Seismic depth imaging workflow for imaging the vicinity of the COSC-1 borehole, central Sweden

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Collision of the palaeocontinents Baltica and Laurentia in the Palaeozoic resulted in the development of the Scandinavian Caledondies. Today, after 400 Ma of erosion along with uplift and extension during the opening of the North Atlantic Ocean, the geological structures in western central Sweden are comprised of far transported allochthons, the underlying Precambrian crystalline basement, and a shallow west-dipping décollement that separates the two and is associated with a thin layer of Cambrian black shales. These structures, in particular the Seve Nappes (upper part of the Middle Allochthons), the Lower Allochthons and the highly reflective basement are the target for two deep scientific cored boreholes that are part of the project COSC (Collisional Orogeny in the Scandinavian Caledonides). Thus, a unique approximately 5 km deep tectonostratigraphic profile through the Caledonian nappes into Baltica's basement will be recovered. The first borehole, COSC-1, was successfully drilled to a total depth of 2.5 km in 2014 and revealed a thick section of the seismically reflective Lower Seve Nappe, consisting mainly of felsic gneisses and mafic amphibolites. The second borehole, COSC-2, will be drilled during 2020 and will penetrate the underlying thrust-sheets, the main Caledonian décollement and the Precambrian basement. To allow for extrapolation of findings from core analysis and downhole logging to the structures around the COSC-1 borehole, several surface and borehole seismic experiments were conducted after drilling of it. Here, we present the complete seismic depth imaging workflow that was used to characterize the vicinity of the COSC-1 borehole along three seismic profiles centred on it. We started with velocity model building, taking also into account the seismic anisotropy of the Seve Nappe Complex. Then we calculated Green's functions using an anisotropic eikonal solver for a VTI (transversely isotropic medium with vertical axis of symmetry) velocity model. In the next step we applied anisotropic Kirchhoff pre-stack depth migration to image the structures around and below the COSC-1 borehole. We show that the anisotropic results are superior to the corresponding isotropic depth migration results. In a last step we used converted waves to further characterize the rock in the vicinity of the borehole.

The imaging results provide a link between a high-resolution 3D data set and the existing regional scale 2D COSC Seismic Profile (CSP) and complement these data sets, especially in the deeper parts below the borehole. Many different structures are imaged using the different data sets, most of which can be correlated with the Precambrian basement or the transition zones between Middle and Lower Allochthons and the basement. The origin of the deeper reflections remains enigmatic, they possibly represent dolerite intrusions or deformation zones of Caledonian or pre-Caledonian age.