# 9th International Symposium on Ice Drilling Technology

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Potsdam

# Book of Abstracts

This is the biginning of the book of abstracts

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## British Antarctic Survey, Recent Hot Water Drilling Activities

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Over the past six years, BAS Hot Water Drilling (HWD) systems have been successfully deployed across Antarctica in collaboration with several polar research operators. In 2019, the International Thwaites Glacier Collaboration (ITGC), a partnership between the UK and the US National Science Foundation (NSF), funded the drilling of access holes above and below the grounding line of Thwaites Glacier and the deployment of the IceFin ROV, resulting in the first live imaging of a grounding line. Following 2020, the COVID-19 pandemic introduced significant collaborative and logistical challenges, including the cancellation of plans to access Subglacial Lake CECs. However, new opportunities emerged through collaboration with the Korean Polar Research Institute (KOPRI), culminating in the co-development of a new 1500 m HWD system, together with training and field support. As a result, boreholes were successfully drilled through the Dotson Ice Shelf in 2021 and the Nansen Ice Shelf in 2022.
In 2023, three access holes were drilled through the Fimbul Ice Shelf as part of the Troll Observing Network (TONe) project, supported by the Norwegian Polar Institute (NPI). Additional successful IceFin deployments were also completed.
All drilling campaigns utilized the diverse array of HWD equipment in the BAS inventory, allowing for system customization based on ice thickness, logistical constraints, and other operational requirements. These capabilities, along with the achievements of recent fieldwork, will be presented in detail.

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## Large-Diameter Firn Drilling with the IceCube Independent Firn Drill

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The Independent Firn Drill (IFD) was developed to improve firn hole quality and operational efficiency of the drilling campaign for the IceCube Project. The IFD is used to create an initial 60 cm borehole through the firn layer at the South Pole to a depth of approximately 40 m, where melt water begins to pool in the borehole. At that point, the deep hot water drill (Enhanced Hot Water Drill, now the IceCube Upgrade Drill) is used to continue drilling the borehole to the required total depth of 2500-2600 m. The top 40 m of firn is permeable to water and using lost-water hot water drill techniques for this section is highly inefficient, and therefore a hot point technique is preferred. The IFD uses a closed-loop water-glycol system that electrically heats the fluid in a local reservoir and circulates it through a coiled copper tube cone-shaped hot point. Drill rates are slow, however designing the system to be independent from the main hot water drill operations allows the IFD to begin making firn holes well ahead of main drilling activities, in some cases a year or more ahead of time. Coupled with a mobile generator, the IFD system is completely standalone and highly mobile. It requires 1 person to operate during drilling, but can also be left unattended for extended periods because the system is fully electric. A functional description of the IFD system will be presented.

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## A SHALLOW WET DRILL FOR IMPROVED CORE QUALITY IN BLUE ICE AREAS

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The U.S. National Science Foundation (NSF) Ice Drilling Program (IDP) has encountered challenges in consistently recovering high-quality ice cores with dry electromechanical drills from shallow depths in Blue Ice Areas (BIAs), such as the Allan Hills in Antarctica. These difficulties are attributed to elevated internal stresses within the ice sheet and the frequent presence of rocks and sediments. To address these issues during the 2025-2026 Antarctic field season, IDP is developing a "Shallow Wet Drill"system.

This specialized system integrates components from several existing IDP drills into a single system capable of retrieving 1-meter-long, 98-mm-diameter ice cores from fluid-filled boreholes up to 700 meters deep. Despite its capabilities, the system remains lightweight and compact enough to be transported on just one to two Twin Otter flights.

The Shallow Wet Drill will be deployed to extract a 400-meter ice core at the Allan Hills during the 2025-2026 season. Core quality will be carefully evaluated to determine whether wet drilling offers a viable solution for improving core quality at sites with challenging drilling conditions.

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## INFLATABLE TENT, INITIAL FIELD RESULTS

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A drill tent, utilizing inflatable beams, has been procured and used for the Mueller Ice Core Project in the Canadian arctic during the summer of 2025. We present the specifications of the tent as well as the results and our reactions during the field season.
The logistics required to support ice drilling camps are challenging and expensive so reducing the logistical burden is an ever-present goal. Drilling enclosures are required for long-duration drilling campaigns, but they also are heavy and require significant man-power and time to construct. An inflatable tent, designed and built by Nixus (Zepelin, s.r.o.), was constructed according to our unique needs that both reduced weight and construction time without sacrificing performance.

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## The Danish Replicate Drilling System –Results from the First Field Test

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We report on the successful test of a new replicate drilling system for ice cores. The test was done in drill fluid, at 140 m depth of the EastGRIP borehole in central Greenland.
To drill a replicate ice core with the Danish Replicate Drilling System, three steps need to be done. First, we determine the orientation of the borehole, to drill the replicate core on the "downhill" side of the borehole. Access to the parent borehole remains possible, but difficult, as gravity guides downhole tools into the new borehole. As a second step, we broach a groove into the "uphill"side of the borehole. This groove will guide the milling tool during the third step. The milling tool is guided and pushed by a spring, here an antitorque blade, into the "downhill"side of the borehole. We mill the side of the borehole and produce a ledge. We rest the drill on the ledge with all its weight to verify that the milling tool has deviated from the borehole. Our test stops here, as deviation from the parent borehole has been achieved and future logging of the EastGRIP parent borehole remains possible. To produce replicate cores, one would now mount the ice core drill and continue drilling. The drill gradually deviates into the side of the borehole, first producing crescent moon cores, then full-diameter ice cores.
Following the test in the EastGRIP borehole, a new broaching tool has been designed. The new design will improve chip clearing around the cutting tool and include failsafe features.

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# Diagnostics for Drilling Fault Prediction in Planetary Drills

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Searching for evidence of ancient climates and extant life in icy planetary environments will require robust hardware and software to obtain surface and subsurface samples. Ice drills like The Regolith and Ice Drill for Exploring New Terrain (TRIDENT), a 1 meter rotary percussive drill manufactured by Honeybee Robotics, are uniquely suited hardware for obtaining cores and samples, but functionality beyond earth's immediate orbit will require autonomous software operation. Robotic ice drills on Mars or other planetary bodies must respond to potential indicators of fault and prevent hardware failure to allow clean acquisition of subsurface samples. Past arctic planetary-analog fieldwork in Haughton Crater (Glass 2025) has given us methods for identifying and preventing drilling faults in arctic environments with periglacial features, like ice lenses or permafrost. This will better inform development of autonomous drilling and sampling methods in planetary environments.
Faults can be categorized into five categories: Binding faults that increased torque to friction along drill string, choking faults, where pulverised cuttings caught in the borehole causing increased torque, hard-materials faults, where rate of penetration is stalled despite increased percussion and torque applied to the drill string, corkscrewing faults, where flutes become caught on protruding rock, and bit inclusions, where small gravel is caught in drill flutes causing torque increase. These are often diagnosed later when reviewing time-series telemetry data.
Changes in force telemetry data indicating faulty conditions have a high likelihood of online prediction with tailored methodologies (Boelter 2025). Using change point detection techniques, we can monitor change scores in telemetry data, which often spike prior to faulty conditions for torque or weight on bit. We can also monitor downward velocity, to monitor stalled or slowed drilling progress approaching a velocity of zero. We can also monitor percussive sound wave data during active percussion, as higher frequency or skipped percussive beats are fault indicators. Active percussion indicates hard or differing subsurface composition. We use methods that calculate a novelty curve corresponding to an increase in spectral energy of the vibration signal. Then, an algorithm is used to pick which points in the novelty curve correspond to beats. Beat bounds are found from the local minima of the novelty curve. After applying the Fourier transform to beats, features like

frequency peaks and overall energy are used to determine if the beat denotes a fault or nominal operation. Analysis of test data shows that non-faulting beats typically have a frequency peak around 6 kHz and faulting beats tend to have higher frequency peaks and more overall energy.
Preliminary results during May 2025 lab testing indicate change point detection methods are accurately able to catch subtle telemetry signal changes preceding faulty drill conditions and collected sound wave data also indicates faults can be predicted through sound wave amplitude changes and faulty and skipped beat detection. These methods will be verified during analog arctic field testing in July 2025 at Haughton Crater.
References
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Glass B, Boelter S, Vendiola V, Fortuin C, Stucky T, Stocker C (2025) Planetary analog drill automation tests at Haughton Crater. Lunar Surface Innovation Consortium Spring Meeting

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## DEVELOPMENT OVERVIEW OF POWER SUPPLY AND CONTROL UNITS FOR SHALLOW ICECORE DRILLING WINCHES AT AWI (~2010-2025)

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During the last 15 years there have been quite a few iteration steps in the process of developing a shallow icecore drilling sytem at AWI.
To keep up with mechanical and electrical changes of the key ingredients for the drilling process (like tower, winch, drill-unit..), to simplify logistics and due to optional further development several power supply and control units for the AWI shallow icecore drilling winch system have been built and brought into action.
In this talk I will give a brief overview of above mentioned units and their development from ~ 2010 to our current system.

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## Model construction and mechanism analysis on subglacial bedrock core breaking during hydraulic reverse circulation continuous coring

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In the field of polar research, acquiring bedrock samples from beneath polar ice sheets is of great significance for reconstructing ancient climates, exploring ancient life, and studying subglacial geological structures, among other related applications. However, subglacial bedrock core drilling is extremely challenging, and to date, there have been few successful cases, with insufficient subglacial bedrock samples obtained. In comparison with conventional rock core drilling methods, hydraulic reverse circulation continuous coring offers significant advantages. To ensure its successful implementation, rock core breaking is a critical issue.
This research systematically investigates the synergistic effects of splitter angle, core diameter, and core length on the breaking force of subglacial bedrock cores during hydraulic reverse circulation continuous coring. A multi-factor coupling model was established based on elastic mechanics and the maximum tensile stress theory, decomposing the breaking force into radial and axial components. The model accounts for the combined effects of bending moment and eccentric compression at the critical cross-section of the rock core, where tensile stress from Fx and compressive/bending stress from Fy determine failure initiation. Nonlinear regression of experimental data revealed high goodness-of-fit for both radial and axial breaking forces, validating the theoretical framework. Fitting parameters showed consistent trends inversely proportional to the rock core's ultimate stress, confirming the model's accuracy in describing the dependency between geometric parameters and breaking force. The results of experimental validation and microstructural characterization show that: (1) As splitter angle increases, breaking force exhibits a non-linear upward trend due to reduced radial bending stress and increased axial compressive stress. Smaller angles promote radial tensile cracking, while larger angles shift the failure mode to mixed-mode (tensile-shear) cracking, requiring higher F to overcome frictional resistance and stress concentration at mineral interfaces. Microstructural analysis via polarizing microscopy showed that mineral grain interfaces act as preferential crack nucleation sites, aligning with theoretical predictions of stress concentration effects. (2) The core diameter demonstrates a positive correlation with radial and axial breaking forces, primarily governed by geometric size effects. Radial breaking follows flexural mechanics. Axial failure originates from combined shear-tensile stress, showing nonlinear enhancement in load threshold through section modulus and moment of inertia. Smaller diameters favor low-energy fracture propagation along mineral interfaces, while larger diameters override interface density effects through geometric superiority. Material strength degradation rates remain negligible compared to the core diameter-driven geometric reinforcement, ensuring geometric mechanisms predominantly govern failure thresholds. (3) The core length exhibits a negative correlation with radial and axial breaking forces, governed also by three mechanisms: Mechanical leverage, eccentric compression and microstructural effects. Increased moment arm in longer rock cores reduces the peak force required for crack initiation via enhanced bending moment. Stress superposition in extended rock cores promotes mixed-mode (tensile-shear) fracture propagation while lowering failure energy thresholds. Mineral heterogeneity amplified by length scales synergistically degrades material ultimate strength through combined mechanical leverage and microstructural weakening. (4) Polarizing microscopy revealed that the material ultimate stress is influenced by mineral composition and grain interfaces in the breaking section. Quartz-rich regions exhibited higher due to their rigid stress-bearing framework, while biotite-rich interfaces, characterized by low shear strength, acted as weak points reducing critical stress thresholds. This microscale insight validated the inverse proportionality between fitting coefficients and the material ultimate stress, bridging macroscopic mechanical behavior with microscopic failure mechanisms.
In conclusion, this research bridges theoretical modeling with experimental and microstructural analysis, clarifying the subglacial rock core breaking mechanism. The findings provide a theoretical basis for designing reliable, efficient hydraulic reverse circulation continuous coring drilling tools that are suitable for polar extreme and complex conditions, addressing critical challenges in subglacial bedrock core drilling. It paves the way for establishing systematic, standardized coring theories in extreme environments, as well as achieving technological breakthroughs in "automatic isometric rock core breaking during hydraulic reverse circulation continuous coring, enabling the acquisition of more and higher-quality subglacial bedrock cores".

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## Three generations of borehole loggers

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It has proven to have great importance to be able to monitor parameters down though a borehole in connection with an ice core drilling project. The measurements can support the drilling during the ice core drilling by monitoring the borehole diameter, temperature, inclination and borehole shape. After the ice core has been drilled borehole measurements can be used for precise temperature profiles, and diameter, inclination and borehole shape can be followed giving information on the ice deformation.
Borehole logging tools have been available in the Danish research group since 1983, where it was used to log the Dye3 borehole (Gundestrup and Lyle-Hansen, JoG, Vol 30, nr 106, 1984). Since then the logger has been used in all the deep Greenland borehole and many of the Antarctic deep boreholes.
During the last five years a new logger has been developed using IMPACT SUBSEA sensors and last year a autonomy logger has also been developed as a light and easy logger to use both in deep and intermediate boreholes not depending on communication to the surface.
The borehole loggers will be described combined with results obtained by the loggers.

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## TRIPLE-ICECRAFT: A PLATFORM FOR SCIENTIFIC ACCESS TO DEEP ICE –ANTARCTIC RESULTS AND FUTURE OPPORTUNITIES

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Subglacial lakes and unexplored water reservoirs in the polar regions of Earth represent some of the most isolated and pristine environments known to science. Exploring these hidden ecosystems is of great significance not only for understanding our own planet, but also in the context of astrobiology and the search for life beyond Earth. Several celestial bodies in our solar system—such as Jupiter's moon Europa, Saturn's Enceladus, and the polar subsurface regions of Mars—are believed to host liquid water beneath thick layers of ice. Autonomous melting probes offer a promising technological pathway to access and investigate these environments in a minimally invasive and contamination-free manner.
The TRIPLE-IceCraft is a modular melting probe platform designed to enable in-situ scientific investigation of water-bearing layers within and beneath glacial ice. During descent, the probe can transport sensors and scientific payloads through the ice and into subglacial water bodies, enabling continuous data collection along the melt path and in the water column. One of the key features of the TRIPLE-IceCraft is the ability to re-freeze its access channel, ensuring environmental protection and preserving the integrity of potential subglacial ecosystems. This characteristic is particularly crucial for future astrobiological missions where planetary protection standards are essential.
This contribution presents and discusses the results of two successful technical demonstration campaigns conducted at the Neumayer Station III in Antarctica. The tests focused on validating the operational functionality, system reliability, and integrated sensor performance of the TRIPLE-IceCraft platform under realistic environmental conditions. During these deployments, housekeeping data were collected to monitor and optimize system behavior. A camera was included as a demonstration payload to verify data transmission capabilities. The primary objective was to demonstrate

the probe's capability for controlled thermal descent and reliable operation in deep ice, rather than conducting scientific measurements. Based on these findings, we outline future opportunities for TRIPLE-IceCraft in both terrestrial and planetary exploration missions, and evaluate the integration potential of scientific payloads tailored for hydrological, chemical, and biological investigations in extreme cryoenvironments.

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## REWIND: BRITISH ANTARCTIC SURVEY ICE CORE DRILLING PROJECT

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The British Antarctic Survey (BAS) have recently undertaken numerous ice drilling projects, including the first phase of the multi-year REWIND project. This project proposes to drill through the Antarctic Peninsula ice sheet to bedrock, retrieving an ice core from the entire depth of approximately 716 m using the BAS shallow and intermediate ice core drills. The principal scientific objective is to obtain new reconstructions and a high-resolution record of sea ice, westerly winds, and $CO_2$ in the Pacific sector of the Southern Ocean, during the Holocene which spans approximately the past 11,000 years.
During the 2024-2025 season, geophysical surveys were conducted to finalise the drilling location, and cores to a depth of 70 m were drilled at the chosen site. A new firn-air sampling system was successfully tested, providing $CO_2$ measurements to a depth of 65 m. Equipment is currently overwintered at the camp, and drilling will continue in the 2025-26 season to bedrock. This contribution will focus on the progress and future of the REWIND project, and briefly highlight other recent drilling project achievements.

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## THE CURATION OF ICE CORES AT AWI

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This contribution will give an overview about the workflow in handling, processing and data management of ice cores drilled over the last decades under logistic support of AWI. Since drill campaigns at remote polar sites are associated with high personell efforts and high financial costs a thorough curation is desirable and a prerequisite for successful ice core research. In its best sense, a comprehensive and low-threshold access to important information concerning sample availability and meta-data/ data analysis may even trigger research.
To this end a relational sample management software was implemented at AWI, called iceDB, which enables scientists to search for ice samples and associated information like campaign meta data, logging, transport, cutting, core quality, breaks, additional observations and all kinds of measurements

that have been performed so far on respective samples. In the presentation we will give an introduction to iceDB using specific case studies:
• Exploring the spatial coverage and availability of firn core/surface samples in Greenland
• Exploring the availability of subsamples from BEOIC –use case with focus on subsample activitities
• Exploring the measurement acticities on NGT-Greenland ice cores –use case with focus on core sample selections

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## Field Processing of Ice Cores at Dome Fuji: An Overview of Three Drilling Periods and the Ongoing Third-Phase Project

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At Dome Fuji in East Antarctica, deep ice coring projects have been conducted three times over the past three decades. The first core (DF1) was drilled between 1992 and 1998, reaching a depth of 2,503 m (Watanabe et al., 2003). The second core (DF2), which extended to 3,035 m and nearly reached the ice sheet bed, was drilled between 2004 and 2007 at a location 44 m from the DF1 borehole (Motoyama, 2007). Nearly two decades later, we are currently engaged in the third-phase Dome Fuji ice coring project. The drilling site for this phase is located approximately 4 km south of the previous sites.
Field processing of ice cores refers to the procedures carried out from the time of drilling until the cores are transported to research laboratories in Japan. This includes: (i) creating various core logs and documentation; (ii) preparing and executing operations for storage and transportation, both for shipment to Japan and for local preservation; and (iii) performing essential analyses. These analyses involve documenting properties that must be recorded immediately after drilling, conducting on-site measurements such as dielectric profiling (DEP), and collecting samples for laboratory analyses (e.g., for water isotopes). Additionally, field processing includes cutting, packaging, and storing the cores; loading them onto sledges and transporting them to the coastal area; maintaining and preparing the necessary facilities and equipment; and developing a long-term storage plan for the ice cores in Antarctica.
In this presentation, we provide an overview of the field processing conducted during the three Dome Fuji drilling campaigns, discuss the effective integration of field operations with subsequent full-scale analyses, and introduce the ongoing field processing activities for the third-phase deep ice core drilling project.

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## A simple approach to field sampling ice cores for stable water isotope analysis

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With the advent of laser spectroscopic methods, stable water isotope analysis of ice cores can now be performed in the field with minimal sample preparation, extremely low sample consumption, and high measurement precision. This development enables continuous assessment of ice core drilling progress through real-time water isotope profiles, offering significant advantages to deep ice core operations allowing for real time adjustments to drilling, processing, and logistics.

We present a simple and effective sampling approach based on a brass violin maker's plane mounted in a custom-designed 3D-printed holder. The brass plane accommodates a variety of blades, while the holder ensures efficient and user-friendly handling of both the core and the collected sample. The design accounts for the practical workflow of ice core processing lines and the needs of field personnel.

The plane has been successfully used at Little Dome C during the 2023–2024 and 2024–2025 Antarctic field seasons, contributing valuable isotope data during the transition into the oldest (>1 million-year-old) ice. It has also been used at EastGRIP ice core camp in 2024 and Müller Ice Cap in 2025. Its reliability, simplicity, and low-cost construction make it an appealing solution for real-time field sampling in remote ice core campaigns.

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## UNIQUE CHALLENGES OF DRILLING OLD, SHALLOW ICE AT ALLAN HILLS

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The Center for Oldest Ice Exploration (COLDEX) is one of the U.S. National Science Foundation's (NSF) current, predominant scientific programs in Antarctica, and their recent work involves ice core drilling in very old and shallow (<200 m) ice, often entrained with silt and rocks. The silt and rocks quickly dull cutters, with the rocks also causing downhole hammering as the drill cuts through them. The old ice adds its own challenges, as it is composed of large (>25 mm) ice crystals requiring significant cutting force, and there are rapid and large changes in ice fabric slope. It is uncommon to recover ice cores from even 100 m depth without significant fracturing and wafering. Environmentally, all of this occurs in an area with average 37 kph winds, thus tent setup and robustness have a large impact on the success of the season. This presentation will discuss the challenges and success IDP has had drilling this challenging ice and working in this harsh environment.

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## REPLACEABLE CUTTER INSERTS –PRELIMINARY RESULTS

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In recent years the U.S. National Science Foundation (NSF) Ice Drilling Program (IDP) has dry drilled numerous shallow cores in areas with rocky and silty ice. This leads to significant degradation in core quality as the drilling conditions rapidly dull hardened steel cutters, often within the first few meters. In the past, the only remedy was to have drillers spend hours each day sharpening cutters in the field, adding burden to the season and limiting drilling hours. To make better use of the limited field time available, IDP has developed and implemented replaceable cutter inserts, allowing inexpensive carbide and steel cutters to be quickly swapped as they dull. Presented here are the results of IDP's initial efforts utilizing these inserts, showing both core quality and production rate improvements.

**Poster sessions oral introduction / 11**

## NEW JLU MULTI-ARM LOGGER AND FIELD TESTING AT THE BEDROCK BOREHOLE IN PRINCESS ELIZABETH LAND, EAST ANTARCTICA

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operations were conducted, revealing significant borehole constriction at the bottom section under drilling fluid-free conditions. These observations provide valuable scientific guidance for drilling engineering practices.

This project focuses on the deep ice core borehole drilled during the 2023-2024 China-Russia joint Antarctic scientific expedition, utilizing a high-precision logging instrument independently developed by Jilin University to conduct comprehensive parameter measurements. By monitoring the dynamic changes in borehole diameter in real time, it evaluates the borehole closure effect under ice stress conditions, providing a basis for subsequent drilling process optimization. Simultaneously, the logger records borehole azimuth and deviation data to invert glacial flow characteristics. Combined with vertical temperature profile measurements, it allows to estimate subglacial geothermal heat flux, revealing the mechanisms of subglacial geological activity and ice-rock interactions.

The drilling site is located at 69°35′08.27″ S, 76°23′03.65″ E, about 28 km from China's Zhongshan Station. The ice thickness at this location is 541 m (Talalay et al. 2025). In 2024, a full-depth ice core was successfully drilled, reaching the bedrock and retrieving bedrock core samples. The logger enables measurement of borehole parameters, including diameter, temperature, pressure, and azimuth, providing critical data for ice core drilling and subglacial environment analysis.

The logger was deployed by first connecting the instrument to an armoured cable via the IBED cable termination, enabling both power supply and data communication. However, due to insufficient sensitivity of the built-in temperature sensor, real-time temperature profiling during tool retrieval was unreliable. As a result, supplementary sensors were later employed for thermal measurements, restricting the logging tool's primary function to borehole diameter and azimuthal deviation monitoring.

During operation, the tool was lowered to the borehole bottom using a winch-controlled descent.

However, borehole closure near the base initially prevented penetration beyond 474 m. After reaching this depth, the spring-loaded caliper arms were activated, and the tool was gradually retrieved at a speed of 25–30 mm/s. This retrieval process allowed continuous, real-time acquisition of diameter variations and azimuthal orientation along the ice column.
The borehole logging tool successfully obtained diameter measurements and azimuthal orientation data down to the depth of 474 m. Following the completion of drilling fluid retrieval, multiple repeat logging operations were conducted, revealing significant borehole constriction at the bottom section under drilling fluid-free conditions. These observations provide valuable scientific guidance for drilling engineering practices.

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**Oral sessions / 19**

## TRIPLE AND THE RETRIEVABLE MELTING PROBE TRIPLE-ICECRAFT

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Prime targets in the search for extraterrestrial life are the subsurface oceans of icy moons in the outer Solar System (Klenner 2024), particularly Jupiter's moon Europa and Saturn's Enceladus. Future space missions to explore these ocean worlds are of great interest, and a proposed mission scenario includes landing on the surface, penetrating through the massive ice shell with a melting probe, and diving into the ocean with a miniaturized autonomous underwater vehicle that collects samples to identify potential habitats. To facilitate such missions, key technologies are developed within the TRIPLE project (Technologies for Rapid Ice Penetration and subglacial Lake Exploration), initiated by the German Space Agency at DLR. The project focuses on developing technologies capable of exploring Europa's subglacial ocean, beginning with technology demonstrations in Antarctica.
The authors central effort is the development of the TRIPLE-IceCraft melting probe (Heinen 2021), a modular payload carrier system designed to traverse several hundred meters of ice to access subglacial water reservoirs and return to the surface. The TRIPLE-IceCraft has undergone testing in an analogue environment on the Ekström Ice Shelf in Antarctica during 2023 and 2024.
This talk will provide an overview of the TRIPLE project and present the design of the melting probe TRIPLE-IceCraft.

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**Poster sessions oral introduction / 6**

# DEPTH-DEPENDENT ICE CREEP AT PRINCESS ELIZABETH LAND, EAST ANTARCTICA

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Quantifying the depth-dependent rheology of Antarctic ice is essential for understanding ice sheet dynamics and their response to environmental forcing. In recent decades, borehole-based deformation measurements—including inclinometers, tiltmeters, optical strainmeters, and borehole imaging—have provided new insights into the internal mechanics of ice sheets and glaciers across Greenland, Antarctica, and selected alpine sites. Extensive campaigns in Greenland's ablation and marginal zones, the French Alps, and at Siple Dome, Antarctica, have revealed pronounced seasonal and depth-dependent variability in ice creep and basal sliding, with field measurements demonstrating that the flow law parameters governing ice deformation can vary substantially with both depth and time. These studies have established the crucial role of in situ, depth-resolved observations for constraining the partitioning of basal sliding versus internal deformation, quantifying the influence of temperature, water content, and microstructure on creep rates, and supporting model development for predicting ice sheet behavior under changing climatic conditions. Despite these advances, large areas of East Antarctica—particularly Princess Elizabeth Land—remain under-sampled, and little is known about their depth-dependent ice rheology.

In this study, we present borehole-based measurements of ice deformation at the IBED-2 site in Princess Elizabeth Land, East Antarctica. Temperature measurements carried out at the bottom of the borehole immediately after drilling termination revealed a cold underlying base (Talalay et al., 2025). To study internal deformation processes, 10 months after drilling was completed, a borehole was logged to approximately 9/10 of total borehole depth (541 m), because the lower part of the borehole was plugged by ice chips. To capture both spatial and temporal variability, a multi-armed logger was deployed to measure borehole diameter, inclination, and temperature profiles from the surface to the base. Between 9 January and 2 February 2025, a total of 11 logging campaigns were conducted, yielding a high-frequency time series of depth-resolved data that spans nearly one month. These repeated measurements resolve temporal and vertical variations in strain rate through the ice column.

We present direct observations of strain-rate profiles with depth and analyze their implications for Glen's flow-law parameters. Our results reveal substantial variation in creep rate with depth, highlighting the influence of ice temperature, and possibly ice microstructure. Comparative discussion of our borehole measurement approach is provided, referencing previous deployments in polar and alpine settings. Our findings contribute to the growing body of field-based evidence characterizing the spatial and temporal variability of Antarctic ice rheology and provide important constraints for the understanding and modeling of polar ice sheet dynamics.

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**Poster sessions oral introduction / 7**

# DEEP SUBGLACIAL LAKE EXPLORATION VIA RECAS SONDE INTEGRATED WITH HOT-WATER DRILLING SYSTEMS

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The exploration of subglacial lakes plays a pivotal role in deciphering the life characteristics within extreme environments. Currently, the drilling techniques used mainly include hot water drilling technology, deep ice core drilling technology, and RECoverable Autonomous Sonde（RECAS）. Compared to the other methods, RECAS offers distinct advantages for subglacial lake detection: compact equipment size, high automation, minimal external contamination, and ease of deployment.
Pavel et al. (2014) initially introduced the design concept of RECAS. Subsequently, in 2022, they successfully completed the research and development of the RECAS-500 prototype, which boasted a drilling capacity of 500 meters. Drilling and retrieval verification experiments were conducted on the Dalk Glacier in Antarctica. The cumulative drilling depth reached 517 meters, with a maximum drilling depth of 200.3 meters. Notably, the meltwater within the borehole froze and sealed it effectively, validating the working principle feasibility of RECAS (Sun et al. 2022). However, for subglacial lakes buried deeper than 3000 m, the RECAS drilling duration exceeds six months, making long-term reliable operation at Antarctic sites challenging. Consequently, integrating RECAS with hot-water drilling represents the optimal approach.
Jilin University is currently developing a RECAS-3000 system compatible with hot-water drilling. The system comprises four main components: a surface winch system, a relay cable, a relay module, and the RECAS probe. To minimize cable power loss, the relay cable employs conductors with a larger diameter and lower resistance. High-voltage power transmission is implemented between the surface and the relay module. Within the relay module, this high-voltage power is rectified and transformed before being supplied to the RECAS probe via dedicated RECAS cables.
Furthermore, to achieve clean exploration of subglacial lakes, four distinct deployment schemes combining hot-water drills and RECAS probes were proposed. The advantages and disadvantages of each scheme were comparatively analyzed.

**Oral sessions / 68**

## INCREASING THE DRILLING SPEED IN BEOI DEEP ICE CORING BY DRILLING ICE CORES OF UP TO 4.5 METRES IN LENGTH

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Drilling deep ice cores is an undertaking that is rarely carried out, due to the time-consuming nature of such projects. The key contributing factors to the project timeframe are the remote locations with limited access, and the sequential sampling nature of typical coring technologies. The most significant lever that can be influenced is the reduction of travel time between the surface and the increasing depths of the borehole bottom. The total travel duration is only dependent on two factors: the achievable travel speed and the total travel distance within the liquid-filled borehole.

From the outset of the BEOI project, it was agreed that existing EPICA equipment and technology would be reused. This included the winch and its cable, as well as the fundamental shape of the drill. Therefore, the only other option for ensuring that the project's timeframe is achievable is to reduce the total travel distance. This was achieved by extending the core barrel length to 4.5 metres, thereby increasing the totally obtainable ice-core length per run and, consequently reducing, the number of runs required to reach a set borehole length.

This presentation will highlight the design differences and outline the resulting challenges experienced during the four-year drilling operations at Little Dome C, where a 2,800-metre-long ice core was drilled.

**Oral sessions / 66**

## THE CHALLENGES INVOLVED IN DEVELOPING A POWER SUPPLY, COMMUNICATION SYSTEM AND DRIVE UNIT FOR A DEEP ICE CORE DRILLING RIG.

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This presentation will provide a comprehensive overview of the development process of the power train and drive chain of a deep ice core drill, with particular emphasis on the challenges encountered during the project.

The covered deep ice coring drill system is of the type of the commonly used cable-suspended electromechanical ice-core drill. In such systems, the electrical power and communication are distributed through the conductors inside the winch cable. The intended drive chain was a brush- and gearless motor.

**Oral sessions / 67**

## A NEW DYNAMOMETER FOR TESTING ICE CORE DRILL MOTORS AND GEARS

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Specialised test equipment is frequently required during the design and verification phases of a project. However, this equipment is often expensive, not always readily available at the time, or just time-consuming to use. This can result in reliance on systems that have not been adequately tested prior to field campaigns. This may lead to system failures or substandard designs.
This newly designed dynamometer is intended for use in testing motors and gears of ice core drills. The aim is to resolve the issue of a missing test facility by using off-the-shelf components in its construction, with a relatively small and user-friendly form factor.
This presentation will introduce the design concept and its intended use cases.

**Oral sessions / 69**

## ITERATIVE IMPROVEMENTS TO THE CHIP TRANSPORT PUMP USED IN THE BEOI'S DEEP ICE CORE DRILLING PROJECT

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Transporting and collecting ice cuttings generated by the drill head is a necessary task for an ice-core drill. In boreholes stabilised by liquids, such as the one in Little Dome C in Antarctica as part of the BEOI project, this collection process can be enhanced by the use of pump devices placed between the core barrel and the chip collection chamber.
This presentation will showcase a newly redesigned pump used in the BEOI drill. The design is based on the proven technology of previously used pumps in deep coring projects, such as EPICA, GRIP and others.
The design objectives were threefold: to optimise the construction for CNC manufacturing; to eliminate unnecessary parts; and to adapt it into the new 4.5m drill while keeping it backward compatible.
The most significant innovation of this revised design is the the introduction of a new sealing solution that provides the required torque transfer and linear bearing of the pump in addition to the pure sealing function between the pump pistons and the outer barrel.
The development includes a dual-layer filter for the drive shaft inside the chip collection chamber. In addition, experimental testing is being conducted on a 3D-printed intermediate spiral booster that centres on the longest shaft and aids the flow inside the chamber.

**Oral sessions / 49**

## RAID - NEW OPPORTUNITIES FOR DEEP ICE-SHEET RESEARCH AND RAPID SUBGLACIAL ACCESS DRILLING

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The U.S. Rapid Access Ice Drill (RAID) is a new research drilling technology capable of quickly accessing the glacial bed of Antarctic ice sheets, retrieving deep ice core and rock core samples, providing boreholes for down-hole logging of physical properties, and creating long-term borehole observatories. The RAID platform can support deep ice-sheet reconnaissance for 1.5 million year-old or older ice, validation of englacial ages with optical borehole logging, study of ice deformation, assessment of geothermal heat flow, observation of basal material properties, and recovery of rock cores for study of landscape history and crustal evolution. Recent field trials in Antarctica (Goodge et al., 2021, Ann. Glac., doi.org/10.1017/aog.2021.13) demonstrated the ability of the RAID platform to perform as designed, including fast borehole cutting, recovery of short ice and rock cores near the bed, penetration into hard bedrock, and deployment of a borehole optical dust logger for in-situ dating of ice. A full operational sequence in three boreholes succeeded in augering through firn, creating a borehole seal, establishing fluid circulation, drilling an ice borehole at penetration rates up to 1.2 m min−1, acquiring short ice cores, penetrating the glacial bed at ~677 m, recovering a ~3 m core of ice, basal till and subglacial bedrock, optically logging the borehole on wireline, testing hydrofracture potential during overpressure, and operating in an environmentally benign way. RAID is coming online as much has been learned about very old (up to 6 m.y) ice, subglacial materials, the basal ice-sheet environment, and geotectonic development of Antarctic lithosphere. Together with other novel technologies and methodologies, and with a new generation of scientists engaged in cryosphere and solid-earth research, RAID is poised for impactful deep ice-sheet research in Antarctica.

**Oral sessions / 28**

## 700 DRILL DEVELOPMENT AND FIELD PERFORMANCE

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Following a call by U.S. scientists in the U.S. National Science Foundation (NSF) Ice Drilling Program (IDP) Long Range Science Plan, IDP undertook the design and fabrication of a new ice coring drill capable of 700 m depth but light enough for use in remote areas such as mountain glaciers. To minimize associated logistics, including the amount of drilling fluid and ice core boxes required, the drill was designed to collect 70 mm-diameter ice cores. The system was designed, fabricated, and used for an NSF-funded science project conducted at Summit Station in summer 2024. This presentation will highlight the design of the drill system, including features adopted from the Hans Tausen and IDP Foro series drills, as well as new features incorporated. A review of the 2024 field season will cover drill system performance, auxiliary systems used, lessons learned, and drill modifications envisioned by IDP.

**Oral sessions / 57**

## The CASCA project and its initial development for clean access to Subglacial Lake Cheongsuk, East Antarctica

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The Korea Polar Research Institute (KOPRI) has conducted extensive ice-penetrating radar (IPR) and seismic surveys across the David Glacier catchment in East Antarctica to identify subglacial lakes that are both scientifically promising and logistically accessible. These efforts led to the detailed characterization of Subglacial Lake Cheongsuk—an active lake approximately 50–80 m deep and 19 km2 in area, lying beneath ~2,300 m of glacial ice. In 2020, KOPRI initiated the Clean Access to Subglacial lake Cheongsuk in Antarctica (CASCA) project, with the goal of accessing this pristine environment using clean hot water drill (CHWD) technology. The full-scale drilling operation is currently scheduled for the 2028/29 Antarctic field season and is being developed in collaboration with the British Antarctic Survey (BAS). The CASCA system is based on the CHWD platform originally designed by BAS for the Subglacial Lake CECs (SLC) project. To meet the rigorous standards required for clean access, KOPRI is advancing several contaminant-minimization technologies. These include a mobile clean laboratory for real-time drilling monitoring, a wellhead UV collar for sterilizing drill hoses and equipment surfaces, and a drill water sterilization unit. We here introduce the current development of these clean-access components, describes their design and function, and shares preliminary test

results. These integrated systems are critical to ensuring successful and contaminant-free sampling during the first clean access to Subglacial Lake Cheongsuk.

**Oral sessions / 79**

## THE BELDC ICE CORE PROCESSING WORK FLOW

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This presentation provides an overview of the ice core workflow –from logging and processing in the field, (long-term) storage at Concordia station, transport to the Antarctic coast, shipping at temperatures below −50°C, storage and handling in the curational ice core stores in Europe to running a dedicated processing in the ice laboratories at AWI. We will focus on the infrastructure and procedures involved in the processing.
Once the ice core has been drilled at Little Dome C, it is embarked on a long journey until it is analysed in the participating laboratories. In the remote field sites, the ice cores are logged, i.e. measured and cut. Then, they go through initial processing steps and measurements, before being securely packed in special insulated boxes and shipped.
We addressed the cold chain carefully, starting from re-designed custom ice core boxes, bespoke reefer containers to cross the equator on board RV Laura bassi, and navigating from New Zealand to Italy around Cape Horn, to avoid the Suez Canal for safety.
An archive piece is partly stored at Concordia station, while the aliquots are moved by Basler BT-67 and traverse to the coast.
Once the samples arrive at the Alfred-Wegener-Institut (AWI) the main processing begins. There are multiple cold rooms available at AWI for different purposes of ice core handling. The large ice laboratory is set up for the processing with different kinds of saws for cutting the ice into the required sub-samples.

**Oral sessions / 30**

## GREENDRILL PROJECT –SUBGLACIAL ROCK CORING IN GREENLAND

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A subglacial rock coring project called GreenDrill was completed over the course of two Greenland summer field seasons starting in 2023 and completing in 2024. The U.S. National Science Foundation (NSF) Ice Drilling Program (IDP) supported this project with two subglacial coring drill systems: the Agile Sub-Ice Geological (ASIG) Drill and the Winkie Drill. The ASIG Drill was used the first season in northwest Greenland near Prudhoe Dome to drill through 510 m of overlying ice and recover 3 m of basal sediment and 4.5 m of granitic bedrock. The Winkie system drilled through 97 m of ice to recover approximately 2 m of mixed sediment and rock from the subglacial region. During the second season of GreenDrill, the ASIG Drill did not make it to the field site due to aircraft and logistical limitations. However, the Winkie Drill system was able to deploy with reduced logistics and drilled two holes through 47 m and 21 m of ice, respectively, and recovered over 14 meters of subglacial bedrock.

**Poster sessions oral introduction / 22**

# BASAL ACCESS SUBGLACIAL EXPLORATION (BASE) DRILL DEVELOPMENT

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A new subglacial coring drill called the Basal Access Subglacial Exploration (BASE) Drill is currently under development at the U.S. National Science Foundation (NSF) Ice Drilling Program (IDP). Based on the proven design of the IDP Agile Sub-Ice Geological (ASIG) Drill, the new drill system is designed to quickly penetrate overlying ice and sediment to reach bedrock at up to 200 m total depth. The BASE Drill consists of a modified commercial minerals exploration drill rig that uses off-the-shelf downhole tooling and includes equipment for rapid ice drilling, drilling fluid circulation, and filtration. Both coring and non-coring bits can be used depending on project requirements. Primary core size is 39 mm diameter and 1.5 m length, although the drill rig can also use other tooling sizes. The completed system is scheduled to be field-ready in 2026.

**Poster sessions oral introduction / 58**

# Traverse, modular system, and drill camp operations for CASCA clean hot water drill

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Since 2016, the Korea Polar Research Institute (KOPRI) has operated a tractor traverse system designed to transport scientific personnel, research equipment, and supplies from Jang Bogo Station to the interior of the Antarctic Plateau, enabling round-trip traverses of up to 1,500 km. In 2020, KOPRI launched the Clean Access to Subglacial lake Cheongsuk in Antarctica (CASCA) project, aiming to cleanly access Subglacial Lake Cheongsuk beneath David Glacier, East Antarctica. The CASCA mission targets drilling through ~2,300 m of glacial ice to reach a 50–80 m deep freshwater column within the subglacial lake, using clean hot water drilling (CHWD) technology. To support this effort, KOPRI has developed a containerised, modular CHWD system mounted on sleds, adapted from the CHWD platform originally designed by the British Antarctic Survey (BAS) for the Subglacial Lake CECs (SLC) project. This sled-mounted modular system enhances operational reliability, scalability, and transportability. It allows for efficient deployment, reduced manual handling, a flexible drill camp layout, and a minimized environmental footprint. These integrated developments represent a significant step forward in KOPRI's capability to undertake clean subglacial access missions not only for the upcoming CHWD at Subglacial Lake Cheongsuk, but also for future clean access efforts in the Antarctic Plateau.

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## DRILLHEAD CONFIGURATIONS AND MAINTENANCE IN THE BEOI'S DEEP ICE CORE DRILLING PROJECT

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Sometimes maybe more on the conservative side then cutting-edge a well-adjusted drillhead is one of the keys to a successful drill-run. Setting up the next drillhead is mainly based on what has proved to be working –or not working - during the last runs, but also on the conditions to be expected next.

This presentation will dive into the different types of cutters and shoes used during the BEOI project as well as drillhead maintenance and ideas for minimizing the pain of maintaining cutters and drillheads. We also will look at the challenges faced when drilling in silty ice and how we tried to cope with these very special conditions.

References
Wilhelms, F et al. (2014): EPICA Dronning Maud Land EDML ice core drilling protocol
https://doi.org/10.1594/PANGAEA.841035

**Oral sessions / 75**

## Technical Innovations of the BEOI Field Seasons

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This presentation is a concise collage of technical innovations and their usefulness in the latest field seasons of the Beyond Epica Oldest Ice drilling project. Improvements were made with the following newly developed equipment:
• Replacement drill-head for filtering of the borehole.
• Fine slush filtering with the drills shaft within the chip chamber.
• Daily maintenance routines and de-icing of the drills shaft and pump.
• Glove box for drying and warming of drillers gloves.
• Jig for sharpening of drillhead cutters. (please see also the presentation "Drillhead Configurations and Maintenance in the BEOI's Deep Ice Core Drilling Project"
• Temperature logging of the bore hole.
• 3D printing in the field.
1. custom made medical finger orthosis
2. Light-Diffusor for illumination of ice-core crystal observation.
3. Clamps for aligning a tape ruler on an ice-core for logging
4. Clamps for marking the ice-core for cutting.
5. Improvements to the support of ice-cores for cutting with a rotational saw.
6. Ice-core scraper (please see also the additional talk)
7. Team building with BEOI cookie-cutters.
• Devices for cutting ice-cores without the material losses of a saw kerf.
• Vial holders for transport of ice-samples and handling of liquid in the lab.
• Fine filtering of recycled drill liquid.
• Lessons learned with recycling drill liquid by ice-melting. Challenges with plastic material and leaking hoses in contact with warm drill liquid and Hose handling.
• Light-tight covers for handling ice-cores in the dark.
• Scooper for collecting firn samples.
• Safe and efficient work environment: Improved stairs and steps, floor gratings in front of doors, custom build shelves, repair of shovels.

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## Resilient gear design for deep ice drilling systems

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This presentation addresses the requirements and design considerations for an open and pressure-tolerant cycloidal gearbox. Electric motors often require reduction gears to achieve sufficient torque at the output shaft at comparably low speeds. Conventional gearbox designs feature closed compartments with static and dynamic seals to contain the oil or grease required for bearings and the teeth of gear wheels. The application of gears in ice drills in liquid filled bore holes is challenged by temperatures down to -50℃ and cyclic loads of hydrostatic pressure up to 250 bar. To cope with these conditions especially for dynamic sealing of rotating shafts only special PTFE seals of limited availability and high price can be used. Furthermore these seals cannot be stretched for installation

in grooves and therefore require a more complex embodiment design of the housing. This often results in a higher number of individual parts and additional static seals, all of which must function flawlessly, otherwise endangering the whole system. An alternative gear design is proposed that radically shifts the focus from durability causing complexity towards simplicity and ease of maintenance. As drilling fluid unfortunately is more a solvent than lubrication the tribological requirements of the contact of the working surfaces has to be considered. In contrast to the sliding contact of conventional teethed gearwheels, cycloid gears feature only rolling motion for the contact of its main components, rendering it applicable to an unsealed open housing and direct contact to drill liquid.

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## WINCH AND HOSE SYSTEM OF LARGE-DEPTH HOT WATER DRILL

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Hot water drilling technology is a crucial method for exploring subglacial environments in polar regions. The winch and hose system form an essential component of the hot water drill, becoming increasingly critical as drilling depth increases. China discovered a large subglacial lake, whose buried depth is approximately 3600 meters, in the Princess Elizabeth Land through aerial ice radar surveys. Named the Qilin Subglacial Lake, a large-depth hot water drill winch and hose system was developed to support the Qilin Subglacial Lake scientific drilling project.

This system primarily consists of a drilling winch, drilling hose, water return winch, and water return hose. To provide power to the drill tool and enable real-time monitoring of drilling parameters, an embedded-cable non-metallic composite hose was developed as the drilling hose. The length of drilling hose is 3800 meters, with an inner diameter of 40 mm and an outer diameter of 68 mm. It has a breaking force of no less than 100 kN and a working pressure rating of no less than 12 MPa. To achieve precise deployment and retrieval of the drilling hose, a multi-motor cooperatively driven drilling winch was developed. This winch mainly comprises a fully electric injection head and a large-capacity drum. The injection head is responsible for raising and lowering the drilling hose, while the drum follows to spool or unspool the hose. The injection head offers a maximum lifting capacity of 50 kN. The drum has a hose capacity of 4000 meters, with a speed range and control accuracy of 0-15 m/min ± 0.01 m/min. The water return hose also utilizes an embedded-cable non-metallic composite hose. It incorporates power cables, signal transmission lines, and anti-freeze heating lines. These lines are responsible for powering the submersible pump, transmitting signals from the downhole return water system, and preventing freezing/thawing the hose, respectively. The length of water return hose is 380 meters, with an inner diameter of 40 mm and an outer diameter of 73 mm. The water return winch adopts a conventional winch design concept and is responsible for raising and lowering the submersible pump. It has a hose capacity of 400 meters, a maximum speed of 30 m/min, and a lifting capacity of 25 kN.

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## DESIGN AND EXPERIMENTAL STUDY OF A PENDULUM-TYPE RECOVERABLE THERMAL MELT PROBE FOR VERTICAL ICE DRILLING IN POLAR REGIONS

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Thermal melt probe, which utilizes electric heating power to melt ice, is a clean and lightweight tool for ice drilling in polar regions. However, uneven heating power and drilling load on the thermal head often lead to deviations of the melting trajectory, making it difficult to maintain vertical drilling and reach the target depth. To address this issue, this study proposed a pendulum-type recoverable thermal melt probe (PRTMP) that integrates three independently controllable heating components: a lower thermal head, a central heating ring, and an upper thermal head. The lower thermal head and central heating ring work in coordination to generate a "pendulum effect," which ensures vertical drilling and enables rapid inclination-correction. The upper drill head primarily facilitates return of the PRTMP. Laboratory experiments were conducted to investigate how the key design parameters, such as power distribution, diameter ratio, length-to-diameter ratio, and center of gravity, affect the change rate of borehole inclination. Based on the experimental results, optimal design parameters for achieving the best inclination-correction performance were identified. The system underwent preliminary field testing on Laohugou glacier No.12, Qilian Mountain. Field test results showed good performance of the PRTMP. The borehole inclination remained within 3° during 2.5 hours of continuous drilling. The inclination-correction capability of the PRTMP was significant, which can reducing the borehole inclination angle from 10.5° to 1.5° within one hour. In general, the vertical stability and the inclination-correction capability of the PRTMP proved to be an effective.

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## A NEWLY DEVELOPED MUTI-PROCESS DRILLING SYSTEM (MPDS) FOR SUBGLACIAL BEDROCK SAMPLING BENEATH POLAR ICE SHEET: DESIGN AND PRELIMINARY TEST

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Subglacial bedrock, buried beneath polar ice sheet, is important for the study of the historical evolution of ice sheets, revealing geological tectonics and paleoclimate. However, the sampling of subglacial bedrock is extremely difficult in technology and logistics. At present, only several subglacial bedrocks have been sampled from polar regions.

China is developing a muti-process drilling system (MPDS) for sampling at least 10 m bedrock beneath 1000 m ice sheet in polar regions. The MPDS is designed to remove drill cuttings using compressed air or drilling fluid in reverse circulation. The MPDS generally has five subsystems: drill rig, down-hole drill tool, generator, air system and drilling fluid circulation system. All the subsystems were modularly designed and can be integrated in standard 20 ft container, and could be easily moved on the ice surface by sledges. During drilling, compressed air with reverse circulation was used to penetrate firn and ice. The process continued until the ice pressure at the depth posed a risk of downhole drill sticking, necessitating operational adjustments. Then, drilling liquid was used to drill the ice that was leftover and the subglacial bedrock.

In 2024/2025 season, the MPDS was preliminarily tested at a site of 25 km away from the Zhongshan station in Pricess Elizabeth Land, East Antarctica. In the test, air drilling in firn performed

very poor, because the air reverse circulation can't form well and a lot of compressed air lost into highly permeable firn. Then, a casing made by unplasticized polyvinyl chloride has to be lowered down to 42 m to isolate the firn and was then cemented by freezing melting water. Subsequently, kerosen-based drilling fluid was used to drilling ice in reverse circulation. Finally, a 110 m borehole was drilled without coring. In the test, many problems were found in drilling rig, down-hole drill tool, air system and drilling fluid circulation system. Base on the experiences and lessons learned from field test, the MPDS is being improved and another test in Antarctica is expected in the coming season.

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## A PRESSURE-RESISTANT SELF-CONTAINED OFFLINE TEMPERATURE MEASUREMENT DEVICE FOR VARIOUS POLAR ICE BOREHOLE ENVIRONMENTS

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Accurate measurement of temperature within Antarctic ice holes is crucial for understanding the thermal state of ice sheets and subglacial environments, especially for the study of ice sheet dynamics, subglacial heat flux, and the broader Antarctic thermal environment. However, conventional temperature-measuring devices become inapplicable in ice boreholes due to extreme cold, high pressure, and the corrosiveness of drilling fluids. We have developed a new device, named iBOLT (ice Borehole Offline Logger of Temperature), that provides a simpler, portable, and efficient solution for downhole temperature measurement in the Antarctic. The iBOLT device can measure temperatures in various environments within the range of -45℃ to +85℃ (±0.1℃ accuracy), withstand pressures up to 40 MPa, and can be used in a Φ80 mm borehole, thus highly suitable for temperature measurement in Antarctic ice holes, subglacial lakes, and other liquid environments requiring temperature monitoring. It is powered by a self-contained power supply and can continuously record temperature for more than 50 days with a data interval of 1 minute. All the recorded data can be read, exported, and stored via Bluetooth after being recovered to the surface. Laboratory tests and field borehole applications of iBOLT show that temperature readings stabilize within 10 minutes in liquid environments. Therefore, surface personnel only need to record the time and the corresponding depth. In this study, we present the development process of the iBOLT temperature measurement device, including structural design, simulation analysis, testing procedures, and results from field borehole applications.

**Oral sessions / 12**

## Tere Tīpako Tio Rapid Ice Sampling Aotearoa

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Current ice sheet evolution models have a very simple representation of glacial ice, and it is difficult to improve on this as there are a limited number of physical property measurements of glacial ice samples, particularly from locations where ice dynamics are important such as fast flowing ice and shear margins. To address this issue, we need samples that represent critical distinct ice bodies: requiring faster sample recovery from a range of depths. The key objective of the Tere Tīpako Tio project is to assess the potential of a new method of rapid ice sampling for physical property analysis. The approach is based around hot water drilling for rapid access and was developed and tested on the McMurdo Ice Shelf, Antarctica. Access boreholes were hot water drilled with a minimum diameter of 125 mm. The borehole melt water and drilling water were bailed from the borehole using a series of systems including: a downhole pump, bailing buckets, and a self-contained battery powered bailer. Any minimal water remaining the borehole was left to freeze overnight before deploying specially designed ice sampling tools. Two prototype sampling tools were designed, built and tested: (1) A bottom hole core sampler, and (2) A sidewall core sampler. This hot water drilling method in conjunction with the bottom hole ice sampler prototype was successful at collecting 10 samples at depths of interest in three boreholes over a 10-day period.

**Poster sessions oral introduction / 13**

## Design and Development of Rapid Ice Sampling Devices

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Hot water drilling provides rapid access to depth in ice. Sampling with annular hot water drill lances is possible but gives samples of variable quality (Engelhardt et al., 2000; Liu et al., 2019, 2021). Here we take different approach, bailing water from the hole to allow ice sampling from an air-filled hole. Two prototype methods of ice sampling are proposed for use in dry, hot water-drilled boreholes: (1) A bottom hole core sampler, and (2) A sidewall core sampler. A challenge here is that the hot water drilling creates boreholes with variable diameter, in some cases with the diameter increasing up to double the diameter of the lance. The proposed bottom hole ice core sampler has a similar design to conventional electromechanical ice core drills; however, a key difference is the self-adjusting anti-torque system that mechanically adapts to the variation in hot water drilled borehole diameters. The novel design for the adjustable anti-torque system must provide a consistent torque reaction and, hence, remain in contact with the borehole wall as the diameter ranges from 125mm to 250mm while allowing the drill to move downwards as it cuts a sample. The proposed sidewall ice core sampler has expanding plates to adapt to diameter variation, and a core barrel that extends into the sidewall at a 60-degree angle. The prototypes for the bottom hole core sampler and the sidewall core sampler were successfully field tested on the McMurdo Ice Shelf, Antarctica.

**Oral sessions / 20**

## ADVANCING SUBGLACIAL SCIENCE: A BRIEF HISTORY OF HOT WATER DRILLING AT BRITISH ANTARCTIC SURVEY

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For nearly 50 years, hot water drilling has enabled direct access to and sampling of Antarctica's subglacial environments, providing critical insights into basal and ocean processes, ice sheet dynamics, and sub-ice ecosystems. British Antarctic Survey (BAS) was among the early adopters of this technique to support oceanographic and glaciological research and has maintained a continuous drilling program since the late 1970s. Over time, BAS has developed and refined hot water drilling systems and techniques, which use high-pressure hot water to melt boreholes through thick ice, allowing direct access to previously unobserved subglacial environments.

Early drilling operations began on warm 100-200 m thick ice on the George VI Ice Shelf, before progressing to colder, thicker ice on the Filcher-Ronne Ice Shelf, with access holes up to 941 m deep. In 2019, this evolution in depth capability culminated in multiple subglacial access holes on Rutford Ice Stream as part of the BEAMISH project. At 2,154 m, these are the deepest hot water drilled subglacial access boreholes to date and enabled the direct sampling of subglacial water and sediments, offering new insights into basal hydrology, ice stream behavior, and microbial life in extreme conditions.

A further major development was the 2012 Lake Ellsworth project. Although the lake was not reached, the project established a new benchmark for clean access drilling and sampling. It introduced rigorous environmental protocols, including multi-stage filtration, UV sterilization, and clean sampling systems that have since become the standard for subglacial exploration.

Challenges remain in developing lighter-weight, more efficient, and agile hot water drills. Also, achieving clean subglacial access into Antarctica's deep continental interior subglacial lakes remains an ongoing challenge for the global ice drilling community.

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## DEEP RAPID ACCESS DRILLING: DOWNHOLE DRILLING PARAMETER MEASUREMENT SYSTEM DESIGN

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Hot water drilling technology, characterized by high efficiency, minimal environmental disturbance, and rapid penetration, has become a key method for subglacial lake exploration in polar regions. However, current hot water drilling systems still face significant challenges in deep operations exceeding 4000 meters, such as long communication distances, real-time monitoring of borehole conditions, and spatial constraints in system integration. To address these challenges under the specific conditions of Antarctic ice sheet drilling, this paper presents a systematic solution—a downhole drilling parameter monitoring system for hot water drilling, specifically designed for Deep Rapid Access Drilling (Deep RAD). This system, which is one of the core functional units of the hot water drilling operation, provides data support and ensures engineering safety.

The system comprises three subsystems: a remote power supply and data transmission system, a central control circuit system, and a distributed sensor system. The distributed sensor system connects to the control circuit via bus interfaces, which in turn communicates with the surface through the remote power and data transmission system.

The remote power supply and data transmission system provides power and communication to the downhole system through the wires embedded in the hose wall. An enhanced bus communication architecture was developed for the hot water drilling system, incorporating hardware-level anti-interference designs and optimized communication protocols, enabling stable, long-distance, multi-node data transmission.

The central control circuit system features a customised mainboard based on a microprocessor and a supporting software platform based on an embedded operating system. To address the limited space within the measurement chamber, a slender circuit board and compact watertight connectors were implemented.
The distributed sensor system forms the core of the entire measurement solution. Temperature and pressure sensors are used to measure the water temperature and pressure inside the borehole and the main hose. An attitude sensor captures the spatial orientation of the driller, and an ultrasonic sonder is utilized to determine the borehole diameter. To further enhance the reliability of the borehole diameter measurements, a displacement sensor is additionally employed to provide a mechanical measurement of the borehole diameter.
The system has successfully completed functional and performance test under laboratory conditions. Full-scale validation tests of DEEP RAD are scheduled for the summer of 2025.

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## HIGH-ALTITUDE THERMAL DRILLING

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The Thermal Drill maintained by the U.S. National Science Foundation (NSF) Ice Drilling Program (IDP) was recently used for ice coring at high-altitude sites in both the northern and southern hemispheres. In 2022, researchers from the University of Maine and an IDP engineer/driller joined international colleagues in an ice coring effort on Quelccaya Ice Cap in Peru. In 2023, three IDP drillers operated the Thermal Drill on Mt. Waddington in British Columbia, Canada. This presentation will highlight recently-designed features of the drill, such as the ethanol deployment system, describe borehole deviation in attempts to drill around embedded rocks, and discuss logistics challenges in accessing these remote locations.

**Oral sessions / 33**

## WINKIE DRILL - DEVELOPMENT AND DRILLING IN WEST ANTARCTICA

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The U.S. National Science Foundation (NSF) Ice Drilling Program (IDP) has upgraded two Winkie diamond coring drills for agile subglacial coring in polar environments. Over the past five years, the IDP Winkie Drills have been used in three subglacial coring campaigns in West Antarctica at Mt. Murphy, in the Hudson Mountains, and at Mt. Waesche. This presentation will detail the drilling lessons learned from these field campaigns and the resultant continued development of the IDP Winkie Drill. Specifically, this presentation will discuss implementation of a fluid chiller to mitigate warm drilling conditions, review upgrades to downhole tooling to improve coring performance in mixed media, and highlight successes using PDC drag bits for blue ice access hole drilling.

**Poster sessions oral introduction / 25**

## UNIQUE IDP SUB-ICE DRILLING YIELDS SUCCESS FOR SCIENCE IN GREENLAND

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The U.S. National Science Foundation (NSF) Ice Drilling Program (IDP) provides specialized ice and sub-ice drilling technology and operational support to enable NSF-funded scientific discoveries about earth's past climate and the environment. As part of its multifaceted inventory of drills, IDP maintains the ice adapted Winkie and Agile Sub-Ice Geological (ASIG) drills to enable access to the basal zone of ice sheets of varying ice thickness. The Winkie Drill is optimized for light logistics with a depth capability of 0 - 100 m while the ASIG Drill is a larger system and extends the depth capability to 700 m. These drills have both successfully collected basal material from under shallow ice in Antarctica. This poster describes their first use on the Greenland Ice Sheet, where IDP drilled sediment and rock cores for the 2023 GreenDrill Prudhoe Dome project to collect basal material at a shallow and deep site.

During the Winkie drilling campaign, 96 m of blue ice was rapidly drilled using a new full face ice bit allowing for efficient access to the basal zone while reducing the logistics footprint of the drilling system. Battling issues with chip transport and poor weather, IDP used the Winkie Drill to collect 2 m of frozen sediment from below 96 m of ice over 17 days of drilling. During the 2024 GreenDrill season, IDP deployed a new coring system with larger waterways enabling efficient penetration through frozen sediment and clay.

At the deeper site, IDP used the ASIG Drill to drill through 509.4 m of ice to the bed and recover 7.5 m of core consisting of 3 m of sediment and 4.5 m of gneiss bedrock. Experiencing a hydro fracture event mid-season, the borehole was saved by trying a novel technique of resetting the casing string at a deeper depth and switching to normal circulation drilling. It was learned reverse circulation is not needed for efficient access to the basal zone, simplifying drill operation for future seasons.

During the 2023 GreenDrill season, IDP successfully deployed its Winkie and ASIG Drills at Prudhoe Dome to successfully recover a total of 9.4 m of basal material. Both drills more than doubled their previous depth records, and the lessons learned during operation will be invaluable for future drill technology development. Moving forward, IDP's successful sub-ice bedrock drilling breakthrough at Prudhoe Dome will open possibilities for further exploration of the basal zone.

**Poster sessions oral introduction / 50**

## RAPID ACCESS ICE DRILLING TO RECOVER BEDROCK MATERIAL

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The project "Interglacial Collapse of Ice Sheets revealed by Subglacial Drilling of Bedrock"(INCISED) seeks to recover geological samples from beneath the ice sheet for cosmogenic isotope analysis. This ERC Advanced Grant funded project (PI Mike Bentley, Durham) aims to determine the extent of the loss of the West Antarctic Ice Sheet during the Last Interglacial period (approximately 125 kyrs before present) and the consequence for global sea level rise. The approach is to drill a series of boreholes through increasingly deep ice down the slope of several incompletely buried nunataks, taking samples for cosmogenic isotope analysis from the surface rock on the nunatak, and from the bedrock beneath the ice sheet. Cosmogenic isotopes only accumulate when the bedrock is exposed at the surface to cosmic rays, and hence when the ice sheet cover was absent. A series of bedrock samples from progressively deeper ice cover should reveal dateable horizons of when the ice sheet was absent.

Our approach was to deploy the BAS RAID drill, a rapid access drilling system based on a winch and cable suspended motor-driven enclosed auger that had been successfully used in the past for depths of more than 460 m in East Antarctica (Rix et al, 2019) and to 330 m in West Antarctica (Mulvaney et al., 2022), to drill from the surface to the bedrock in a matter of days. Then, the motor and auger barrel of the BAS RAID drill would be replaced by a percussive rock drill (P-RAID), developed by the University of Glasgow, attached to the RAID antitorque section, and deployed to the bottom of the ice borehole using the same winch system to recover a 20 mm diameter core of bedrock material up to 400 mm deep. Once a sample of bedrock had been recovered, the drill system was to be moved to a new site and the ice and rock drilling repeated. Experience with the BAS RAID drill suggested a turnaround at each site of around one week for ice depths of 100 to 250 m. During tests in Antarctica we have drilled two boreholes each of around 175 m, but we have so far not been able to recover basal rock samples.

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**Oral sessions / 47**

## Resurrection of the Enhanced Hot Water Drill for the IceCube Upgrade Project

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The IceCube Neutrino Observatory will be upgraded to include seven more strings of instrumentation at the South Pole during the 2025/26 austral summer season. Construction of the original IceCube detector required drilling boreholes ~60 cm in diameter to depths of 2500 m. The IceCube Upgrade Project again requires drilling boreholes that are approximately 60 cm in diameter, but now to depths of 2600 m with extended operational hole lifetimes. To achieve this, the original Enhanced Hot Water Drill that originally delivered the 86 boreholes for IceCube has been resurrected, repaired, and upgraded. This effort started at the beginning of the project in 2018, and the first and only drill season for IceCube Upgrade is planned for 2025/2026. The process of recommissioning the 5 MW hot water drill system presented many challenges and offered many lessons. Much of the system had been distributed all over the world and was found in various states of condition. Many

mechanical systems required repair and upgrades, and some subsystems needed to be replaced completely. The legacy motor drives and control system were determined to be obsolete and unusable, necessitating a system-wide replacement. In addition, the logistical landscape is vastly different from the original IceCube Project, and the operational processes needed to be remembered and relearned. An overview of the approach taken for this resurrection and some key takeaways will be presented.

**Poster sessions oral introduction / 62**

## THE DESIGN AND SPECIFICATIONS OF A VERSITLE "MINI LOGGER"

**Authors:** Dorthe Dahl-Jensen[1]; Grant Vernon Boeckmann[None]; Kevin Nikolaus[1]; Steffen Bo Hansen[1]

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A compact ice borehole logger has been developed at the Niels Bohr Institute to reliably measure temperature, pressure, and orientation with minimal logistical demands. Designed for use with a simple line and winch, the lightweight device enables high-fidelity data collection at remote coring sites without requiring complex infrastructure. The first iteration, the minilogger, integrates the ISD4000 deep-sea navigation sensor with an OpenLog Artemis data logger. Fully self-powered and requiring no specialized software, it is configured and offloaded via a standard USB interface. The logger is mechanically centralized in the borehole and can be fastened to the end of any physical cable for deployment, with no electrical communication through the line. The pressure vessels containing the sensor and the logging electronics are designed for 3000 meters, allowing for use at a full range of drill sites. These features make it a versatile and practical addition to our existing suite of logging tools.

**Oral sessions / 46**

## Fast Dry Borehole Drilling and Bulb Formation with the Askaryan Radio Array Hot Water Drill

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The Askaryan Radio Array (ARA) is a radio-based neutrino telescope that was constructed at the South Pole between the period of 2011 to 2018. Construction of the array required dry boreholes 18 cm in diameter to depths of 200 m to install the radio antenna instrumentation. The ARA Hot Water Drill (ARAHWD) was developed specifically for this task, and can achieve the required boreholes in 7 hr of drilling with a hole-to-hole turnaround time of 10-12 hr. Using hot water to create dry holes is a unique approach. Hot water drilling technology was selected because it offers the high drill speeds needed to deliver a maximum number of boreholes in a limited window of seasonal time, however it requires more personnel resources to operate than some other mechanical drilling methods. The drill system has a 300 kW thermal capacity and is packaged onto three sleds that are towed in a train configuration to maintain high mobility. In addition to drilling for ARA, the ARAHWD has become a valuable resource for other drilling activities at the South Pole, including firn drilling and subsurface bulb creation for the South Pole Station, and integration into the recently commissioned IceCube Upgrade Hot Water Drill for management of that system's dedicated Rodwell. The basic design principals of the ARAHWD and its various applications will be summarized.

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# Development and Field Deployment of the HWD700 Hot Water Drill for Subglacial Instrumentation on a Land-Terminating Glacier of the Greenland Ice Sheet

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As part of the ERC Consolidator Grant project REASSESS, we have developed and successfully deployed a new hot water drilling system, the HWD700 (Hot Water Drill, 700 m capacity). The system is specifically designed to operate on land-terminating glaciers of the Greenland Ice Sheet, where surface meltwater is available and water recirculation is not required.

The design requirements focused on rapid deployment (capable of drilling through 700 meters of ice in less than 10 hours), helicopter portability, and mobility over a 1 km radius on glacier surface without heavy machinery. These constraints led to a compact, modular system that can be efficiently operated in remote and logistically constrained environments.

In July 2025, the HWD700 was field-tested on Isunnguata Sermia, a land-terminating outlet glacier in West Greenland. During the campaign, four boreholes ranging from 600 to 675 meters deep were successfully drilled. Each borehole was equipped with a suite of subglacial instrumentation, including piezometric pressure sensors and optical fibers. These sensors enable high-resolution measurements of temperature profiles (DTS), ice deformation (DSTS), and seismic activity (DAS), contributing valuable data for understanding ice sheet dynamics.

This presentation will outline the design concept, technical specifications, and operational performance of the HWD700, as well as preliminary insights gained from the deployment.

**Oral sessions / 83**

# BigRAID –an 11.2”diameter version of the BAS Rapid Access Isotope Drill

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The BigRAID is a large diameter version of The British Antarctic Survey (BAS) Rapid Access Isotope Drill (RAID), whereas the original RAID was based around a 3-inch barrel and has cutters with an outer diameter of 85.2mm, the BigRAID has cutters with an outer diameter of 285mm. Both drills work on the same principle with full face twin cutters that create chippings which are then collected

internally within the drill sonde. The drill sonde is then winched to the surface and the chippings ejected by running the drill motor in reverse. This presentation focuses on the concept and design of the full BigRAID drill system highlighting the differences between the BigRAID and the RAID. The most significant are, a direct drive drill motor, an asymmetric cutting head to reduce chip loss during borehole transit, anti-torque slip ring and above surface anti-torque.
The BigRAID has been drilling access holes as part of the Radio Neutrino Observatory –Greenland (RNO-G) up at Summit Station. The drill is mounted on an plastic sheet and can be setup quickly and moved easily from one site to the next.

**Oral sessions / 65**

## EGRIP Drilling 2016-2024

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At EGRIP an ice core was collected to 2663.63 m below the surface of the Northeast Greenland Ice Stream (NEGIS) using the latest modifications of the drill based on the Danish Hans Tausen (HT) concept (Johnsen et al., 2007). The end of the drilling at EGRIP was highlighted by penetration into the subglacial environment upon which wet sedimentary material was collected using a custom adaptation of rock cutting tools to the HT ice drill.
The execution of the EGRIP drilling presented many challenges and development opportunities for ice drilling with HT-technology and associated procedures. The EGRIP project was born out the foundations established from the drilling at NEEM (Popp et al., 2014) and the progressive evolution of technology and project organization that has a direct line stretching back more than four decades through deep drillings at NGRIP and pre-HT projects at Summit (GRIP), and DYE3, among others. From its inception in 1995, the HT design concept has been responsible for numerous deep ice core drilling projects, both in its Danish form and other internationally recognized versions of the same. Like previous projects, EGRIP provided an opportunity for educating drilling teams, testing new drilling hardware and procedures, and for testing new core and liquid handling systems to eventually be used for other programs.
Going into the project, challenges specific to drilling a deep ice core at EGRIP included uncertainty about conditions near the bedrock in a fast moving ice stream. Potential complications to drilling included the effects of basal sliding, the presence of liquid water, and in particular, the potential for borehole deformation due to ice flow velocity changes with depth. If present, deformation could inhibit drilling from one summer drilling season to the next, or potentially from one drill run to the next if severe enough.
Additionally, the advancement of continuous melting systems for the analysis of isotopic, gas, and impurity content of the ice core, required that a particular premium be placed on core quality at EGRIP, notably in the brittle zone, where at EGRIP there is the potential for annual layer counting in a zone underrepresented in the previous ensemble of Greenland ice core layer-counted chronologies.
Another challenge was the upgrade of aging motors and motor control units, surface and downhole electronic systems, and protocols for stable downhole communication, all of which ended up spanning the first several years of the project before stabilizing. One result of these upgrade efforts, however, included the ability to correct and control borehole inclination, which in turn fed into a new approach and eventual testing of a system for deviating from the parent borehole for replicate core drilling.
The EGRIP project was paused for two full drilling seasons due to the COVID pandemic response. The camp was left abandoned out of necessity from the conclusion of the 2019 season before reopening in 2022 with approximately 500 m remaining to be drilled. This pause seriously tested the lifespan of the subsurface tunnel systems developed for hosting the drilling infrastructure.
This talk will address these and other notable features of the EGRIP drilling. With the EGRIP camp

now closed and all remaining equipment transferred to the old GRIP site at the summit of the ice sheet, a historical epoch in deep ice core drilling in Greenland has come full circle.

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**Poster sessions oral introduction / 80**

## A Compact Autonomous Melting Probe for Subsurface Sensor Deployment

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Autonomous access to ice layers up to 100 meters in depth is increasingly important for a range of scientific applications, including glaciology, climate studies, and astrophysics. Compact melting probes represent a promising solution for the deployment of sensors in and beneath the ice, particularly in remote environments where conventional drilling is logistically challenging.
The system presented here was developed within the framework of the Radio Neutrino Observatory Greenland (RNO-G) and built on behalf of the collaboration. Its primary purpose was to autonomously create reference holes for detector stations during expeditions to Greenland. At RNO-G, near-surface calibration transmit antennas are typically installed in shallow, hand-dug holes (~2 m deep) in the absence of a suitable tool to create deeper installation holes with adequate effort. At two stations (21 and 23), these near-surface calibration transmit antennas were instead installed in augered boreholes between 10 and 20 m depth, allowing a more favorable transmit-receive angle between the log-periodic dipole antennas (LPDAs) and vertically polarized (Vpol) receiver antennas on the power string.
The melting probe enables the creation of these deeper boreholes in an automated, efficient, and logistically lightweight manner. Following the improved results, it is envisioned to install near-surface pulsers at such depths (~20 m deep) for future RNO-G stations, using a melting system such as the one presented here.
Its successful use by the RNO-G team has demonstrated the feasibility of replacing traditional augering techniques with autonomous melting systems for future deployments.
While the RNO-G deployment served as a specific use case, the broader objective of the project lies in advancing autonomous melting probe technology for general sensor delivery in icy environments. The compact probe can operate fully autonomously after setup, reaching target depths and optionally remaining embedded in the ice as a long-term sensor node with surface communication.

This contribution details the design and control logic of the system, as well as power considerations and operational autonomy. Field results from Greenland include performance metrics such as melt

rate, energy consumption, and mission reliability, highlighting the system's suitability for scientific deployments in polar and alpine ice.

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**Oral sessions / 40**

## DEEP RAPID ACCESS DRILLING: SURFACE CONTROL SYSTEM DESIGN

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Hot water drilling has the advantages of less environmental pollution and fast drilling speed, but due to the wide variety of ice surface equipment, there are problems such as complex coordinated control of multiple systems and difficulty in troubleshooting. This paper presents a centralized surface control system specifically designed for a polar hot water drilling, known as Deep Rapid Access Drilling (Deep RAD). The system integrates multiple functionalities, including status monitoring, video surveillance, independent module debugging, coordinated system control, fault diagnosis and warning, and automated emergency handling, enabling comprehensive monitoring and precise control of the drilling process.
The system incorporates multiple high-definition cameras to monitor the operational status of key components such as the boiler, the winch, and the borehole head in real time. Video data are transmitted via industrial-grade routers and switches to a hard disk recorder supporting dual-disk hot backup, ensuring redundant and highly reliable video storage. The core control unit employs an industrial-grade computer running a custom supervisory application. This system continuously acquires real-time sensor data from multiple subsystems, performs dynamic analysis, initiates threshold-triggered alarms, and executes automated control actions. All operational data is stored in a local database with redundant protection implemented through real-time data mirroring.
The video surveillance system connects to two screens for real-time display of multi-channel monitoring images via a hard disk recorder; the human-machine interaction system uses an industrial computer connected to the other two screens to dynamically display the host computer control interface, data curves, and alarm information using communication protocols like Modbus RTU, Modbus TCP, and S7.NET, thereby ensuring system operation efficiency and data monitoring. A multi-objective centralized control strategy based on a fuzzy PID algorithm was developed, and the dung beetle optimization algorithm was introduced for automatic tuning of the PID parameters. At the same time, an early warning system based on a multi-system fault library was developed, which analyzes and diagnoses according to the constraint relationship between the parameters of each device, displays the corresponding alarm information, and realizes the rapid fault location, automatic alarm and system emergency protection functions under complex polar conditions, improving the overall safety and reliability of the system. All equipments are housed in a dedicated control room, enabling operators to maintain a full overview of system operations.
The system has successfully completed functional and performance testing under laboratory conditions. Full-scale validation tests of DEEP RAD are scheduled for the summer of 2025.

**Poster sessions oral introduction / 63**

## AN OVERVIEW OF SHALLOW ICE CORES ALONG THE TRANSECT FROM COAST TO DOME A, EAST ANTARCTICA

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Shallow ice cores are crucial for reconstructing climate variability over the past several hundred to thousands of years, as well as for understanding the underlying mechanisms driving these changes. To date, the Chinese inland Antarctic expedition team has recovered more than ten shallow ice cores (> ~50 m in depth) along the transect from the coastal Zhongshan Station to Dome A, the summit of the Antarctic ice sheet. In general, three generations of electromechanical ice core drills have been employed to extract these cores. The first-generation drill, developed by the Lanzhou Institute of Glaciology and Cryopedology, has relatively unstable performance and requires operators with specialized experience. The second-generation drill, the "D-3" Ice Core Drill System (600-m type), was provided by the National Institute of Polar Research, Japan. The third generation is an improved version of the "D-3" system, featuring enhanced drilling efficiency and user-friendliness. These ice cores have been instrumental in studying explosive volcanic events, shifts in large-scale atmospheric circulation patterns, temperature fluctuations, sea ice extent, and the atmospheric oxidizing capacity (e.g., Li et al., 2009; Jiang et al., 2012, 2019; Li et al., 2013; An et al., 2021; Li et al., 2025).

**Oral sessions / 29**

# ADVANCEMENTS IN DRILL SYSTEM ELECTRONICS

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Ice drills have historically used "dumb"electronics systems where it is up to the operator to decide how to drive the drill, sometimes on the basis of minimal feedback data. While such systems can offer highly robust solutions which have performed steadily for decades, they sacrifice the operational efficiency possible with a partially automated "smart"system. This presentation will cover the basic ingredients for a smart system, some of the ways that the U.S. National Science Foundation (NSF) Ice Drilling Program (IDP) has addressed challenges along the way (including: the benefits of a simple scheduler for modular software design, our strategy to efficiently maintain safety, ways to keep the operator in control with partial automation), and details of how IDP plans to retrofit existing deep drill systems with the latest control scheme.

**Poster sessions oral introduction / 26**

# ELECTRONICS IN THE BOREHOLE

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All deep wireline drills must deliver power to the cutting face and sense forces on the sonde to avoid cable knots. The U.S. National Science Foundation (NSF) Ice Drilling Program (IDP) is looking to

inform future development with the best approaches to solving these problems in the context of the Foro series drills. The goal is to maintain safety, performance, and durability with a design that supports meaningful verification testing prior to deployment. Existing solutions are presented along with associated downsides, to spur discussion.

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## USING SNOW AS CONSTRUCTION MATERIAL FOR UNDERGROUND TRENCHES, CABLE DUCTS, SNOW FOUNDATIONS AND AIRCRAFT HANDLING AREAS

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EGRIP camp was established in 2015 by packing down the former NEEM drilling camp and pulling all materials and structures, including the main building on ski to the EGRIP site by a 440 km traverse train. For the first time on the Greenland ice sheet, nothing was left behind, except for the borehole and 25 ton broken and buried timber roofs of the former underground trenches. At EGRIP all underground trenches were constructed using snow as the only construction material and balloons to create underground caves. This has been so successful that these principles also have been used at several locations in Antarctica. We will present the principles of construction, our observations of cave deformation over time and compare construction times, life times and work involved with classical wood covered trenches used at NGRIP and NEEM ice drilling sites and we will suggest improvements to the balloon technique. We will also show results of casting electrical cable ducts using the balloon technique. The overall purpose of construction has been to minimize loss of material by re-using existing material and minimize the amount of construction material needed.

**Oral sessions / 5**

## GENERAL CONCEPT AND LABORATORY TESTING OF A DEEP HOT-WATER DRILLING SYSTEM FOR ACCESSING SUBGLACIAL LAKE QILIN IN EAST ANTARCTICA

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The project aims to explore Subglacial Lake Qilin, located within long subglacial canyons in Princess Elizabeth Land, East Antarctica. This lake is ~42 km in length and has an area of 370 km2, making it one of the largest subglacial reservoirs in Antarctica (Yan et al. 2022). The lake is overlain with an average ice thickness of about 3600 m. The estimated maximal water thickness in the central part of the lake is ~240 m. The average temperature of the ice at the surface is −41 ℃.

Subglacial Lake Qilin has been chosen as a candidate for exploration because it is (a) logistically accessible through Chinese scientific field operations (it is located ~520 km from the Chinese Zhongshan Station); (b) thought to have been isolated for potentially hundreds of thousands of years and may provide unique information about microbial evolution, past climate, and the formation of the ice sheet; (c) representative of many other deep subglacial Antarctic lakes in terms of pressure and temperature. During the 2024-2025 season, field radar and seismic surveys were conducted above Subglacial Lake Qilin, and the optimal location for the drilling site was identified in the central part of the lake.

The proposed exploration concept is based on a deep clean hot water drilling system, which is considered to be the most environmentally friendly access technology at the moment. We also plan to test an alternative option for subglacial exploration –combimnation of hot-water drilling with thermal drilling by RECoverable Autonomous Sonde (RECAS). RECAS allows us to drill ice both downward and upward, and to sample subglacial water, while keeping the subglacial lake isolated from the surface.

The proposed drilling system includes eight subsystems: (1) primary heating system, (2) secondary heating system with high-pressure pumps, (3) cleaning system, (4) hoisting system of the main hole, (5) downhole drill-nozzle, (6) return water system, (7) electrical generators, and (8) control system (Talalay et al. 2024). The total estimated weight of the system, excluding generators and fuel, is 85.8 t. The working power of all the equipment is in range of 200-275 kW, and the estimated disel fuel consumption for drilling and maintaining of the access hole with depth of 3600 m is approximately 110 t.

All the drilling components passed through intensive subassembly tests, and the whole system was tested in Qiaowei Lab, Jilin University, Changchun, China. According to the proposed schedule, the hot-water drilling system will be delivered to Antarctica in November-December 2025, and then transported to the selected site. Access drilling to the lake is planned for January-February 2026. In an ideal scenario without any accidents, it would take approximately 170 h to penetrate through the ice with hot water drill, sample the water, and collect sediment samples.

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## Selection of Ice Core Drilling Sites in the Grove Mountains Blue ice Area, East AntarcticA

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Deepening our understanding of million-year-scale climate evolution, particularly unraveling the

mystery of the Mid-Pleistocene Transition (MPT), urgently requires obtaining older ice core records extending beyond current limitations (approximately 800,000 years), especially continuous climate archives reaching back 1.5 million years. While deep-sea sediments reveal the dominance of 40,000-year glacial cycles in the Early Pleistocene and the shift towards 100,000-year cycles during the MPT, they lack the precision to resolve crucial atmospheric greenhouse gas concentrations. Shallow ice core drilling in Blue Ice Areas (BIAs) with exposed old ice offers an efficient complementary. These areas often form where bedrock topography is highly variable; unique ice flow dynamics can bring million-year-old ice to shallow depths, as evidenced by the discovery of ice core record over 2.7 million years old in the Allan Hills region, demonstrating their potential. In this study, we focus on the Grove Mountains area of Antarctica (approximately 100 km from China's Taishan Station), characterized by nunataks, highly variable bedrock topography, and complex ice layers disturbance, where BIAs with the potential for exposing older ice have formed. To support China's 2025-2027 Grove Mountains BIA drilling program aimed at obtaining high-resolution climate and environmental records extending back millions of years, we comprehensively utilized multi-source remote sensing data and high-resolution airborne radar data. Our study precisely revealed ice thickness, internal layering structures, and bedrock topography features. Through in-depth analysis of the impact of ice flow-bedrock interactions on the uplift and exposure processes of ancient ice, we successfully identified and determined three high-potential ancient ice core drilling sites within the Grove Mountains. This site selection strategy significantly enhances the probability of successfully drilling to retrieve ultra-long-scale paleoclimate records of major scientific value. This study holds the promise of filling the gap in direct climate records prior to the MPT and underpinning million-year-scale climate reconstruction.

**Poster sessions oral introduction / 56**

## STUDIES OF THE SKAFTÁRKATLAR SUBGLACIAL LAKES, VATNAJÖKULL ICE CAP, ICELAND

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In the western part of the Vatnajökull ice cap, two subglacial geothermal systems cause steady melting of the overlying ice and collection of meltwater in subglacial lakes that empty out in jökulhlaups (glacier lake outburst floods) every 2 years (on average). Release of the meltwater, which contains a geothermal fluid component, leads to subsidence of the surface and the formation of 50–150 m deep, nearly circular cauldrons, the Skaftárkatlar (Skaftá cauldrons), which are 1–3 km wide (Björnsson, 2010; Einarsson et al., 2016).

In the years 2006–2015, we conducted several hot-water drilling, sampling and logging projects in both the western and the eastern Skaftá cauldrons. A drill with built-in sterilization (Thorsteinsson et al., 2007) was used to penetrate the 230–300 m thick ice cover seven times at five different locations within the cauldrons. The program included the following efforts:

**June 2006:** First drilling in the Western Skaftá cauldron. Successful sampling of the subglacial lake for geochemical and microbiological analysis, demonstration of a biological habitat in this extreme environment (Gaidos et al., 2008). Measurement of the temperature profile in the 115 m deep lake,

modelling of circulation within the water body and estimation of ice-melting rates at the ice-shelf base (Jóhannesson et al., 2007).
**June 2007:** Drilling into the lake beneath the Eastern Skaftár cauldron, at 3 locations. Continued sampling program and microbiological studies (Marteinsson et al., 2013). Deployment into the lake of a thermistor string with 15 temperature sensors at different depths and collection of data over 12 months. Installation of a GPS-receiver to record vertical movement of the ice shelf at the start of a jökulhlaup and deliver early warning.
**2008–2010:** Smaller reconnaissance projects in Skaftárkatlar and Kverkfjöll (N-Vatnajökull).
**March 2014:** Successful drilling into the eastern cauldron during wintertime conditions. Continued sampling and temperature profile logging.
**June 2015:** Successful drilling into both cauldrons, sampling at different depth levels in the subglacial lakes. Temperature profile measurements.

Results obtained and lessons learned during these projects include:

**Hot-water drilling.** Under favourable conditions within the cauldrons, the 230–300 m thick ice cover could be penetrated in less than 10 hours. Minimal problems were encountered in penetrating volcanic tephra layers, but englacial crevasses and water bodies where sometimes encountered. This caused difficulties which could be alleviated by drilling a new hole a few tens of meters away. Sterilization of the drilling water was successful.
**Sampling method.** A commercial sampler produced by Mt. Sopris Instruments, with an opening and closing mechanism operated from the surface, worked without problems.
**Temperature profiles.** We used Starmon mini and Geokon temperature sensors to measure the lake temperatures. In the western lake, the water temperature was at 3.5–4.7℃ in June 2006 and large-scale circulation in the lake body was inferred from the observed stratification (Jóhannesson et al., 2007). In June 2015, lake temperatures were at 4.0–4.5℃ throughout most of the water column. The eastern lake displayed a more stable temperature profile close to 4℃ in 2007 and limited change in the vertical profile was observed over the 12-month period during which the deployed thermistor string survived. In 2015, the temperature was stable at 3.5℃ in an 86 m water column.
**Jökulhlaup mechanisms.** The subglacial lake studies have allowed determination of the initial temperature of jökulhlaup water released from these water bodies. Moreover, estimation of lake volumes during the onset of outburst floods has greatly improved since the start of the program and in related work (Magnússon et al., 2021). Combining data on lake properties with GPS-measurements of vertical and horizontal movement of the glacier surface at locations downstream, a new picture has emerged of the mechanisms of water flow along the 40 km long subglacial flow path, where alternating sheet flow and tunnel flow is the most plausible explanation of the observed flow behaviour (Einarsson et al., 2017).
During drilling in the western cauldron in 2015, the drill stem hit an englacial water body and water was rapidly released through the borehole into the subglacial lake. This sudden influx of water probably triggered a jökulhlaup from the lake two days later (Gaidos et al., 2020).
**Early warning systems.** A GPS-station delivering data on vertical and horizontal surface movement was operated in the Eastern Skaftár cauldron for several years. The station recorded lowering of the cauldron surface when the lakes emptied out in jökulhlaups. This allowed early warning to be given to civil protection authorities at least 20 hrs before emergence of the floodwaters from beneath the western margin of Vatnajökull.

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## 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.

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## Drilling for the Radio Neutrino Observatory in Greenland (RNO-G): field performance of BigRAID

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The Radio Neutrino Observatory in Greenland (RNO-G) is designed to detect ultra-high-energy neutrinos by capturing the radio signals generated when these rare particles interact with glacial ice. Located near Summit Station on the Greenland ice sheet, RNO-G will ultimately consist of 35 autonomous stations, each spaced 1.25 km apart and equipped with arrays of in-ice antennas. A key component of each station is a set of three subsurface strings of antennas, which require boreholes approximately 100 meters deep and wider than 6 inches in diameter. Construction of the observatory began in 2021, and eight stations have been deployed to date. To meet the drilling requirements, the project utilizes the BigRAID system. Developed through a collaboration between the University of Wisconsin–Madison, the British Antarctic Survey (BAS), and the RNO-G team, BigRAID is being

continually refined to improve its reliability, enhance drilling speed, and incorporate advanced automation and control software. This presentation will review recent upgrades to the drill and assess its performance in the field through the four seasons of drilling.

**Poster sessions oral introduction / 84**

## THE AAD MILLION YEAR ICE CORE (MYIC) DEEP DRILL SYSTEM

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The Australian Antarctic Division (AAD) deep drill is an electromechanical cable-suspended drill based on the US IDP FORO3000 drill design, a derivative of the Hans Tausen family of drills. The drill system has been developed for the Million Year Ice Core (MYIC) Project and was built in-house at the AAD with collaborative input from US Ice Drilling Program and the University of Grenoble and other in the drilling community. The drill is designed to recover 3-m long 98mm diameter cores and is built to operate to ice depths over 3 km and at temperatures <-50˚C.
In the 2024-25 season and Inland Station support camp was established for the MYIC project at Dome Concordia North (DCN), 75.0422S, 123.6312E (ice thickness 3064 m). The site is ~9 km NE of Concordia Station and 45 km NE of the European Beyond EPICA Oldest Ice site at Little Dome C. MYIC field operations in 2024-25 included installation of the above-ground drill shelter along with completion of the drill incline trench, core processing line. Pilot drilling and reaming operations were completed using a modified Eclipse drill. Pilot drilling took 4.5 days to 150 m. Reaming was completed in 3 steps to 120 m in a further 6 days. In the coming 2025-26 season the program aims to install the fiberglass bore casing and drill fluid handling system and set up and commence drilling with the AAD deep drill system. Drilling to bedrock is scheduled for completion in 2028-29.
This presentation will provide an overview of the AAD deep drill design, build and capabilities and discuss some of the challenges experienced.

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## INCLINOMETER APPLICATIONS USING ENCAPSULATED ACCELEROMETER DATA CALIBRATED FOR VARYING MEGAPASCAL PRESSURE AND CRYO-TEMPERATURE CONDITIONS

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INCLINOMETER APPLICATIONS USING ENCAPSULATED ACCELEROMETER DATA CALIBRATED FOR VARYING MEGAPASCAL PRESSURE AND CRYO-TEMPERATURE CONDITIONS

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MEMS accelerometers offer high precision in tilt sensing but are sensitive to temperature and pressure. This work presents a robust inclinometer design and calibration method for harsh environ-

ments such as deep ice boreholes. We model drift behavior at cryo-temperatures and pressures up to 350 bar, showing that angle-based calibration significantly improves accuracy.
Beyond inclination sensing, we outline a compact logger concept that integrates the same calibrated sensor to also estimate borehole cross-sectional shape. While inclination performance has been experimentally validated, the sensor's high precision and successful calibration also make it a promising candidate for estimating borehole cross-sectional shape within the same logger system.
This approach enables accurate inclination monitoring and offers the potential for repeated borehole shape profiling throughout the decade, supporting both drill performance evaluation and glaciological deformation studies.

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**Oral sessions / 10**

## CoreCaster: A Probabilistic Simulator for Ice Drilling Campaign Planning

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Ice core drilling campaigns require careful planning to optimise field operations while continuously refining strategies throughout the season to navigate logistical challenges. CoreCaster is a Python-based simulation tool designed to forecast drilling progress under both idealised and probabilistic conditions. Developed in the field during the Beyond EPICA Oldest Ice Core drilling campaign, CoreCaster utilises probabilistic modelling to simulate individual drill runs, full seasons, and entire drilling campaigns. By iterating these simulations over numerous cycles, the tool generates a range of plausible scenarios, aiding logistical decision-making and contingency planning.
Initial field validation has demonstrated strong alignment between CoreCaster's forecasts and actual performance, reinforcing its potential as a planning tool for future drilling campaigns. CoreCaster can also extrapolate drilling performance for systems without real-world trial data, using input parameters from existing equipment to model expected behaviours in novel setups. While currently implemented as a Python module to be used within scripts, plans for an enhanced interface—including a GUI—would improve usability and accessibility for research teams.
This contribution explores CoreCaster's methodology, validation against real drilling operations, limitations, and potential extensions, including broader integration with other aspects of drilling logistics. By improving planning precision and easing logistical demands, CoreCaster supports more efficient and adaptable ice core drilling campaigns.

**Oral sessions / 3**

## STUDY ON THE FORMATION MECHANISM OF DEEP HOT-WATER DRILLING BACKWATER CAVITY

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For explore and sample subglacial lakes in polar regions, hot-water drilling has emerged as the most rapid and efficient penetration method（P. G. Talalay et al. 2024）. In a deep polar hot-water drilling system, the backwater system is an essential component , with the backwater cavity playing a pivotal role（Zhipeng Deng et al. 2025）. Located at a specific depth beneath the ice sheet surface, this ice-enclosed void is crucial for storing and recycling water during the drilling process. It also ensures hydraulic equilibrium upon reaching subglacial lakes, thereby enhancing overall drilling efficiency significantly. This study employed scaled-down laboratory model experiments to systematically investigate the formation of backwater cavities under various parameters. The research comprised two initial test series: (1) examining cavity formation using nozzles of different diameters, and (2) analyzing cavity formation with different nozzle divergence angles. These tests identified the optimal nozzle specifications for cavity generation. Subsequently, four sets of experiments were conducted using the selected nozzles, including the formation of backwater cavities with multiple nozzles, the formation of backwater cavities with different hot water temperatures, the formation of backwater cavities at varying flow rates, and the formation of backwater cavities with different nozzle installation angles. By exploring the influence of these parameters on the backwater cavity formation process, the study aimed to determine the parameter settings most suitable for field operations in Antarctica. Based on the experimental findings, the study deduced the appropriate nozzle parameters for Antarctic fieldwork and designed the corresponding nozzle types. The test results indicated that the optimal water spraying speed for backwater cavity formation is 37.23 m/s. For single-row, six-nozzle configurations, fan-shaped nozzles with a diameter of 4.4 mm and a scattering angle of 80° are recommended; for five-row, six-nozzle setups, fan-shaped nozzles with a diameter of 2.0 mm and a scattering angle of 80° are deemed most effective. In summary, this research provides valuable insights into optimizing the design and operation of hot-water drilling systems for polar exploration, laying a solid foundation for future subglacial lake exploration projects.

**Oral sessions / 42**

## RAPID DRILLING THROUGH DEEP ICE INTO BEDROCK IN ANTARCTICA: RESEARCH PROGRESS AND FUTURE PLAN

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Rapid penetration through Antarctic ice sheets to directly recover subglacial bedrock core and samples for cosmogenic nuclide and mineralogical analyses holds critical significance in advancing research on Antarctic geological structures, reconstructing ice sheet evolution history, and evaluating future climate change. Current drilling technologies face substantial challenges under Antarctica's extreme surface environments and complex subglacial geological conditions, particularly due to heterogeneous ice-rock interfaces and the technical difficulties of maintaining borehole stability while recovering bedrock cores. Internationally, only a few shallow subglacial bedrock boreholes (with limited core recovery) have been completed to date, falling short of supporting comprehensive scientific investigations. This underscores the urgent need for innovative multi-process drilling theories and methodologies tailored to Antarctica's subglacial geological complexity.
This project aims to establish novel multi-process drilling techniques capable of increasing penetration rates by 50–100%, while developing lightweight modular drilling rigs and multi-process systems with an ice-penetration capacity exceeding 1,000 meters and subglacial bedrock core recovery of ≥10 meters. To achieve these objectives, four key research components have been implemented: (1) research of rapid drilling technology with air reverse circulation for firn/ice layers, (2) research and development of ice-rock interface/core sampling tools, (3) research and development of low-temperature drilling fluid formulation for ice-rock interlayers, and (4) research and development of polar drilling equipment and system integration. The resulting technological suite includes: a fully hydraulic top-drive rig with large channel capacity, high-performance air compression and purification systems, cryogenic drilling fluid circulation/pumping modules, a 300-kW power supply

system, and multi-process downhole toolkits (e.g., 550m-long Ø89 aluminum alloy dual-wall drill pipes, Ø110/102 reverse circulation bits, wireline coring tools, and vertical rock-entry tooling for ice-rock interfaces).
The operational drilling technology strategy combines: (1) Air reverse circulation (ARC) full-face drilling using aluminum dual-wall drill pipes for rapid ice sheet penetration; (2) Hydraulic reverse circulation (HRC) with cryogenic fluids for ice-rock transition zones; (3) Wireline coring or continuous HRC coring for bedrock core recovery.
Field validation commenced in July–October 2024 at Zhangjiakou City (China), demonstrating successful performance in full-face drilling, core recovery, and system integration. Subsequently deployed during China's 41st Antarctic Expedition, the entire system was transported to Princess Elizabeth Land, East Antarctica (69°35'10.12"S, 76°23'03.87"E) in January 2025 (2024/2025 summer season). Initial field tests achieved a 110mm-diameter borehole penetrating 110m of ice using ARC and HRC methods, confirming equipment functionality under Antarctic conditions.
Identified operational challenges from these trials will guide system optimizations. The research team plans to participate in China's 42nd Antarctic Scientific Expedition to conduct extended experiments targeting 500m ice penetration and subglacial bedrock core recovery. This phased approach ensures iterative refinement of drilling protocols while progressively addressing technical barriers in ultra-deep Antarctic ice drilling. Upon full validation, the methodology is anticipated to enable unprecedented access to Antarctic subglacial bedrock, providing critical samples for cross-disciplinary studies in glaciology, geology, and climate science.
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# RAPID ICE DRILLING AND CONTINUOUS CORING WITH AIR REVERSE CIRCULATION IN ANTARCTUCA: SYSTEM DESIGN AND RESEARCH PROGRESS

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The acquisition of polar ice cores is of great significance for researching global climate change, searching for ancient biological life forms, analyzing the characteristics of biogeochemical cycles, and revealing the evolutionary laws of glaciers and ice sheets. Currently, there are numerous challenges in polar ice core drilling. To address the bottleneck of low efficiency in traditional polar ice core drilling technologies, a Continuous Coring with Air Reverse-Circulation (CCARC) drilling system has been designed and developed. Through the optimized design of the gas-solid two-phase flow field in the entire borehole, it enables the simultaneous removal of ice chips and rapid coring without stopping the drilling. By integrating core technologies such as reverse-circulation top-drive automated drilling, precise guidance and automatic addition of double-wall drill pipes, adaptive continuous cutting of ice cores at the borehole bottom, intelligent sorting, non-destructive testing, and anaerobic encapsulation and automatic storage of ice cores on-site, it is expected to increase the

drilling efficiency by 5 times to 100 meters per day, with the continuous coring depth of 500-1000 meters. This system can achieve the non-destructive preservation of the original structure of ice cores, preliminary dating of ice cores on-site, and quantitative inversion of climate change. It provides key technical support for hot point of polar research, such as revealing the climate change mechanism of the Last Interglacial, analyzing current climate abrupt changes, predicting future global changes, and exploring ancient ice core drilling target areas at the bottom of ice sheets.

This CCARC drilling system uses air, an easily obtainable and environmentally friendly medium, as the circulating fluid for polar ice layer drilling, thus avoiding the harm of low-temperature drilling fluids to humans and the polar environment. By developing the reverse-circulation drilling technology with double-wall drill pipe in polar ice layers, compressed air reaches the borehole bottom through the annular gap of the double-wall drill pipe. It then carries ice chips and ice cores into the central channels of the drill bit and the inner tube of the double-wall drill pipe and quickly returns to the surface, realizing a closed-loop flow of compressed air in the double-wall drill pipe throughout the borehole. This overcomes problems such as the leakage of the circulating medium in the firn layer and the collapse of the borehole caused by the scouring and disturbance of the borehole wall, thereby ensuring safe drilling. By developing CCARC system and process for polar drilling fluids, ice cores can be automatically cut off and quickly transported by pneumatic force, eliminating the need to stop drilling for coring during the entire drilling process and achieving the goal of rapid and continuous coring in the deep polar ice sheets. By developing non-destructive ice physical testing technologies and methods such as ice core spectral scanning, dielectric constant (DEP) testing, and CT scanning in the extreme on-site polar environment, as well as multi-stage ice core deceleration devices, intelligent sorting devices, anaerobic nitrogen-filled protection devices, and automatic storage devices, digital imaging, intelligent sorting, protecting and storing of ice cores on the polar site can be realized.

The CCARC drilling system mainly consists of seven subsystems: The full-bore air reverse-circulation continuous coring drilling tool system; The surface rapid drilling system; The rapid drill pipe addition system; The real-time drilling status detection system; The compressed air delivery and post-processing system; The on-site ice core digital imaging, intelligent sorting, and automatic storage system; The mobile working cabin system.

Regarding the key technologies of rapid drilling, ice core breaking and transportation in the CCARC drilling system, preliminary theoretical and experimental research has been completed: established a mechanical model for ice cutting and analysis of factors influencing cutting torque based on ice core drilling process; explored the influence mechanism of cutter structure and drilling parameters on cutting depth of rotary ice- core drill bits; got the regularity of particle size distribution of ice chips produced under various drilling conditions in the process of ice core drilling; obtained key parameters and mechanisms of ice cores autonomously breaking with air reverse-circulation drill systems; acquired the mechanism of ice core transportation with air reverse circulation.

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## DEVELOPMENT OF A LIGHTWEIGHT HOT WATER DRILL AND BOREHOLE IN-SITU OBSERVATION SYSTEM

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Drilling hot-water holes in glaciers and deploying various sensors into the holes for observation represents a direct approach to acquire internal parameters of glaciers. Since the 1960s, a large number of observations on internal ice temperature, subglacial water pressure, ice flow velocity, and borehole photography have been carried out globally for polar ice sheets and mountain glaciers, generating abundant data that have significantly advanced the understanding of the mechanisms underlying glacier changes. In China, however, the observational data on internal glacier parameters are relatively scarce, primarily due to the lack of efficient drilling methods and in-site observation instruments. To achieve rapid ice drilling and in-site multi-parameter detection in glaciers, a lightweight hot water drill and two sets of wired multi-parameter in-situ observation systems was developed by Jilin University.
The maximum drilling depth of hot water drill is 200 m, with a borehole diameter of not less than 100 mm, and the maximum mass of a single component does not exceed 60 kg. Using this hot water drilli, a drilling footage of 122 m was completed at an altitude of 4531.5 m on Glacier No. 12 in Laohugou, Qilian Mountains, China. During drilling, the maximum penetration rate reached 37.5 m/h, and the average penetration rate was 17.5 m/h, with the borehole diameter exceeding 105 mm. The in-situ observation systems for ice boreholes integrated with temperature, water pressure, and attitude sensors can realize multi-point observation at varying depths within the borehole via cable cascading. The temperature detection range is from - 30 ℃ to 0 ℃, with an accuracy of ±0.5% FS. The water pressure detection range is from 0 to 3 MPa, with an accuracy of ±0.3% FS. The accuracy of the X and Y axes of the attitude sensor is 0.2°, and that of the Z axis is 1°. During the 41st Chinese Antarctic Research Expedition (2024/2025), this system was employed to monitor the internal ice parameters of the existing JLU-2 borehole located 30 km away from Zhongshan Station. The sensors were deployed to a depth of 430 m, with a module interval of 25 m. Preliminary analysis of the data reveals that the lowest temperature in the JLU-2 borehole occurs at a depth of 180 m, reaching - 20 ℃. Below 180 m, the ice temperature gradually increases, reaching - 12.5 ℃ at a depth of 430 m. The temperature gradient in the ice below 180 m is 0.03 ℃/m. The ice flow velocity calculated from the sensor indicates that the maximum difference between inglacial and surface flow velocity can reach 8.47 m/year.

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## Study on Sediment Coring Techniques in Antarctic Subglacial Water Environment

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Antarctic subglacial sediments preserve important geological and ecological records, including paleoenvironmental changes, glacier melting processes, and subglacial ecosystem dynamics. However, current coring technology is difficult to cope with heterogeneous formation sediments containing hard particles (such as gravel, granite pebbles) and viscous clay matrix, which have high shear strength (2-22kPa). This study focuses on developing advanced sediment coring techniques for complex structural formations in the Antarctic ice water environment, aiming to address key challenges such as insufficient penetration depth (<3m), severe sample interference, and difficulty in recovery in existing sampling methods. This study employed multiple methods: Studies include: (1) reconstructing subglacial sedimentary layers through laboratory simulations, incorporating mineral composition and particle size distribution based on actual samples; (2) using energy dissipation models to study the infiltration mechanism under impact loads, in order to analyze crack propagation in hard particles and stress response in clay layers; (3) develop low interference sampling technology with innovative tool design to minimize interference with the water sediment interface layer; (4) Research on reducing the pulling force of sampling tubes through pressure compensation and core tube structural optimization. The penetration mode mainly focus on hammering and vibration sampling, which are expected to achieve deeper footage in these complex sedimentary formations. Laboratory coring tests, load analysis, and sample recovery were also studied through relevant experiments. These results will provide technical support for sediment sampling under the Antarctic ice shelf, glacial lakes, and subglacial lakes.

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## The importance of preserving basal ice under appropriate subdued red-orange-light conditions for reconstructing past ice-sheet retreats and advances

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Small pieces of rock and sediment found at the base of ice cores can be used to reconstruct the first appearance, evolution, and age of ice sheets, as well as the vegetation that existed prior to ice-sheet formation. However, accurate reconstructions, particularly those based on luminescence dating methods for determining burial ages, require that these materials remain unexposed to light after drilling. Even brief light exposure can partially reset the luminescence signal and thus compromise dating accuracy. Implementing dark (subdued red-orange-light) extraction techniques in the drill surfacing and core extraction process is a relatively simple adjustment that can greatly enhance the scientific value of basal ice samples. We present field experiences and techniques from the EastGRIP (Greenland), Little Dome C (Antarctica), and Muller's Ice Cap (Arctic Canada) drilling projects, as well as results from the EastGRIP core. We emphasize the importance of adopting dark extraction protocols within the ice-core drilling community to expand the global archive of basal material suitable for luminescence dating and to improve our understanding of ice sheet formation and dynamics.

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## Drilling 613 m through Muller's Ice Cap, Arctic Canada - advances in drill equipment and camp infrastructure

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From late March to late May 2025, a collaboration between Canada and Denmark drilled a 613m ice core through the Muller ice cap in the high Canadian Arctic. It is the deepest ice core in the Americas to date. The ice cap is in close proximity to the Arctic Ocean, supporting the primary goal of understanding the evolution of Arctic sea ice over the 10,000+ year record contained within the ice.
We will discuss several novel solutions that were implemented, as well as lessons learned and statistics for projects (with a similar scale) in the future.
For the drilling, we used a newly designed intermediate winch and control system, with a previously existing tower, and the Danish deep drill system with 2.2 m core barrels. The newly designed winch is staged on a movable platform, resulting in a fixed level wind and a short distance to the tower.
Furthermore, we tested an inflatable tent to host the drilling and core processing. This worked well and withstood multiple strong wind days with gusts above 40kt. The tent was a fraction of the weight of a traditional steel-framed tent.
Drilling concluded after 30 drilling days with 10 m of debris-rich / silty ice by hitting bedrock at 612.98m depth.

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# THE BELDC DEEP DRILLING OPERATION TO BEDROCK

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The European Project for Ice Coring in Antarctica (EPICA) Beyond EPICA –Oldest Ice aims at retrieving a continuous ice core record of climate feedback and forcing spanning about 1.5 Ma back in time. In that period the cyclicity of glacial/interglacial changes in continental ice sheet volume and temperature changed from 40 ka to the well-known 100 ka cycles encountered over the last 800 ka.
After determining a suitable drill site Little Dome C (LDC), 35 km southwest of Concordia station, during an extensive pre-site survey, we penetrated to 2800 m depth during the third deep drilling season 2024/25, roughly spanning at least 1.2 Ma and a basal unit below 2584 m.
Here, we will focus on the implementation of the drilling operation: starting from an overview of the timeline of the project, the layout of the camp, upgrades to the drill system that enabled to drill 4.5 m long cores in a stable production mode, and ultimately drill in three seasons from the bottom of the pilot hole at 131.65 m below the surface to the bed at 2800 m depth. We will report on the drilling and core processing activities, that comprised Dielectric Profiling (DEP) and Laser Ringdown Spectrometry for water stable isotope determination already in the field, and provided a match of the record to existing ice core records like EPICA Dome C and marine records to estimate the climatic periods we recovered in the core.
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## ANTI-TORQUE SYSTEMS OF HOT-WATER ICE-CORING DRILLS WITH POSITIVE DISPLACEMENT MOTOR

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Hot-water drilling is the fastest method of drilling through ice, with penetration rates typically ranging from 40 to 60 m/h, and in some cases reaching as high as 200 m/h. Currently, hot-water drilling is being actively used to observe ocean cavities beneath ice shelves, study internal ice structures, measure temperature and deformation within the ice, and clean access subglacial lakes. In general, hot-water drill drills are full-face (non-coring) drilling tools that can only produce meltwater and the borehole itself. To recover ice cores from desirable depths, specialized hot-water ice-coring drills can be used in combination with a full-scaled hot-water drilling system. However, the recovered cores suffer from water circulation issues (Liu et al., 2021).
In an attempt to overcome this limitation, mechanical hot-water core drills with a positive displacement motor which has been proposed (Das et al., 1992; Koci, 1994). These systems can be used to recover core samples not only from the clean ice but also from debris-rich basal ice, subglacial till, and bedrock. The preliminary laboratory tests have shown a high potential for the use of mechanical hot-water core drilling technology for ice coring (Liu et al., 2020). The main challenge of this technology is the reliable design of an anti-torque system to prevent the upper, non-rotating part of the drill from spinning in a large, irregular borehole. The robustness of the anti-torque system is essential, as failure of this component could lead to the twisting and breakage of the hose in the absence of a hydraulic swivel.
In order to design a more reliable and efficient anti-torque system, two different structures are designed for comparison. The first one is to control a part of hot water through an electromagnetic valve, allowing it to be sprayed out centripetally through small nozzles to form anti-directional jets to balance the torque generated during mechanical drilling. The other part of hot water is used to maintain mechanical drilling with a positive displacement motor. The flow rate of the jets is automatically controlled based on the feedback from the encoder that measures the rotational speed of the upper part of the drill. The second one is to design multiple rectangular blades on the surface of the motor or other components that do not rotate with the drill bit to increase the resistance generated during rotation, in order to balance the torque generated during mechanical drilling. The report presents estimations of the torque required for drilling ice and bedrock as well as maximum holding torque for both designs, to choose the suitable structure for further testing.

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## The ISP-CNR Ice Core Drilling System: Addressing Firn Aquifers From Arctic To High-Altitude Glaciers

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Warmer summers increase the glaciers's melting and enhance meltwater infiltration into porous firn. Additionally, increased temperatures of the glacier's active layer reduce its refreezing capacity. The prolonged melt seasons associated with ongoing global air temperature rise promote the formation of perennial firn aquifers, which serve as short- and long-term water storage within glaciers.
Since spring 2023, during three field campaigns conducted as part of the Ice Memory project, the glaciology group at the Institute of Polar Sciences - National Research Council of Italy (ISP-CNR), in collaboration with Ca'Foscari University of Venice, has encountered significant challenges in recovering shallow ice cores from wet and water-saturated firn while below freezing temperatures at the surface. These conditions were observed in both low-altitude Arctic settings (Holtedalfonna, 2023; Svalbard, 1000 m above sea level) and high-altitude Alpine environments (Grand Combin, spring 2025; Switzerland, 4150 m above sea level). The aquifers were found in the deeper firn layers, near the firn-ice transition (FIT) or the pore close-off depth.
In this study, we present the different approaches we adopted to enable ice core retrieval in partially water-filled boreholes (BH), including the use of bailing systems and fully submerged drilling techniques. Both electromechanical (EM) and electrothermal (ET) drills were used under submerged conditions. At Holtedalfonna in 2023, a large volume aquifer at a FIT depth of 24 m allows water inflow to the borehole, estimated at 2 L/min. After the borehole reached a depth of 51 m, the drilling site was relocated 140 meters uphill. However, the ice core was successfully recovered down to 51 m at the original site using a submerged electromechanical drill.
In contrast, the Grand Combin 2025 operation observed a lower water inflow rate between depths of 28 and 35 m. Drilling was carried out to a depth of 50 m using the ET drill, followed by electromechanical drilling to bedrock (~100 m) in two separate boreholes. In Svalbard and Alpine ice coring operations, to compensate for buoyancy (approximately 7 kg), the weight of the EM drill was equipped with additional weights. On the drilling site, modified bailing devices were used to remove meltwater from the BH and deploy ethanol to the borehole kerf when it was necessary. Meltwater and fluids from the BHs were removed during the operation.
In these operations, we use only little amounts of environmentally friendly fluids to lubricate EM drill chip transport passages and core catchers, preventing the drill from freezing in sub-zero air temperatures at the surface. None of the drills were stuck during described field operations.

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# PROGRESS AND LEARNINGS OF THE ICE AND SUBGLACIAL BEDROCK DRILLING PROJECT IN PRINCESS ELIZABETH LAND, EAST ANTARCTICA

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The exploration of the subglacial geological environment represents a pivotal frontier in Antarctic scientific research, offering crucial insights into the Earth's cryosphere and its role in global climate systems. In 2023, a collaborative scientific initiative was launched among Jilin University, China University of Geosciences (Beijing), and VNIIOkeangeologia. This partnership aimed to comprehensively investigate the subglacial geology and dynamic processes of the northwestern region of Princess Elizabeth Land in East Antarctica, an area characterized by its complex geological structures and potential influence on ice sheet stability.
The overarching goal of this project was to penetrate the Antarctic Ice Sheet and retrieve high quality bedrock samples suitable for indepth geological analysis. These samples would provide invaluable information about the region's geological history, tectonic evolution, and physical properties, enabling researchers to better understand the longterm development of the Antarctic ice sheet.
During the 2023 - 2024 austral summer, a dedicated joint research team, composed of members from the Chinese National Antarctic Research Expedition (CHINARE) and Russian Antarctic Expedition (RAE), undertook this challenging mission. Armed with the cable suspended Ice and Bedrock Electromechanical Drill (IBED), a cutting - edge drilling device developed by Jilin University, the team successfully drilled through a 545 m thick ice sheet. This remarkable achievement led to the acquisition of a 0.48 m long subglacial bedrock sample, establishing the deepest bedrock borehole in East Antarctica to date.
The drilling site was strategically selected in the central region of a high - amplitude, linear magnetic anomaly, which was identified through prior geophysical surveys as an area of significant geological interest (Talalay et al. 2025). To accommodate the diverse characteristics of the subsurface formations at varying depths, including snow, firn, glacier ice, brittle ice, and basal ice, the team employed a series of specialized drilling modules. Each module was meticulously designed to optimize drilling efficiency, minimize sample disturbance, and ensure the integrity of the collected materials (Talalay et al. 2021).
This report provides a detailed account of the progress and performance of the ice and subglacial bedrock drilling project. It offers a comprehensive summary of the technical experience gained in the field, a thorough analysis of the root causes of the encountered problems, and an indepth discussion of the treatment methods employed. The findings and lessons learned from this project will not only contribute to future research in the region but also serve as a valuable reference for similar Antarctic exploration endeavors, facilitating a deeper understanding of the subglacial world.

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**Oral sessions / 15**

## DESIGN AND TESTING OF ARAMID/NYLON REINFORCED COMPOSITE PIPES FOR LARGE-DEPTH HOT WATER DRILLING

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The Antarctic cold zone has given birth to a large number of closed subglacial lakes, and hundreds of subglacial lakes with large burial depths have been discovered, which may harbor unknown ancient life because they have been isolated from the outside world for millions of years. Subglacial lakes and sediments contain rich information on ice sheet evolution and paleoclimate. Therefore, the development of Antarctic subglacial lake drilling research is of unique and important scientific significance to the advancement of Antarctic glaciology, geology, and paleontology.
Hot water drilling is currently known to be an efficient drilling process that can rapidly penetrate ice. Fiber-reinforced composite pipe can be used as its core equipment, undertaking the key task of transporting high-temperature and high-pressure hot water. For this reason, we have independently developed an aramid/nylon fiber-reinforced thermoplastic composite pipe. Considering its transport of high-temperature and high-pressure media, we have conducted a high-temperature 90℃ burst test as well as a tensile test on it. The results show that in a 90℃ water environment, the composite pipe burst pressure can reach 53 MPa. At the same time, for the Antarctic low-temperature environment (which can reach -50℃), burst and tensile tests were performed after cryogenic freezing. The tests show that its maximum tensile load-bearing capacity can still reach 190 kN, and the burst pressure can be maintained at 53 MPa. The tests proved that the low-temperature environment does not cause performance attenuation of this aramid/nylon composite pipe. After summarizing the results of a series of tests, it is concluded that this kind of composite pipe can meet the needs of Antarctic hot water drilling, and it is expected to be formally applied to Antarctic on-site drilling operations in the next working season.

**Poster sessions oral introduction / 38**

# SIMILARITY-BASED MODEL OF EXPERIMENTS FOR ANALYZING FREEZING AND MELTING IN HOT WATER DRILLED BOREHOLES

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In hot-water ice drilling, the melting rate of the borehole wall during drilling operations and the freezing rate leading to borehole closure during standstill periods are critical parameters for evaluating drilling efficiency and operational safety. However, in-situ measurements of these parameters present significant challenges, including high costs, operational uncertainties and delay of data acquisition. This necessitates systematic laboratory experimentation under controlled conditions.
As an engineering application of heat transfer theory, hot water drilling technology can benefit from scaled model experiments - a well-established methodology widely employed in heat transfer research for aerospace (Ran et al. 2024, Lin et al. 2022), permafrost (Yang et al. 2025, Chen et al. 2022), metal casting (Ren et al. 2024) and some other fields (Jia et al. 2024, Yang et al. 2024). Such modeling approaches have demonstrated considerable advantages in reducing experimental costs while improving data reliability.
This study proposes a comprehensive theoretical design scheme for model experiments addressing

phase-change phenomena in borehole walls induced by hot water drilling in polar regions. Through dimensional analysis with borehole diameter variation rate and water temperature of outlet of annulus between hose and borehole wall as dependent variables, along with key physical variables influencing the freezing and melting processes as independent variables, a series of similarity criteria were derived. These include temperature similarity criterion, geometric similarity criterion, time similarity criterion, and flow rate similarity criterion.

Based on these similarity criteria, the core parameters for model experiments were determined according to capabilities and conditions of experimental equipment. The scaling ratios between actual engineering variables and model experimental parameters were established as follows: temperature similarity ratio 1:1, geometric similarity ratio 2:1, time similarity ratio 2:1, and flow rate similarity ratio 4:1.

This study innovatively designed a multifunctional experimental platform architecture, incorporating a high-temperature hot-water circulation system, low-temperature ice environment simulation chamber, temperature measurement system, and visual borehole diameter measurement apparatus. This theoretical design scheme establishes a foundation for subsequent physical simulation experiments of phase-change processes in hot water drilled boreholes and provides significant guidance for the scientific optimization of process parameters in polar hot water drilling operations.

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