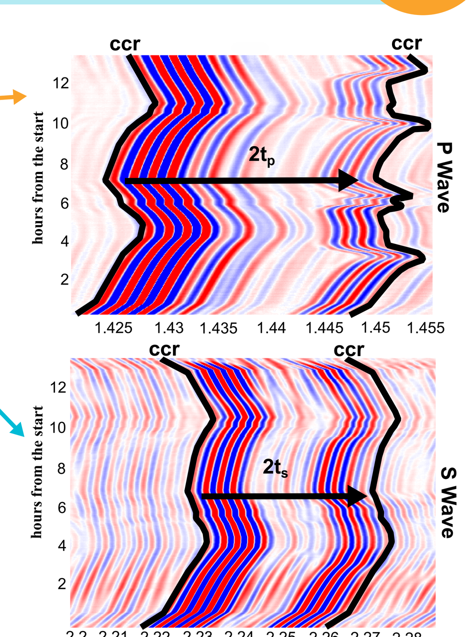
The assemblage used for the experiments is the 10/4. Samples were 0.62 mm in length and 0.8 mm in diameter





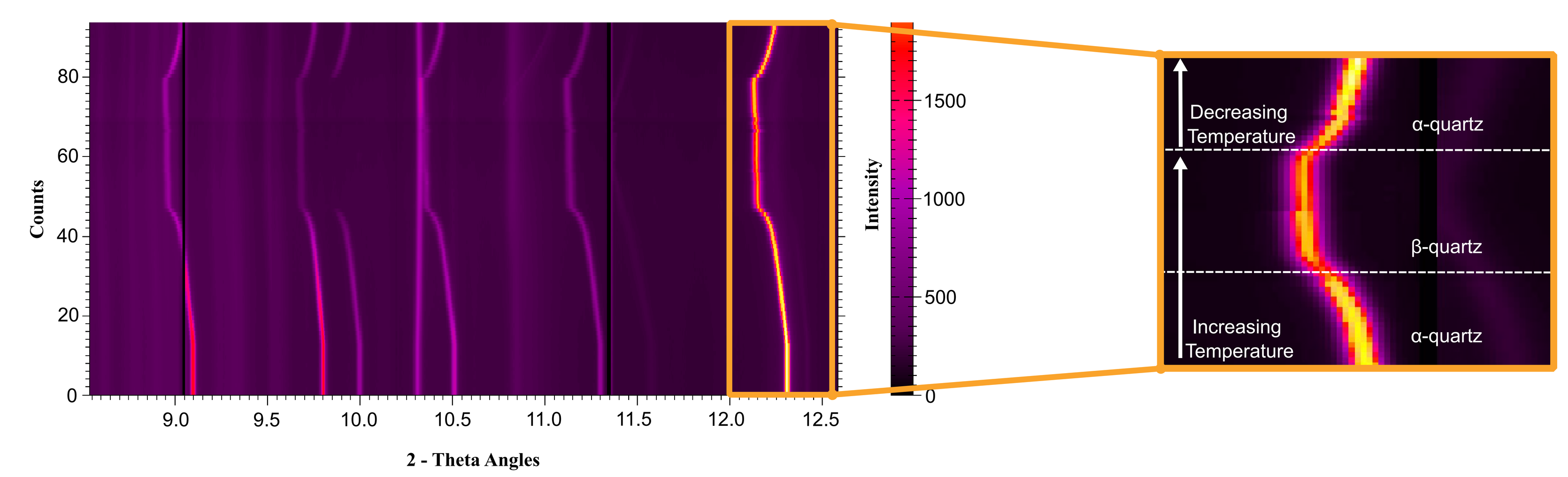
While collecting the diffraction patterns, we measured the wave velocities using a $LiNbO_3$ transducer



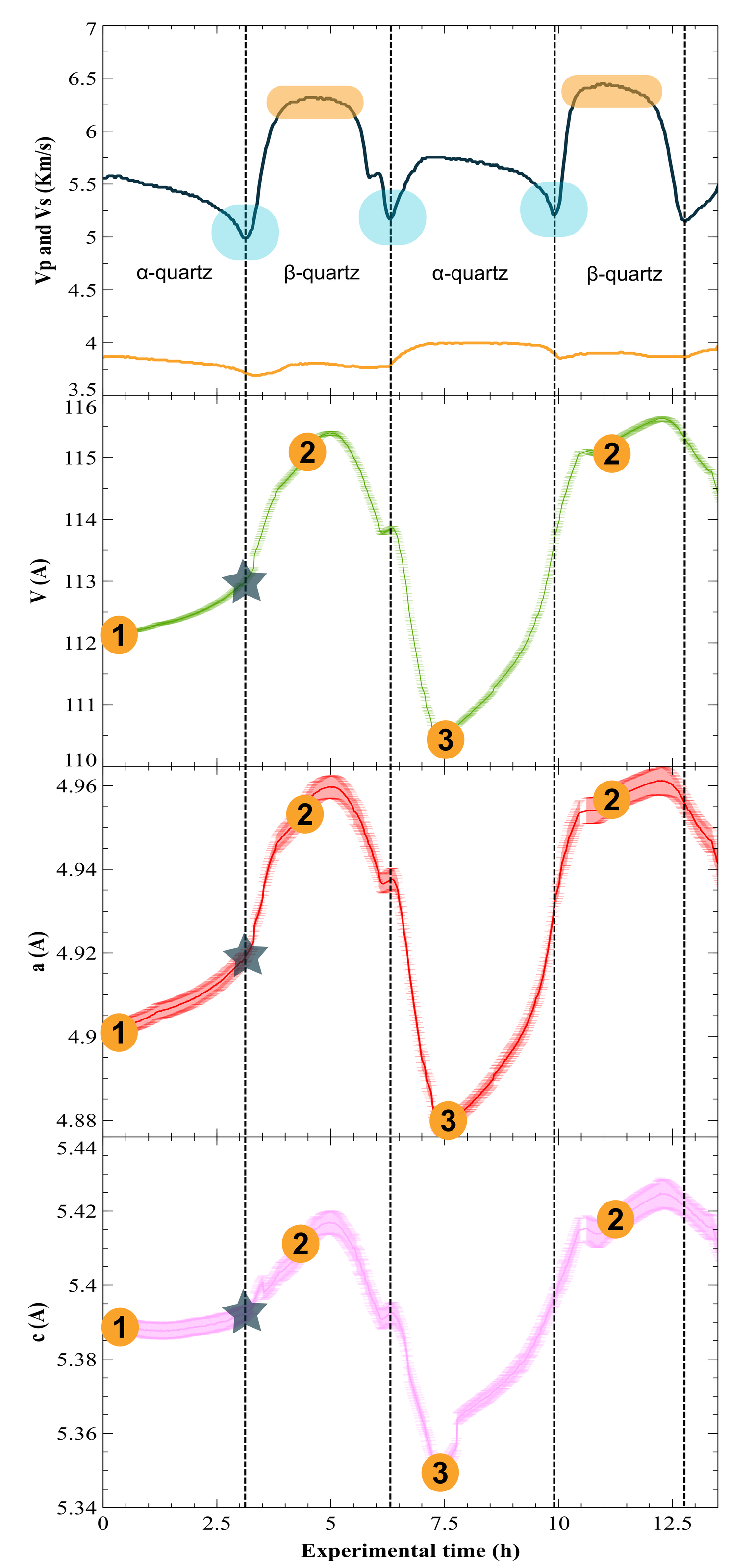


RESULTS

In order to observe the behaviour of the α-β transition at different conditions we stacked the diffraction patterns collected at a constant pressure while increasing the temperature and vice versa.



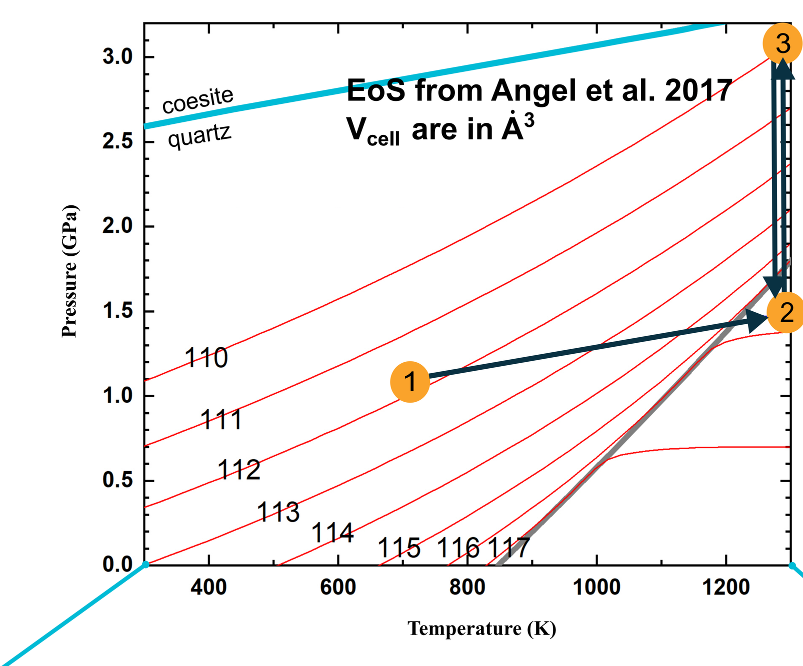
We performed a sequential refinement to obtain **volume** and **cell parameters**. At the same time, we collected **wave velocities** from double travel times and X-ray absorption images of the sample.



As predicted by thermodynamic modelling, we observe that approaching the transition, V_p varies more than V_s, reaching a minimum that marks the **α-β transition.**

In the β-field, V_p increases rapidly and reaches higher values than in the α-field.

From the refinement, volumes and cell parameters estimates don't seem to show the transition at the same time as the acoustic data.
According to predictions from the EoS (Angel et al. 2017), after the transition, with increasing temperature, the volume should remain constant or slightly decrease.

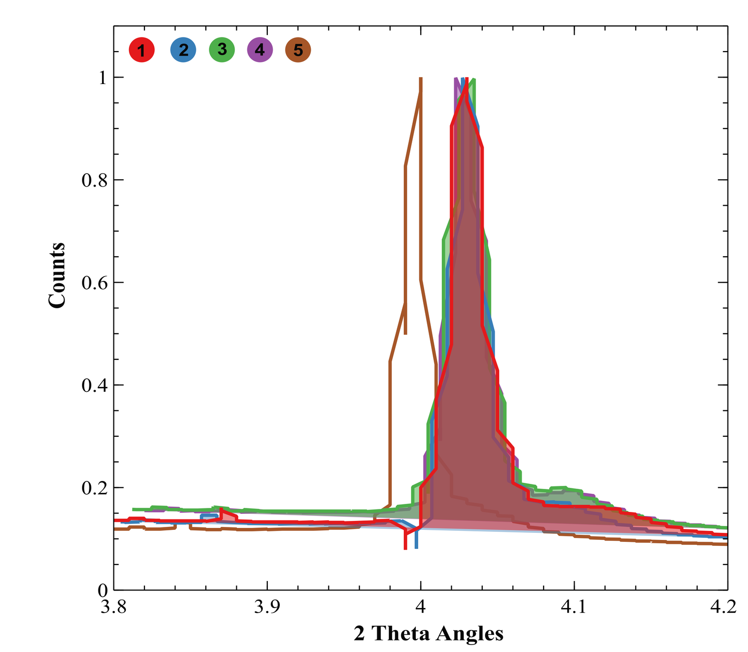


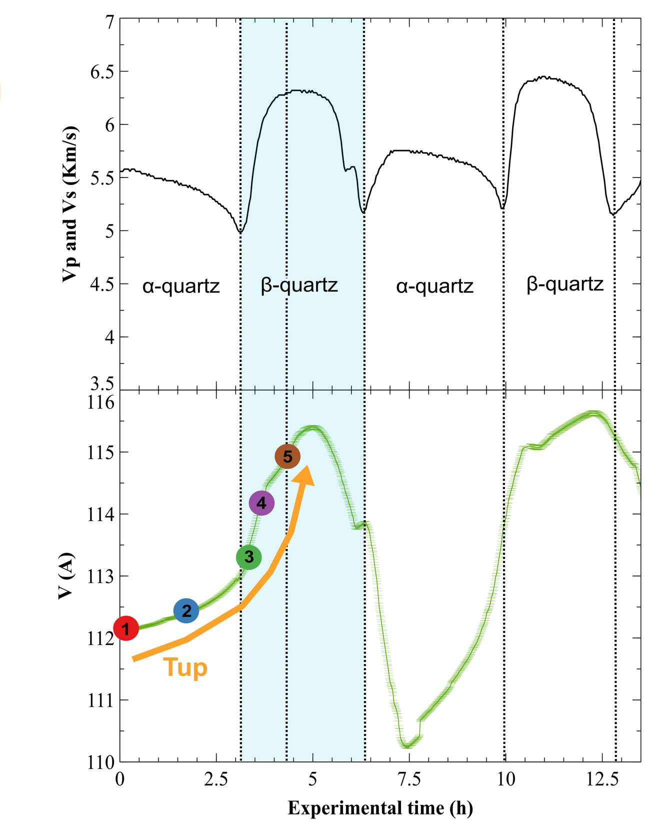
P-T path of the experiment along with quartz isochores

INTERPRETATION

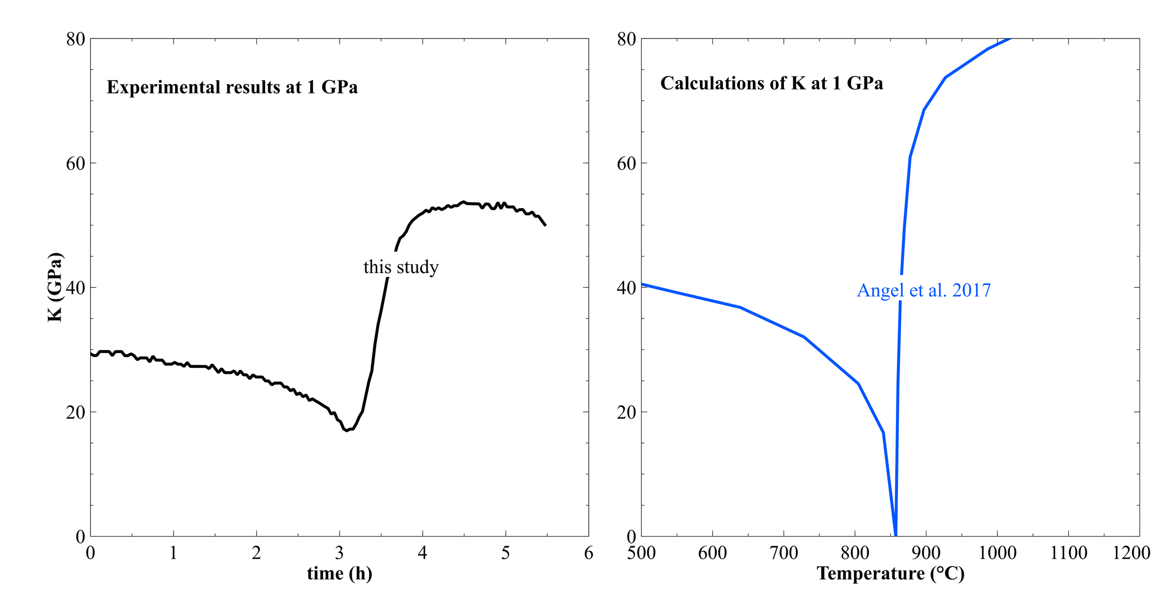
In our preliminary results, we observe that after the α-β transition the volume keeps increasing. This unexpected behaviour could be explained by a **stress gradient** or a **temperature gradient** in the sample. In both cases the sample could be inhomogeneous and characterized by domains at different stages of the transition. Some observations on the diffraction peak widths, suggest that the sample is not transforming in a homogeneous way, causing the incrase of the FWHM of the diffraction peaks after the transition. Once the entire sample is transformed to β-quartz (i.e. velocities are constant), it behaves as predicted by the EoS.

Comparison of FWHM for the same peak along the first temperature ramp at 1 GPa





At this point, one can calculate the elastic moduli from V_p and V_s. In our results, we obtain that the bulk modulus (K), calculated at a constant pressure of 1 GPa and during a temperature ramp, has values of around 30 GPa in the α-field and of around 55 GPa in the β-field. Interestingly, the bulk modulus does not drop to 0 GPa at the transition and is significantly weaker than predicted by the EoS calculations.



References:

Angel, R.J., Alvaro, M., Miletich, R. et al. A simple and generalised P–T–V EoS for continuous phase transitions, implemented in EosFit and applied to quartz. Contrib Mineral Petrol

Abers, G. A., and Hacker, B. R. (2016), A MATLAB toolbox and Excel workbook for calculating the densities, seismic wave speeds, and major element composition of minerals and rocks at pressure and temperature, Geochem. Geophys. Geosyst

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