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Seismic properties of Southalpine metapelite at high temperatures and pressures: revisiting the alpha–beta quartz phase transition

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This work concludes a study started many years ago in the Rock Deformation Laboratory of ETH Zurich, in which the seismic properties (Vp / Vs) of crustal metapelites at high pressure and temperature were characterised. A particular goal was to map the alpha–beta phase transition in quartz-rich rocks, and to link these effects to areas of above average heat flux. Our interest in metapelites is driven by the observation that they are among the most common metamorphic rock types of continental crust and possibly constitute a significant part of lower crust. Metapelites are rich in quartz and hydrous minerals (e.g. biotite, muscovite, chlorite), and are common in the lithology of areas high geothermal activity due to the higher than average heat flux. They are also good candidates to investigate dehydration reactions and phase transitions of the middle to lower crust.

To investigate, we employ a 'Paterson' type apparatus that is configured for petrophysical work, in particular elastic wave velocity and electrical conductivity, installed in the Rock Deformation Laboratory at ETH Zurich in 2002. Using this apparatus, we have been able to greatly expand our understanding of the seismic (and inducted seismicity) properties associated with dehydration reactions and phase transitions, simulating in situ conditions in the shallow crust.

Here we report new measurements of the seismic properties of a metapelite from the Serie dei Laghi basement (Southern Alps, N-Italy), revealing, for the first time under in-situ conditions, evidence for the alpha-beta transition. P-wave and S-wave elastic wave velocities were measured along the principal anisotropy directions at pressures up to 500 MPa. To observe the effects of the alpha-beta quartz transition under hydrostatic conditions, and additionally of muscovite dehydration, we then monitored P-wave velocity continuously as the sample was heated to 800°C, for a range of pressures. At 400 MPa, Vp decreases monotonically with temperature to 675°C; then as temperatures continue to increase Vp rapidly increases until 750°C. The effect is found to be perfectly reversible, and thus we interpret it as the alpha-beta transition in quartz. We measure a linear trend of the transition with increasing pressure, at a rate equivalent of 0.3 K/MPa, consistent with previous work. We also find evidence that the continuous increase of Vp at elevated temperatures (to 750°C) reflects the dehydration of muscovite + quartz to K-feldspar + sillimanite. After recovering the sample, we are able to support this hypothesis by identifying the presence of water in the assemblage and through the presence of newly formed K-feldspar and sillimanite.