

CHALLENGES IN ICE CORE DRILLING ON TEMPERATE ICE CAPS

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Techniques for ice core drilling on polar ice sheets and high-altitude ice caps have been developed and improved by many research groups over the past 60 years, as a means of retrieving records of past climate change and atmospheric composition. Less attention has been given to the natural archives that may be present in temperate ice caps and their physical properties are still poorly known.

In 1972, early in the history of ice core drilling, a 415 m long core was drilled on the flank of Bárðarbunga, a subglacial volcano within the Vatnajökull ice cap (Árnason et al., 1974). The drill was built at the Science Institute, University of Iceland. In the years 1997–2002, shorter cores were drilled on the Langjökull ice cap (70 m), Hofsjökull ice cap (100 m) (Sigurðsson et al., 2002; Thorsteinsson et al., 2002) and on the ice shelf of the Grímsvötn ice-filled caldera in Vatnajökull (115 m) (Thorsteinsson et al., 2006). Shallow drills built at the Alfred-Wegener-Institute were used in these projects. The drills were not designed to operate below the water table, which is at or near the firn-ice boundary in temperate glaciers during the melt season. A modified version of the AWI drill designed for such conditions was used in the Grímsvötn drilling 2002.

A revival of interest in the stratigraphy and past development of ice caps in Iceland has led us to complete a new drill system specifically designed for conditions in temperate ice. The length of the drill is 4.4 m and the core barrel can hold ice cores up to 1.2 m in length. A 1.5 m long shaft connects with the core barrel, forming a chips chamber between the shaft and the outer barrel. Below the water table, the chips float upwards into the chamber from the spiral section on the outside of the core barrel; a system that worked properly during the Grímsvötn drilling. A spiral booster on the lowest part of the shaft assists the upward movement of the chips. The drill motor is a submersible Grundfos MS402 motor delivering 1.1 kW. An antitorque and a winch with a 250 m long cable + control unit has been provided by AWI. Preparatory work is being supported by the Icelandic Centre for Research (RANNIS), as well as by the institutes involved. Plans for drilling and pre-site surveying have been developed by the research consortium involved in the EU-funded ICELINK project.

The main challenges experienced in drilling on temperate ice caps are, unsurprisingly, related to the water in the boreholes. During the 70 m drilling on Langjökull during wintery conditions in April 1997, water only sporadically entered the borehole. At 1790 m elevation on Hofsjökull during the first 10 days of August 2001, the water table was steady at the firn-ice boundary at 40 m depth. At 1350-m elevation in Grímsvötn, the water table was at 17 m during 10–20 June 2002, again coinciding with the depth of the firn-ice boundary.

Since the ice is at the melting point, the shape of the cutters and the lowest part of the drill head must be designed to minimize freeze-on during rotation at hole bottom. The AWI-type cutters do not have a flat base and thus are properly shaped in this respect. We use the same cutter shape in the Icelandic version of the drill and the cutters are made of a hardened steel alloy to allow penetration of tephra layers within the ice.

In this presentation, we first outline briefly the earlier attempts at ice core drilling in Iceland and then describe lessons learned during a drilling test on Langjökull, planned for the summer of 2025 (after the time of submission). Combining efforts with ICELINK-project plans for shallow core drilling in Greenland, we aim to drill a 100–200 m ice core on Vatnajökull in 2026. Studies on the core should include: Stratigraphic observations (meltlayer intensity), density measurements, dust measurements (annual layer counting), detection of volcanic tephra layers and their provenance (aiding the dating), thin section studies of textures, fabrics and bubble structure and measurements of oxygen-isotope ratios.

References

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