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Elastic wave anisotropy in amphibolites and paragneisses from the Swedish Caledonides measured at high pressures (600 MPa) and temperatures (600 °C)

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Among the most important properties of crustal and mantle rocks is seismic anisotropy. Here we present laboratory measurements of directional dependence of elastic waves (velocity anisotropy, shear wave splitting) for eight cubic samples of deformed crustal rocks from central Sweden. The samples originate from a deep drilling investigation in central Sweden, as part of the Collisional Orogeny in the Scandinavian Caledonides (COSC) project and consist in paragneisses and amphibolites from the uppermost ca 1500 m of the borehole. The main aim of the work is to understand how these rocks were emplaced into the middle crust during the Caledonian orogeny, which took place ca 490-390 Ma. The samples were selected because they span a range of deformation conditions in the borehole. Therefore, we seek better understand the seismic properties and their relationship to rock microstructure and mineral composition. Two recent studies, by Hedin et al. (2016) and Wenning et al. (2016) provide an initial understanding of the reflection seismic and petrophysical character of the borehole and its surroundings. However, in order to better understand the elastic wave and anisotropy characteristics of the borehole, further laboratory investigations are desired. Such investigations should integrate laboratory measurements with petrological and textural analysis.

In this study, we address the contribution of microstructural parameters (crystallographic preferred orientation, shape preferred orientation, microcracking) to the elastic anisotropy of different amphibolites and paragneisses under true triaxial experimental condition. Experimental data include the measurements of elastic wave velocities (Vp, and polarized shear wave Vs1 and Vs2) and densities at confining pressures up to 600 MPa and temperatures up 600°C. The results include the determination of temperature and pressure derivatives of density, velocities, and calculation of velocity anisotropy. Measurements confirm strong relations of velocity anisotropy, shear wave splitting and shear wave polarisation to the structural frame of the rocks (foliation, lineation). Importantly, microcrack closure is closely linked to linear strain and our measurements illustrate how microcracks affect the inelastic deformation of samples as well as enhancing anisotropy at low confining pressures. Above ca 150 MPa the effect of cracks is almost eliminated, due to progressive closure of microcracks.

Amphibolites are moderate to highly anisotropic, with P and S wave anisotropies exceeding 10 %. Paragneisses are much less anisotropic, with P and S waves anisotropies <10 %. Measurements presented in this study provide constraints on simultaneous pressure and temperature effects on Vp and Vs, in different sample directions.