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Borehole seismic in crystalline environment at the COSC-project in Central Sweden

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As support for the COSC drilling project (Collisional Orogeny in the Scandinavian Caledonides), an extensive seismic survey took place during September and October 2014 in and around the newly drilled 2.5 km deep COSC-1 borehole. The main aim of the COSC project is to better understand orogenic processes in past and recently active mountain belts. For this, the Scandinavian Caledonides provide a well preserved case of Paleozoic collision of the Laurentia and Baltica continental plates. Surface geology and geophysical data provide knowledge about the geometry of the Caledonian structure. The reflectivity geometry of the upper crust was imaged by regional seismic data and the resistivity structure by magnetotelluric methods. The crustal model was refined by seismic pre-site surveys in 2010 and 2011 to define the exact position of the first borehole, COSC-1.

The completely cored COSC-1 borehole was drilled in Central Sweden through the Seve Nappe Complex, a part of the Middle Allochthon of the Scandinavian Caledonides that comprises units originating from the outer margin of Baltica. The upper 2350 m consist of alternating layers of highly strained felsic and calc-silicate gneisses and amphibolites. Below 1710 m the mylonite content increases successively and indicates a high strain zone of at least 800 m thickness. At ca. 2350 m, the borehole leaves the Seve Nappe Complex and enters underlying mylonitised lower grade metasedimentary units of unknown tectonostratigraphic position.

The seismic survey consisted of three parts: a limited 3D-survey, a high resolution zero-offset VSP (vertical seismic profile) and a multi-azimuthal walkaway VSP (MSP) experiment with sources and receivers along three surface profiles and receivers at seven different depth levels of the borehole. For the zero-offset VSP (ZVSP) a hydraulic hammer source was used and activated over a period of 20 s as a sequence of impacts with increasing hit frequency. The wave field was recorded with 3-component geophones and a receiver spacing of 2 m over the whole borehole length.

As first pre-processing steps, the three component VSP data were decoded and vertically stacked. Afterwards, the shots were merged to get a continuous shot gather. A horizontal rotation was performed, based on the S-wave arrivals.

The rotated ZVSP-data show a high signal-to-noise ratio and good data quality. Signal frequencies up to 150 Hz were observed. On the vertical component, clear direct P-wave arrivals are visible. Several P-wave reflections occur below 1600 m logging depth. On both horizontal components, clear direct S-wave arrivals are visible after rotation what suggests that the penetrated rock is anisotropic. In addition, several PS-converted waves can be identified.

In order to integrate the borehole data into the 3D surface seismic data, further processing concentrated only on the P-waves. First, deconvolution was applied to sharpen the signals and to suppress multiples. Then the wave field was separated into upgoing and downgoing components by median filtering. Finally, a corridor stack was generated using the upgoing wave field in order to allow correlation with the borehole logging data and the surface seismic data.