Scientific drilling to understand the evolution of mountain belts

The Collisional Orogeny in the Scandinavian Caledonides (COSC) scientific drilling project

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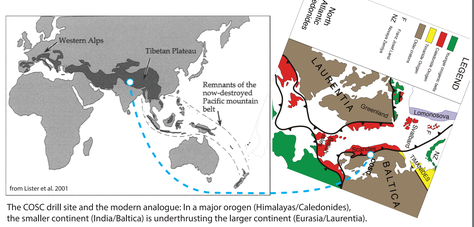
The COSC Project

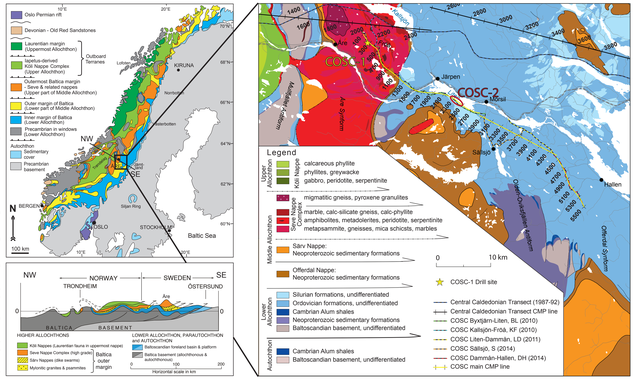
COSC is investigating mountain building processes at mid to lower crustal levels in a deeply eroded Paleozoic collisional orogen of Himalayan dimensions. Two fully cored COSC boreholes will provide a unique circa 5 km deep composite section from a subduction-related allochthon (the Seve Nappe) through the underlying continental margin, mostly cover-derived nappes, and the basal décollement into Precambrian crystalline basement. Utilising the Caledonides as an analogue to comparable tectonic settings, such as the Himalaya, will advance our understanding of orogenic systems and how they affect the stability of the living environment.

COSC aims to establish a coherent model of Caledonian orogeny (c. 490-390 Ma) and apply these new insights to the interpretation of modern analogues. The project will establish the crustal rheology during Scandian continent-continent collision (c. 440-390 Ma) to better understand the tectonic behaviour of the lower and middle crust in the underthrusting plate and build a type model of the crustal structure of the central Scandes based on the unprecedented high density of geophysical field and borehole data and the rock physics and petrology of the drill cores. These provide unique information about the passage from thin-skinned tectonics in the foreland to thick-skinned in the hinterland, which will be utilised as an analogue for other orogens. Topics like inverse temperature modelling, the hydrogeology of mountain belts and the deep biosphere complement the solid Earth sciences research.

COSC is located on the Central Caledonian Transect (CCT), a well investigated area between Östersund in Sweden and Trondheim in Norway. Here, large scale tectonic transport in form of nappes was propsed 130 years ago. Major, regional geophysical surveys (refraction & reflection seismics, MT) were conducted in the 1970-90s. Recent high- resolution reflection seismic and MT surveys of the site investigations cover the central CCT. Borehole seismics and 3D seismic surveying around the drill sites complement the extensive geophysical data sets.



The COSC drill site and the modern analogue: In a major orogen (Himalayas/Caledonides), the smaller continent (India/Baltica) is underthrusting the larger continent (Eurasia/Laurentia).



Tectonostratigraphic map of the Scandinavian Caledonides and geological map of the COSC project area (modified after Geological Survey of Sweden map) with regional and site survey geophysical profiles.

COSC-1 (drilled 2014):

"The emplacement of high-grade metamorphic allochthons during orogeny"

The COSC-1 drill hole penetrated a succession dominated by gneisses of varying compositions. Meta-gabbros and amphibolites are common and apparently correlate with seismic reflections between 500 and 1000 m depth. Also, marbles, pegmatite dykes and minor mylonites occur. All rocks are highly strained. The first signs of a distinct thrust zone appear shortly below 1700 m as narrow deformation bands and thin mylonite layers in the gneisses. Below c. 2100 m, mylonites are dominating and garnet becomes common. A transition from gneiss into lower grade metasedimentary rocks occurs between at c. 2350 m. Below this depth, the drill core is dominated by mylonitic quartzite of unclear tectonostratigraphic position.

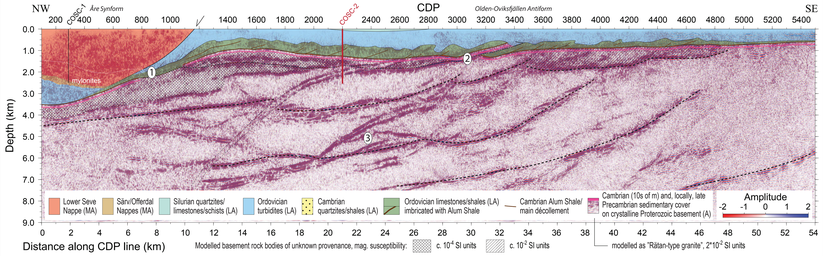
The profile of the drill core is extended along outcrops from the drill site (which is located just below the tree line) to the top of mountain Åreskutan, the centre of the hot allochthon where micro-diamonds were discovered recently.

The focus of the scientific work is to

=> establish a P-T(-t) profile (see poster X2.310)

=> date the deformation episodes (see poster X2.311)

=> research deformation processes at multiple scales (see poster X2.312 & EGU2017-8632)



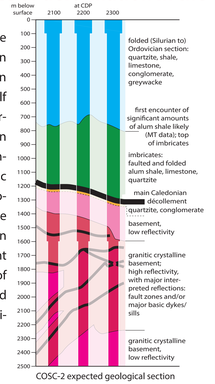
The COSC composite seismic profile (CSP) and interpretation (site-investigations acquired 2010-2014; for position see map to the left). The image shows a thin-skinned translation of deformation towards the foreland along the main Caledonian décollement in the Cambrian Alum shale. Below the Åre Synform, the detachment is folded and rises rather steeply in the first 12 km of the profile, where it flattens out to an average slope of c. 1-2°. Alum shale and Ordovician limestone are intensely affected and thickened by imbricate thrusting in the middle part of the profile.

COSC-2 (applied for):

"The role of orgen-scale detachments and the extent and significance of deformation in the underriding plate"

Although COSC-1 research will continue for several years, planning for COSC-2 is already very advanced and the borehole will be drilled as soon as funding is secured. COSC-2 will define the character and age of deformation of the underlying greenschist facies thrust-sheets, the main Caledonian décollement and the Precambrian basement. The upper part of the borehole will sample a Cambro-Silurian succession, including both distal shelf sedimentary formations typical of the Baltoscandian platform and also foreland basin turbidites of both mid Ordovician and Early Silurian age, separated by significant environmental changes at the Ordovician-Silurian boundary. This part of the drill core will provide a unique distal section through the Baltica Shelf palaeoenvironment, which else is only known from proximal areas with high bioproductivity as they are exposed in the Baltic Sea region. The borehole will sample a laterally extensive imbricate section of Cambrian and, most likely, Ordovician strata that developed above the main Caledonian décollement, i.e. the detachment horizon below the Caledonian allochthons, which is hosted in the very organic-rich Alum shale. After drilling through the main décollement, COSC-2 will penetrate 1-1.5 km into the basement of the Fennoscandian Shield, where prominent seismic reflections indicate the presence of significant crustal shortening of Caledonian or older age. Study of this internal basement deformation is particularly important for understanding the passage from thin-skinned tectonics in the foreland of the orogen to thick-skinned tectonics in the hinterland, where the underriding Baltica plate experienced deformation and (U)HP metamorphism.

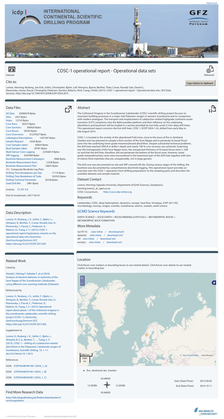
The science team welcomes new collaborators!



COSC-2 expected geological section

COSC-1 data:

COSC is a demonstrator project for good data and sample publishing policies. A better accessibility of data and samples will incite more research and thus, generate a better return on the invested funds. It also makes the project's science more transparent.



A short scientifc paper summarises the outcome of the operational phase

http://doi.org/10.5194/sd-19-1-2015,

which is described in detail in the operational report

http://doi.org/10.2312/ICDP.2015.002.

Associated with the operational report are the operational data sets

http://doi.org/10.1594/GFZ.SDDB.ICDP.5054.2015

and a description of these data sets

http://doi.org/10.2312/ICDP.2015.001.

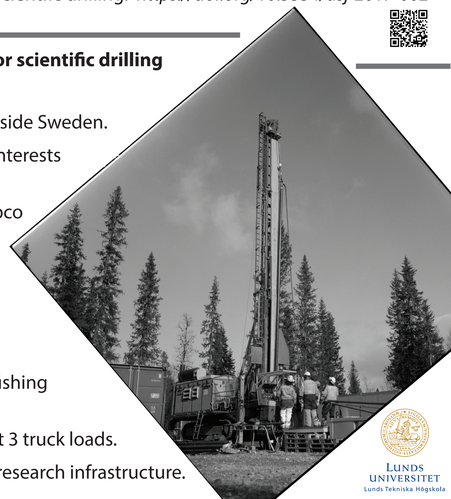
The **International GeoSample Number (IGSN)** is a persistent identifier for Earth samples that is resolvable via the handle.net system. It supports hierarchy and is supported by all major publishers.

The COSC-1 borehole as parent for all COSC-1 samples: *http://igsn.org/ICDP5054EHW1001*

The prarractice paper on IGSN implementation in scientfic drilling: *https://doi.org/10.5334/dsj-2017-002*

The Swedish national research infrastructure for scientific drilling "Riksriggen"

- is available for scientific projects at cost, also outside Sweden.
- is managed by Lund University, no commercial interests are involved (i.e. science is always first).
- is a wire-line diamond core-drilling rig (Atlas Copco CT20C) with a depth capacity of 2.5 km.
- is crawler mounted, i.e. can be driven from an access road or a landing site to drill site.
- includes a comprehensive set of downhole logging probes.
- includes diverse accessory equipment like BOP, fishing tools and more.
- Total mobilisation for drilling equipment is about 3 truck loads.
- Drilling expertise and consulting is a part of the research infrastructure.



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