The Collisional Orogeny in the Scandinavian Caledonides (COSC) project: Some results and current status

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The Scandinavian Caledonides provide a particularly well-exposed example of a Paleozoic mountain belt formed by the collision between the Baltica and Laurentia continents. The opportunities offered by the Caledonides for understanding collisional processes are unique owing to the deep level of erosion (mid-lower crustal) and the paucity of superimposed post-Paleozoic deformation. The Caledonides are often compared to the present-day Himalayan continental collision zone. In the Himalayas, an understanding of the on-going India-Asia collision at depth primarily depends on indirect observations such as the interpretation of geophysical data and analysis of magmatic signatures. By contrast, in the Caledonides, it is possible to directly observe and sample the “fossilized” Paleozoic collisional processes that occurred in the middle and lower crust, from the foreland far into the hinterland, over a lateral distance across the orogen of c. 300 km.

The geometry of the collisional structures, both of the thrust sheets and the underlying basement, can be constrained by combining surface geological data with geophysical data. This allows addressing several unknowns regarding the collision process: the structure and physical conditions of the deformation and metamorphism during nappe emplacement, the effects of the orogeny on the basement of the underriding plate in the foreland of the mountain belt, and the mechanism that allows lateral transport of material in the nappes over distances of several hundreds of kilometers. The COSC project is investigating these unknowns with two fully cored 2.5 km deep boreholes that will provide a unique c. 5 km deep composite section through some of the overriding thrust sheets, the main detachment and into the basement of the collisional underriding plate.

COSC-1 (Fig. 1) aimed at providing a continuous section downwards from within the high-grade metamorphic Lower Seve Nappe into the underlying lower-grade Särv nappe. It sampled a thick section of the lower part of the high grade metamorphic Seve Complex. Main findings from the drilling were: (1) the Lower Seve Nappe proved to be composed of rather homogeneous gneisses, with only subordinate mafic bodies. (2) The basal thrust zone was unexpectedly thick (> 800 m) and the drill hole did therefore not penetrate the bottom of the thrust zone. However, lower-grade metasedimentary rocks were encountered in the lowermost part of the borehole together with garnetiferous mylonites tens of meters thick. (3) Between 300 m and total depth, the compact gneisses host only eight fluid conducting zones of limited transmissivity. (4) Downhole measurements indicate an average geothermal gradient of about 20 degrees C per km, a relatively high gradient for Swedish conditions.

The planned second borehole, COSC-2 (Juhlin et al., 2016) will investigate the main Caledonian detachment that separates the Caledonian allochthons from the autochthonous basement of the Fennoscandian Shield. Basement structures at the planned site are of particular interest and are within reach of the drilling. Scientific targets of the COSC-2 borehole are to understand the geometry, stress distribution and rheology of the main detachment and associated fault systems in the foreland of one of the Earth’s largest orogens, and to determine the relationship between the basement deformation and the thrust tectonics in the nappes above.

The location of the COSC-2 borehole is based on results from high resolution seismic profiling (Fig. 2). Migrated and depth converted results show generally transparent rock down to about 700 m at the optimum location for COSC-2. Between 700 m and 1200 m the reflectivity is strong, but rather discontinuous, while below 1200 m distinct laterally continuous reflections are present. MT data acquired along the seismic profile (Yan et al., 2017) detected a strong conductor with a resistivity of less than 1 Ωm at a depth of about 700 m at m at a depth of about 700 m at the site of the planned borehole. This conductivity boundary is interpreted to represent the uppermost Cambrian Alum shale. Below this depth, the resistivity structure is difficult to resolve. However, the total magnetic field data indicate magnetic Precambrian basement at about 1200 m depth. Combined, the data indicate that the upper 700 m of Silurian and Ordovician strata will be dominated by greywacke with subordinate quartzite, limestone and shale. Between 700 m and 1200 m an imbricate system of shales, limestones and turbidites are expected. Below about 1200 m, Precambrian rocks, including magnetic granites with dolerite sills, are anticipated.

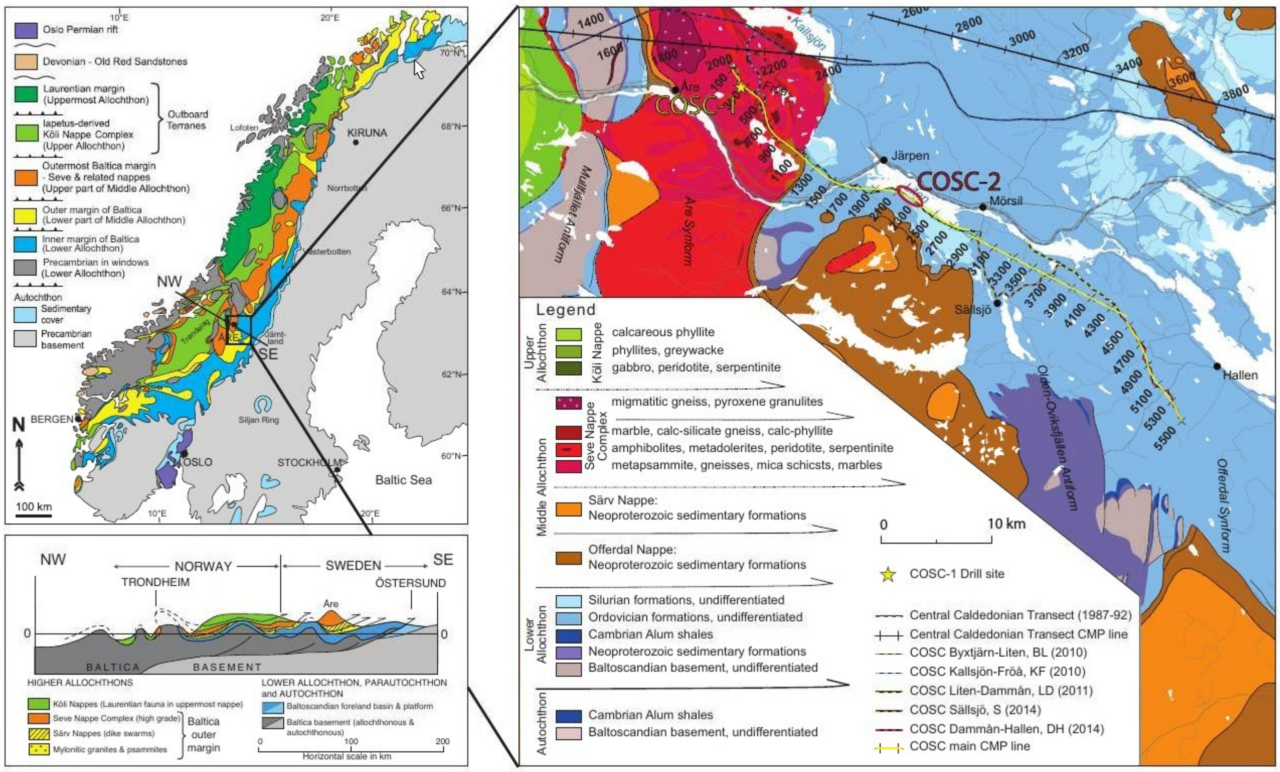

Figure 1. Tectonostratigraphic map of the Scandinavian Caledonides (after Gee et al. 2010) and location of the seismic profile shown in Figure 2. Detailed map is based on the regional geological map by the Geological Survey of Sweden.

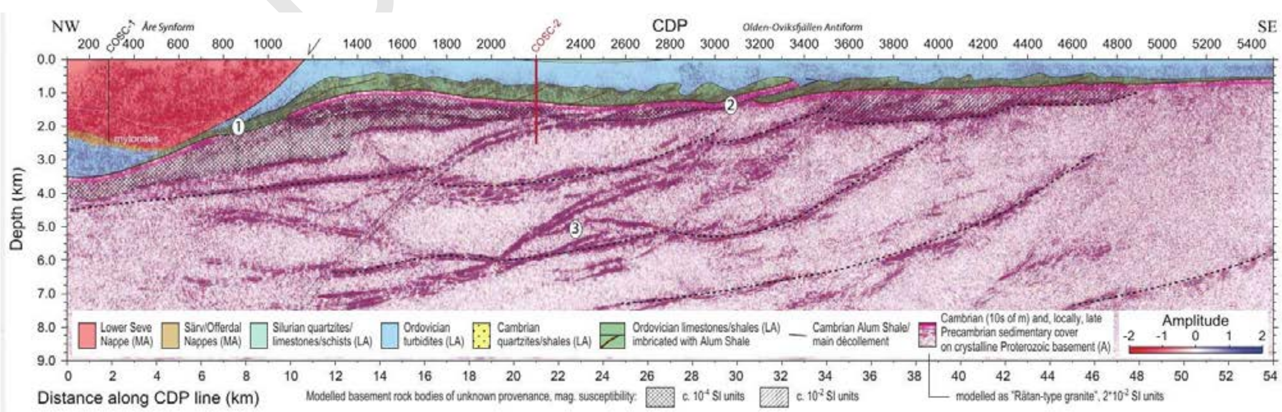

Figure 2. The COSC composite seismic profile and interpretation based on Juhlin et al. (2016). The image shows a thinskinned translation of deformation towards the foreland along the main decollement in Cambrian Alum shale. Below the Åre Synform, the detachment is folded and rises rather steeply in the westernmost 12 km of the profile,

whereafter it flattens out to an average slope of 1-2 degrees. Alum shale and Ordovician limestone are intensely affected and thickened by imbricate thrusting in the central part of the profile.

References

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