Geophysical Research Abstracts
Vol. 20, EGU2018-13654, 2018
EGU General Assembly 2018

Pre-stack depth migration in an anisotropic crystalline environment at the COSC-1 borehole, central Sweden

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The Scandinavian Caledonides represent a well preserved deeply eroded Palaeozoic orogen, formed by the collision of the two palaeocontinents Baltica and Laurentia. Today, after four hundred million years of erosion along with uplift and extension during the opening of the North Atlantic Ocean, the geological structure in central western Sweden consists of allochthons, underlying autochthonous units, and a shallow west-dipping décollement that separates the two and is associated with Cambrian black shales. The project COSC (Collisional Orogeny in the Scandinavian Caledonides) aims to investigate these structures and their physical conditions with two approximately 2.5 km deep fully cored scientific boreholes in central Sweden. Thus, a continuous 5 km tectonostratigraphic profile through the Caledonian nappes into Baltica's basement will be recovered. The first borehole COSC-1 was successfully drilled in 2014 through the seismically highly reflective Seve Nappe Complex (as part of the Middle Allochthons), which was deformed and emplaced hot onto the Lower Allochthons during the collisional orogeny that formed the Scandinavian Caledonides. This unit mainly consists of felsic (gneisses) and mafic (amphibolites) rocks. After drilling was completed, several surface and borehole based seismic experiments were conducted. In this study, the data from a multi-azimuthal walkaway VSP in combination with long offset surface lines was used to image the structures in the vicinity of the borehole. Clear differences in vertical and horizontal P-wave velocities were observed and made it necessary to also account for anisotropy during velocity model building. The resulting VTI velocity model provides the basis for subsequent application of seismic imaging approaches, like Kirchhoff pre-stack depth migration, including calculation of Greens functions using an anisotropic eikonal solver. The resulting images were compared to the corresponding migration results based on an isotropic velocity model. Both images are dominated by strong and clear reflections. However, they appear more continuous and better focused in the anisotropic result. Most of the reflections originate below the bottom of the borehole and therefore are probably situated within the Precambrian basement or at the transition zones between Middle and Lower Allochthons and the basement. The deeper reflections might also represent dolerite intrusions or deformation zones of Caledonian or pre-Caledonian age. Their origin remains enigmatic and might only be revealed by drilling the proposed borehole COSC-2, which is supposed to penetrate some of these reflectors.