COSC

Collisional Orogeny in the
Scandinavian Caledonides
Åre, Sweden

Swedish Scientific Drilling Program

Goal & Scientific Objective

Freshly retrieved core at the COSC-1 drill site.

COSC is investigating mountain building processes in an old (Paleozoic), deeply eroded collisional mountain belt of Himalayan dimensions. Utilising this orogen, the Caledonides, as an analogue to comparable modern settings, such as the Himalayan mountain belt, will advance our understanding of such orogenic systems and how they affect the stability of the living environment. Key scientific targets are i) to research mountain building processes in the deep interior of an orogen and utilise this new knowledge to better understand how collisional mountain building operates, including the nature and occurrence of natural hazards in modern orogenic environments, ii) to investigate the environmental conditions before, during and after continent-continent collision (c. 440-390 Ma), iii) to study the recent (up to 100 ka) evolution of the surface temperature in northern Europe by borehole temperature inverse modelling, iv) to research the (deep) groundwater and thermal characteristics of old mountain belts and v) the composition of deep microbial communities and their energy sources.

After the drilling of COSC-2, two fully cored boreholes will provide a unique c. 5 km deep composite section through the foreland of a major orogen, in a key-locality for research on mountain building processes that has relevance for the study of past and present mountain belts around the globe.

Data & Sample Access

Technical and scientific data from the operational phase are available at https://doi.org/10.1594/GFZ.SDDB.ICDP.5054.2015. For site survey data and other surveys in the borehole, please contact the PIs.

The COSC-1 drill core is archived at the Core Repository for Scientific Drilling at the Federal Institute for Geosciences and Natural Resources (BGR), Berlin.

Operational Achievements

The borehole COSC-1 was drilled as the first of two c. 2.5 km deep drill holes, cored and open (no casing) from 102.7 m to total depth. Two additional boreholes of 50 and 100 m depth, respectively, were drilled before drilling of the main hole and equipped with seismometers for passive monitoring of the drilling operations.

April to August 2014:

drilling operations at the main hole, final depth 2495.8 m.

Downhole logging and borehole vertical seismic profiling (VSP) conducted by OSG, GFZ and Lund University.

Core studies: MSCL (Multi Sensor Core Logging) including density and magnetic susceptibility; DMT core scanner, mud gas analyses (OLGA), geological logging.

A demonstration of the excellent drill core quality in the Seve gneisses.

Web & Media Resources

http://cosc.icdp-online.org/

www.facebook.com/collisionalorogeny/

Timeline

2009 COSC workshop proposal approved

2010 international COSC science workshop

2011 ICDP full proposal for COSC-1 approved

2014 COSC-1 borehole was drilled

2015 international COSC-2 science workshop

2017 ICDP full proposal for COSC-2 approved

Principal Investigators

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Scientific Findings

During the COSC-1 drilling operations, a nearly complete 2.4 km long drill core was obtained. It sampled a section through the Lower Seve Nappe, which is a during orogeny highly affected and modified rock unit that was emplaced over hundreds of kilometres from the deep internal part to the foreland of the orogen (Lorenz et al. 2015). Since COSC is a two stage project and COSC-2 not yet drilled, the scientific findings are preliminary and restricted to COSC-1 only.

Detailed pressure-temperature studies on drill core samples unexpectedly proved that the Lower Seve Nappe was affected by very high pressure and temperature (up to the amphibolite/eclogite metamorphic facies boundary) in the interior of the mountain belt before it was emplaced onto less affected rocks of the continental margin (Jeanneret et al., in prep.). This on-going study is central for our understanding how mass and heat is transferred within a developing mountain belt.

The rock volume around the drill hole was extensively characterised by geophysical methods. Thus, it was possible to refine the interpretation of regional (>150 km) and COSC (c. 60 km site investigations) multidisciplinary geophysical data sets and integrate them with the geological findings (Hedin et al. 2016, Wenning et al. 2016, Simon et al. 2017). This work is not finished yet, pending the drilling and investigations of the COSC-2 borehole.

The bedrock drilled in COSC-1 was surprisingly massive and does not provide good conductivity for groundwater. However, seven zones of limited groundwater inflow into the borehole could be detected and characterised (Doughty et al. 2016, Tsang et al. 2016). Such compact bedrock is not very favourable for deep microbial life. However, the limited results and COSC-specific methodological developments in both microbiology and hydrogeology did contribute significantly to applied studies about how to characterise relevant aspects of the subsurface for (mainly) engineering purposes (Eriksson et al. 2016, Dobson et al. 2016).

Key Publications

Dobson, P., Tsang, C.-F., Kneafsey, T., Borglin, S., Piceno, Y., Andersen, G., Nakagawa, S., Nihei, K., Rutqvist, J., Doughty, C. and others (2016) Deep Borehole Field Test Research Activities at LBNL, Lawrence Berkeley National Laboratory (LBNL), Berkeley, CA (United States). [online] Available from: http://www.osti.gov/scitech/biblio/1306290

Eriksson, L., Edlund, J., Johansson, L., Rabe, L., Bengtsson, A. and Pedersen, K. (2016) Methods for sampling and analysis of attached and planktonic microorganisms in deep granitic rock aquifers, SKB report R-16-09 p 61. [online] Available from: http://www.skb.com/publication/2484526/R-16-09.pdf

Hedin, P., Almqvist, B., Berthet, T., Juhlin, C., Buske, S., Simon, H., Giese, R., Krauß, F., Rosberb, J.-E., Alm, P.-G. (2016) 3D reflection seismic imaging at the 2.5km deep COSC-1 scientific borehole, central Scandinavian Caledonides. Tectonophysics 689 40-55. doi.org/10.1016/j.tecto.2015.12.013

Lorenz, H., Rosberg, J.-E., Juhlin, C., Bjelm, L., Almqvist, B.S.G., Berthet, T., Conze, R., Gee, D.G., Klonowska, I., Pascal, C., Pedersen, K., Roberts, N.M.W., Tsang, C.-F. (2015). COSC-1 – drilling of a subduction-related allochthon in the Palaeozoic Caledonide orogen of Scandinavia. Scientific Drilling. 19, 1–11. doi.org/10.5194/sd-19-1-2015

Lorenz, H., Rosberg, J. E., Juhlin, C., Bjelm, L., Almquist, B., Berthet, T., Tsang, C. F. (2015). Operational report about phase 1 of the Collisional Orogeny in the Scandinavian Caledonides scientific drilling project (COSC-1). Deutsches GeoForschungsZentrum GFZ. doi.org/10.2312/icdp.2015.002

Lorenz, H., Rosberg, J. E., Juhlin, C., Bjelm, L., Almquist, B., Berthet, T., Tsang, C. F. (2015). COSC-1 operational report Explanatory remarks on the operational data sets. Deutsches GeoForschungsZentrum GFZ. doi.org/10.2312/icdp.2015.001

Doughty, C., Tsang, C.-F., Rosberg, J.-E., Juhlin, C., Dobson, P. F. and Birkholzer, J. T. (2016). Flowing Fluid Electric Conductivity (FFEC) Logging of a Deep Borehole During and Following Drilling: Estimation of Transmissivity, Water Salinity and Hydraulic Head of Conductive Zones. Hydrogeology Journal. doi.org/10.1007/s10040-016-1497-5.

Wenning, Q. C., Almqvist, B. S. G., Hedin, P. and Zappone, A. 2016. Seismic Anisotropy in Mid to Lower Orogenic Crust: Insights from Laboratory Measurements of Vp and Vs in Drill Core from Central Scandinavian Caledonides. Tectonophysics..doi.org/10.1016/j.tecto. 2016.07.002.

Simon, H., Buske, S., Krauß, F., Giese, R., Hedin, P., Juhlin, C. (2017) The derivation of an anisotropic velocity model from a combined surface and borehole seismic survey in crystalline environment at the COSC-1 borehole, central Sweden. Geophysical Journal International. doi.org/10.1093/gji/ggx223

Tsang, C.-F.; Rosberg, J.-E.; Sharma, P.; Berthet, T.; Juhlin, C.; Niemi, A. (2016) Hydrologic testing during drilling: application of the flowing fluid electrical conductivity (FFEC) logging method to drilling of a deep borehole. Hydrogeology Journal, Volume 24, 6 1333-1341. doi.org/10.1007/s10040-016-1405 -z