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3D Seismic Processing of Crooked Line 2D Data in the Vicinity of the COSC 2.5 Km Deep Scientific Borehole

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SUMMARY

Two crooked line 2D seismic profiles were acquired in the vicinity of the location of the first scientific borehole of the Collisional Orogeny in the Scandinavian Caledonides (COSC) project. The planned depth of the borehole is 2.5 km and drilling will start in mid-Spring 2014. The data were previously processed in 2D and the borehole was located based on the results of this processing. In order to obtain a better image of the subsurface and provide better predictions of the expected lithology at depth the data have been reprocessed as a sparse 3D data set. The 3D processing suggests that a larger mafic lense is expected to be penetrated at about 1000 m depth and the base of a high grade metamorphic unit at about 2.2-2.3 km depth. The upper 500 m is not well imaged due to the acquisition geometry.

Introduction

A major drilling project has been approved and funded by the International Continental Scientific Drilling Program (ICDP) and the Swedish Research Council (Vetenskapsrådet – VR) for investigating the structure and composition of the Swedish mountains. Main objectives of the project, officially called Collisional Orogeny in the Scandinavian Caledonides (COSC – www.ssd.se/projects/cosc), include (i) improved understanding of mountain building processes (orogeny), (ii) investigating the geothermal gradient and its response to paleoclimatic influences along with the hydrogeological-hydrochemical state of the mountain belt and the deep biosphere in the metamorphic rocks and crystalline basement, and (iii) calibration of surface geophysics and geology. The COSC research program is being developed by five working groups, geology, geophysics, geothermics, hydrogeology and microbiology. It has direct relevance for society by improving our understanding of mountain building processes, hydrological-hydrochemical regimes in mountain areas and Precambrian shields, deep subsurface conditions for underground engineering, ore genesis and assessment of geothermal potential.

Drilling of the COSC-1 borehole, near the town of Åre in central Sweden, will start in late April 2014 and continue through the summer. A total depth of 2.5 km is expected to be reached by August. After completion, extensive geophysical measurements will be made in the borehole, including borehole seismics. The borehole will be fully cored the entire way and the core oriented using a combination of core scanning and borehole wall imaging. We present results from 3D processing of 2D crooked line data acquired near the location of the COSC-1 borehole. We show how the 3D processing allows better predictions to be made for the drilling program compared to the 2D processing.

Seismic survey

Seismic data were acquired in the Åre area along two profiles in the summer of 2010 for the purpose of locating the COSC-1 borehole. A rock breaking mechanical hammer was used as a source and recording was done with 300–360 active channels using 28 Hz geophones. The nominal shot and receiver spacing was 20 m. However, the shot spacing was decreased to 10 m for an almost 2 km stretch in the vicinity of the COSC-1 drill site. This is in an area where the profiles are also quite crooked, resulting in a large lateral spread of the midpoints (Figure 1). Previous crossdip analysis of the seismic data indicated a SW-NE strike of the structures with mainly a gentle NW dip. Based on these results the borehole was placed at a location where the high grade metamorphic Seve nappe was at its thickest. Although highly reflective, no long continuous reflections are observed within the nappe in the 2D processing, suggesting that their lateral extent is also limited in the crossline direction. Therefore the data were treated as a sparse 3D data set and midpoints were binned into 20 m x 20 m bins in a grid inlines and crossline (Figure 1). Standard 3D processing was applied and the resulting migrated seismic volume imported into interpretation software.

Results

Although it contains gaps, the migrated 3D volume shows that the observed reflected structures within the Seve nappe are not only limited in their inline continuity, but also in their crossline continuity. The planned COSC-1 borehole lies at the edge of the seismic volume (Figures 1 and 2), but clear reflected features can be traced for the more clearly imaged central part of the midpoint cloud out towards the planned borehole trajectory (Figure 2). The most important ones are a distinct reflection at about 1000 m depth and what appears to be the base of the reflective unit at about 2.2–2.3 km depth. The reflection at 1000 m is interpreted to be a mafic lense within the generally gneissic Seve nappe while the deeper boundary represents the transition from the Seve nappe to lower grade metamorphic rocks. Knowledge of what lithology will be drilled will help plan the drilling and hydrogeological testing program for the borehole. Due to the location of the borehole (governed by road access) relative to the seismic profiles the upper 500 m are not well imaged near it. There could be significant changes in impedance contrasts within this interval that cannot be predicted from the seismic data.

Figure 1 (left) Profile geometry in the COSC-1 borehole area, (right) fold for 20 m x 20 m bins.

Figure 2 Slices of the 3D image near the COSC-1 borehole (blue line).

Conclusions

3D processing of crooked line 2D data allow better predictions to be made for the drilling of the 2.5 km deep COSC-1 borehole. In particular, a larger mafic lense is expected to be penetrated at about 1000 m depth and the base of the high grade metamorphic Seve nappe at about 2.2-2.3 km depth.

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