The 8th International Ice Drill Symposium

Report of Contributions

https://indico.nbi.ku.dk/e/1121

Contribution ID: **2** Type: **Poster**

Impurities effect on borehole closure rate in ice sheet

Monday, 30 September 2019 17:56 (4 minutes)

Understanding ice sheet dynamics is of high interest to predict the future ice sheet response in times of changing climate, and is also crucial to estimate borehole closure rate during accessing ice sheet especially by deep ice core drilling. Impurities in ice is one of the most influential factors on mechanical properties of ice and causes localized enhanced deformation. High concentrations of impurities is the main driver for development of strong crystal prefrred orientation, fine grain sizes and for decreasing pressure melting point, which favors the borehole clousre rate signaficantly particularly when ice temperature is above -10 ℃. While the control mechanism of impurities on ice deformation rate is still remains much unclear. Thus, we propose to investigate various species and concentrations of impurities effect on ice creep rate between -15 ℃ to -5 ℃ using bubble free, labratory-made polycrystalline ice obtained by isotropic freezing method, in order to figure out the critical species and concentrations of impurities on borehole closure rate.

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Session Classification: Session 2

Contribution ID: **3** Type: **Oral**

Antarctic movable drilling rig: General concept and test results

Tuesday, 1 October 2019 14:20 (20 minutes)

To drill through ice and bedrock, Antarctic Subglacial Drilling Rig (ASDR) with a new, modified version of the cable-suspended Ice and Bedrock Electromechanical Drill (IBED) have been developed in Jilin University. The drilling facilities are divided into two groups: those associated with the movable drilling shelter and those associated with the movable workshop. The drilling winch, control desk, drilling fluid station and other auxiliaries are installed inside a movable sledge-mounted warm-keeping and wind-protecting drilling shelter. Mast has two positions: horizontal for transportation and vertical working position. Movable workshop has basically the same design as drilling shelter and serves for keeping two generators, logging service, workshop for repairing and maintaining of drilling equipment, core processing. Drilling shelter and workshop are transported to the chosen site with crawler tractors together with habitable unit and three sledges with drilling fluid, fuel and auxiliary drilling equipment. All equipment would be ready to start drilling in 2-3 days upon arrival to the site. The IBED drill can drill in firn, ice, debris-containing ice and bedrock by changing different module that permits the accomplishment of three different tasks: (1) augering in the upper snow–firn layers with three sequential reamings for casing installation; (2) coring in solid and debris-containing ice with near-bottom fluid circulation; and (3) bedrock-core drilling using teeth diamond bit and standard core barrel from conventional diamond drill string. IBED was firstly tested in the lab, and during 2018-2019 season the whole ASDR was assembled and tested just outside Zhongshan Station near Antarctic coast. As a result, a 7-cm length of rock core with 41.5-mm in diameter was recovered from the bottom of 198-m deep borehole.

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Session Classification: Session 4

Contribution ID: **4** Type: **Poster**

Multifunctional logger with microelectromechanical measuring systems for logging of the deep boreholes in Antarctic and Greenland ice sheets

Monday, 30 September 2019 17:00 (4 minutes)

We present the main aspects of the design, development and application of the multifunctional borehole logger for geophysical monitoring (temperature, pressure, axis incline angle and radius of borehole cross sections) of ice boreholes. The logger was designed to use in the central region of the East Antarctica in the areas of Dome A at the Kunlun station (China) and Lake Vostok at the Vostok station (Russia).

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Presenter: Prof. TALALAY, Pavel

Session Classification: Session 2

Contribution ID: **5** Type: **Poster**

Core handling for the South Pole ice core (SPICEcore) project

Monday, 30 September 2019 17:28 (4 minutes)

The stable isotope, aerosol, and atmospheric gas records in ice cores provide exceptional archives of past climate. Supported by the U.S. National Science Foundation (Office of Polar Programs – Antarctic Glaciology), a new 1,750-meter long ice core (~54,000 years in age) was recovered from South Pole, Antarctica, during the 2014-2015 (0 to 736 m) and 2015-2016 (736 to 1750 m) field seasons using the new U.S. Intermediate Depth Drill. Ice from the brittle ice zone was left at the site to relax. A third field season was required to pack and ship the brittle ice from the second field season back to US, although in hindsight the ice was not brittle. Very few measurements were performed on the ice in the field. The primary goal of the on-site core handling was to remove as much of the Estisol-140 drill fluid from the core as possible, assign a precise depth to the ice, and safely prepare the ice for transport back to the National Science Foundation –Ice Core Facility in Denver, Colorado, USA, for subsequent intensive processing and sampling. This presentation provides an overview of the core handling operation for the SPICEcore project.

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Session Classification: Session 2

Contribution ID: **7** Type: **Poster**

Concept and testing of hot-water coring system with PDM-motor drive

Monday, 30 September 2019 17:52 (4 minutes)

Hot water drilling technology is prominent in many kinds of polar investigations due to its environment-friendly medium and fast drilling speeds. However, its disadvantage is that it cannot directly obtain ice and bedrock cores. To sample cores from specific intervals, we propose to replace the bottom nozzle with PDM-motor + drill tools that can be directly driven through hot water flow to rotate the drill bit. The ice/bedrock cores can be obtained by installation of the different drill bits according to the type of formation. The PDM motor was chosen by estimating of the temperature difference and pressure loss of hot water from the surface to the bottom. Double-wall core barrel produces high flow resistance. Thus, according to flow field analysis, to ensure the quality of the ice cores, outlet flow rate should be controlled within 90 L/min. Testing was done under different flows and different temperature conditions: drilling speed increased with the increase of temperature and flow. Maximum drilling speed reached 7 m/h. The core recovery was about 80 %, and the diameter of cores/bit diameter ratio was over 80 %.

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Session Classification: Session 2

Contribution ID: **8** Type: **Oral**

ROV-mountable underwater thermal corer: General concept

Monday, 30 September 2019 14:20 (20 minutes)

Ice freezing and thawing process beneath the Antarctic ice shelves is related to climate changing and studies of ice layers at the ice shelves bottom will facilitate further analysis of the interactions between the ice sheet and the ocean. Upwards thermal coring mechanism for using beneath ice shelves equipped with underwater automatically operated system is proposed. The formation mechanism of the bottom ice layers will be deduced by simulating deep ocean environment conditions and comparing them with the real ice structure. Sampling of the bottom part of ice shelves will enable scientists to make extensive measurements of the physical characteristics of different ice layers. The numerical simulation of ice drilling process has been carried out to study the influence of drilling load, power, ice properties, material and structure of drill bit on the drilling speed and borehole/core structure that allows to optimize the technological drilling parameters. The simulation results of the influence of various parameters on the drilling speed and ice core quality is planned to verify by the testing of upwards thermal coring drill.

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Session Classification: Session 2

Contribution ID: **9** Type: **Oral**

Vibrocorer for Sampling of Subglacial Sediments in Antarctica

Wednesday, 2 October 2019 11:00 (20 minutes)

Core sampling from beneath Antarctic subglacial environments offers unique opportunities for examining processes acting of overlying ice. Basal aquatic sediment materials contain important paleo-climatic and paleo-environmental records even more than ice cores, provide unique habitat for life, give significant interactive information between ice bottom, subglacial hydraulic system and the sediments. Sediment coring tools need to pass through the hot-water access borehole and water column before the coring processes, therefore, the corer radial size and its coring ability become the two key points. Several projects have already obtained good cores from Antarctic subglacial environments, but the core lengths were quite short, generally in a 0.1-2 m range. Vibrocoring is a simple and efficient technique for obtaining high–quality long sediment core samples in a variety of configurations and sizes, however, vibrocorers used in deep ocean waters unable to be deployed to subglacial environments due to their oversized vibro-heads that cannot pass through the access borehole. We proposed a vibrocorer built especially for subglacial sediment sampling settings. Techniques, materials and core operation methods are designed on the base of the clean access requirements. An innovative cylindrical vertical vibration system was developed and tested in experimental well with simulated subglacial sediments. The vibrocorer is planned to be used in Antarctica in 2019-2020 season.

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Session Classification: Session 5

Contribution ID: **10** Type: **Oral**

RECAS autonomous thermal sonde for subglacial lakes exploration

Wednesday, 2 October 2019 10:40 (20 minutes)

To date, more than 400 relatively small subglacial reservoirs and several large lakes were discovered in Antarctica. Certainly subglacial lakes exist in Greenland. In recent years, different approaches were taken to access and directly sample subglacial water environments. RECoverable Autonomous Sonde (RECAS) allows to access subglacial lake when water remains isolated from the modern ice sheet surface during sampling. The thermal drill can melt a hole to ice sheet bottom and is able to move upwards. It includes two electrically powered thermal drill bits located at the upper and lower ends of the sonde, heated body, control system, sampling chamber and coiling system. All downhole RECAS components will be sterilized prior to deployment. The melted water is not recovered from the hole and it refreezes behind the sonde. The power and signal line is released from the coil inside the sonde. When sampling and monitoring are complete, the coil motor is activated and the top drill bit is powered. It is proposed that the research personnel leave the site after RECAS deployment and the sonde operates as a fully autonomous system. The power is provided by no-live-operator diesel engine generators. The first laboratory tests of the sonde subsystems were carried out during 2018 and prototype tests are scheduled on the summer of 2019. Field tests are planned in season 2019-2020, in the vicinity of the Chinese Antarctic research Zhongshan Station.

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Session Classification: Session 5

Contribution ID: **11** Type: **Oral**

A New Smart System of Rapid Continuous Coring Drilling with Air Reverse Circulation in Antarctica

Tuesday, 1 October 2019 16:00 (20 minutes)

Rapid ice coring is one of the most important means of the polar scientific research, which is of great significance for research of earth system science. However, rapid ice core drilling technology and equipment is a bottleneck of the polar scientific research under the polar extremely harsh and cruel work condition. The conventional polar ice core drilling equipment work effectively in a short time (effective working time is only about 20 days to estivate at Kunlun Station at Dome A, East Antarctica, and effective working time is less than two months to pass the summer at Zhongshan Station) to drill in the ice at an average drilling speed of 20~30 m per day, then a month maximum drilling depth is about 500 m of ice. Through making a breakthrough in the key technology, a set of ice drilling equipment is researched and developed for rapid continuous coring drilling with air reverse circulation in the polar ice to a depth of 500-800 m in Antarctica at drilling speed of 30-50 m/h within 3-5 days, including a set of drill pipe automatic quick connect system, ice core automatic discharge and collect system, along with high integration, lightweight, automation and intelligence. This equipment mainly includes rapid and continuous ice-coring drilling tools with full-hole air reverse circulation, the fast drilling system on the surface of the ground, automation system of quickly adding drilling pipe and ice core collection, transmission and emission system, etc.

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Session Classification: Session 4

Contribution ID: **12** Type: **Oral**

Vertical stabilization and drilling trajectory of RECAS-200 thermal sonde

Monday, 30 September 2019 15:40 (20 minutes)

The subglacial aquatic environment may provide unique information about microbial evolution and the Earth's climate in the past. The prototype model of RECoverable Autonomous Sonde (RECAS-200) could penetrate through ice to the depth of 200 m by melting ice with thermal drill bit, then take water sample and detect the physical parameters (temperature, pressure, conductivity and pH) of subglacial water. RECAS-200 thermal sonde includes a cable that bear the weight of the sonde and is used for steering in such way that the weight of the sonde is partially compensated by the cable's tension and is partially transmitted to the bottom. The verticality of RECAS-200 during penetrating is necessary for ensuring the verticality of borehole and preventing sticking of the sonde in the crooked hole. The influence of the center of gravity position, the presence or absence of cable in the sonde, the diameter and inclination of borehole on the force diagram is discussed. According to the required vertical load on the thermal bit, the permissible range of hanging force is determined. Using the principle of virtual displacement, the drilling trajectory of RECAS-200 is predicted based on inclination of borehole, the sonde inclination and force diagram. The minimum crooking radius of borehole to ensure the passability of the sonde is also calculated. The influence of rate of penetration and freezing speed of meltwater on the verticality and drilling trajectory of RECAS-200 is analyzed in order to choose safety drilling parameters.

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Session Classification: Session 2

Contribution ID: **14** Type: **Oral**

Scientific Drilling in Subglacial Environments: Results from Recent Drilling Endeavors and New Drill Development Needs

Urgent scientific questions regarding rate and amount of sea level rise from the Antarctic and Greenland Ice Sheets, and exploration of fundamental subglacial geological and biological aspects of both ice sheets have created demand for drills and drilling technologies for retrieving subglacial rock cores and samples from aqueous subglacial environments. New drilling technologies recently developed for use in subglacial environments have enabled scientific discoveries from bedrock and water-rich environments; in this paper we discuss the scientific goals and drilling outcomes from recent drilling programs for retrieving subglacial rock cores or creating access holes through ice. Scientific goals from recent long-range science planning are presented and the associated need for new drills to enable new science is discussed.

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Presenter: Dr ALBERT, Mary (Dartmouth)

Session Classification: Session 5

Contribution ID: **15** Type: **Oral**

The development of portable hot-point drill and measurement of 10-m depth snow temperature at Zhongshan Station –Dome A profile

Monday, 30 September 2019 16:20 (20 minutes)

Snow temperature at 10 m depth in ice sheets and ice caps represents the local average annual temperature. Up to now, in Antarctica, a fair number of long-term observations of temperature and 10 m snow temperature have been made. However, only a handful of measurements have been taken at the eastern part of East Antarctica. In order to obtain the snow temperature data at Zhongshan Station –Dome A area, the method of "electrothermal drilling –temperature measurement by temperature chain –temperature chain recovery and reuse" was adopted to determine temperature distribution in snow at several locations of the studied area. A portable hot-point drill with high efficiency has been designed. During the 35th Chinese National Antarctic Expedition (2018-2019), this system was successfully used to drill more than 20 holes along Zhongshan Station –Dome A profile at the camping time of the snow-vehicle traverse on their way to and from Dome A. The temperature of snow at 16 sites was measured to the depth of 12-15 m (in most cases) and once to the depth of 50 m at Dome A. To some extent, these temperature data can reflect the spatial and temporal distribution characteristics of snow temperature at inland of East Antarctica, thus providing valuable basic research data for further explaining how the Antarctic ice sheet, as the largest cold source in the world, affects the global climate system and global warming.

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Session Classification: Session 2

Contribution ID: **16** Type: **Poster**

Temperature distribution in ice around thermally drilled borehole

Monday, 30 September 2019 17:20 (4 minutes)

As one of the effective methods of rapid ice drill, thermal drilling is widely used to study ice sheets and glaciers. After drilling, the refreezing of the meltwater in the borehole is the key factor hindering down-the-hole observations. The temperature distribution in ice around thermally drilled borehole has a direct impact on the closure rate of the borehole. In order to determine the temperature distribution around the borehole and the ice boundary affected by the thermal drilling, a temperature field detection testing stand using hot-point drill with constant bit load was designed. The temperature distribution around the borehole during hot-point drilling process and the closure process in ice with temperature in the range from -10 to -30 ℃ were measured. The borehole was drilled by different diameters drill bits with 1-2 kW power. The results showed that the distance from the temperature changing boundary to the borehole is about 2-3 times of the borehole radius during thermal drilling, and after drilling, the influence of melting water on the temperature changing boundary is about 10 times of the ice hole radius.

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Session Classification: Session 2

Contribution ID: **17** Type: **Oral**

Optimization of Drill Head Structure and Drilling Parameters of Hot-Water Ice-Coring Drill

Monday, 30 September 2019 11:00 (20 minutes)

How to acquire good quality of ice cores is becoming an increasingly key influence factor due to abundant information of climatic variation in intact ice cores. Compared with the conventional ice coring drill such as armored cable electro-mechanical drill, hot-water ice-coring drill has its unique advantages: drilling rapidly and environment friendly. The hot-water ice-coring drill is used combination with normal hot-water drilling system and can be utilized to get ice cores at some depth of ice layer in accordance with requirement of research. The annular drill head of this drill is the most critical part of the drilling system, on which there are a lot of small nozzles used to spray water out and melt out a cylindrical ice. Penetration rate and coring effect of hot-water ice-core drilling not only depends on the structure of nozzle, mainly including its angle, diameter and quantity, but also depends on drilling process parameters, such as temperature, pressure and flow rate of supplied hot water. To understand well about what factors strongly affect drilling speed and quality of ice core, a hot-water ice-coring drill is proposed, with the drill head being able to be replaced to get different structure of the nozzle, to make an orthogonal experiment, using different flow rate and temperature of hot water. There are 10 drill heads with different structures of nozzle designed and manufactured for orthogonal experiment. The drilling schedule parameters of hot-water ice-coring drilling test were chosen with flow rate 45-160 L/min and temperature 50-70 ℃. Tests were performed in the ice drill testing facility of Polar Research Center at Jilin University.

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Session Classification: Session 1

Contribution ID: **18** Type: **Poster**

Self-contained and portable thermal ice drilling system

Tuesday, 1 October 2019 18:00 (4 minutes)

To this day, there exists a technology gap for drilling to intermediate depth between 30 and 100m. While conventional, manual operated augers are increasingly cumbersome to operate at greater depth, deploying a full sized mechanical rig or a hot water drill is often not feasible for more shallow ice regions due to budget and logistic restraints.
We present a lightweight and self-contained thermal ice drilling system capable of drilling a 60cm hole up to a depth of 100m at a rate of 3.5m/h. It consists of a surface station with an integrated generator, servo winch and control system as well as the melting probe with pendulum stabilization. With a footprint of 105 x 65cm and weight of 120kg, it can be easily transported via snow mobile, helicopter or plane.
After initial setup, the system performs the drilling without supervision and retracts once it reaches the set target depth. When drilling into cold ice, reaming cycles can be performed to keep the borehole open.
We present the development and its technical challenges as well as the operations at the Langenferner Glacier in the Italian Alps where we deployed two thermistor strings and data loggers. In addition, we discuss the possibilities to integrate in-situ sensors into the melting probe for salinity and temperature profiling during drilling.

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Session Classification: Session 4

Contribution ID: **19** Type: **Oral**

EnEx-RANGE: A network of thermal drills for glacial exploration

Monday, 30 September 2019 16:40 (20 minutes)

The access to sub glacial regions gains interest in terrestrial and extraterrestrial research in the past years. In Antarctica lakes or other interesting sub glacial features have been accessed via mechanical (coring and non-coring), hot water or thermal drilling. Still the most of these areas are unexplored because of the lack of rapid access drills. The discovery of liquid water below the Martian ice caps and oceans within icy moons of the outer solar system are boosting the interest for drills that work in extraterrestrial scenarios. The required autonomous operation can be provided by thermal melting probes.

Within the scope of the EnEx-RANGE project a network of thermal melting probes has been developed. Thirteen melting probes have been built and tested for autonomous operation and exploration of a glacial area. Each melting probes has a diameter of 8 cm and a length of about 1 m and achieves melting velocity up to 8 m/h. The positioning of the probes within the network is mostly based on acoustic signals which are exchanged between the probes over distances of several tens of meters. The network provides a reference for the positioning and navigation for robotic navigation within the reference volume. The tests were conducted on several glaciers in the European Alps (Hintereisferner 2015, Langenferner 2016/17/18 and Mittelbergferner 2019) and in Antarctica (Ross Ice Shelf 2016/18).

In this talk we present the EnEx-RANGE melting probe design, the navigation systems and results from the in-ice tests.

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Session Classification: Session 2

Contribution ID: **20** Type: **Oral**

Preliminary Studies on Melting Cutting and Coring Ice by Using Laser for Ice Drilling

Thursday, 3 October 2019 15:40 (20 minutes)

Comparing with conventional ice core drilling method, laser ice drilling falls in the category of a new clean drilling technology involving innovative kind of non-mechanical physical ice destruction . High energy laser beam is applied to the surface of ice directly, and the ice is heated and melted rapidly. Laser drilling technology has been developed promptly by virtue of high penetration speed and efficiency, low costing, high security, and low pollution. A preliminary design of method and instrument for ice core drilling using laser has been developed. The instrument is comprised of laser cutting unit, electric rotation unit, and melt water processing unit. Laser unit acts a part of laser generation and laser transmitting. Laser beam is emitted through laser head, the electric rotation unit drives the drill bit which laser head assembled on rotate, to melt the ice and produce the core, meanwhile. Melt water is the main obstacle for laser drilling, because of the reduction of energy transmitting. A melt water processing unit has been designed to remove the water at the bottom by using a centrifugal pump which is driven by motor with lower reduction ratio. As a result, laser beam can be applied to ice surface directly. The penetration rate will be improved then. The first laboratory tests of the laser drill components are scheduled for 2019-2020.

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Session Classification: Session 7

Contribution ID: **21** Type: **Poster**

High-technology reels and hoses for deep hot-water drilling in ice

Tuesday, 1 October 2019 17:20 (4 minutes)

The hot-water deep-drilling project at Amery Ice Shelf, East Antarctica, employs a multidisciplinary approach to the study of the region. It has been planned to drill 10–12 holes from the edge of the ice shelf to the grounding zone up to a depth of 2100 m at intervals of nearly 50 km. All equipment are installed in 20 standard shipping containers and will be transported from site to site using tracked vehicles. The main reel has an electromechanical drive system and holds a 2200-m-long single-length hose. The maximum hose lifting/lowering rate at full winding on the drum is 30 m/min, and drilling rate can be controlled in the range of 0–120 m/h. The main hose (ID/OD: 38/60.5 mm) with a Thermoelastoplast outer jacket has incorporated 8 × 1 mm2 electrical signal lines for communication with the downhole drill nozzle. A return winch with hose was designed for pumping water out from the subsurface reservoir with maximum depth of 250 m. The return hose (ID/OD: 38/70 mm) has Thermoelastoplast water channel and outer cladding. The hose is reinforced by Kevlar lines and has incorporated power lines to provide electric supply 6 × 16 mm2, signal lines 8 × 1 mm2 and four heating copper lines. The general concept of this hot-water drilling system was tested at an experimental site of Jilin University in Changchun, Northeast China.

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Session Classification: Session 4

Contribution ID: **22** Type: **Oral**

Near-face temperature at the Taishan station, East Antarctic ice sheet

Accurate and reliable near-surface temperature is a critical input factor in ice model for assessing the mass and energy balance of polar ice sheet. Using a 10m temperature chain installed at Taishan station during the 2015/2016 Chinese Antarctic Research Expedition, a vertical profile of the high-precision near-surface snow temperature spaced at 0.1 m was obtained. The temperature dataset is continuous for 20 months. To assess the influence of heat transfer processes of the near-surface snow and ice, we analysis the daily, monthly and seasonal variations of the near-surface snow temperatures, and compare the measurements with a thermal model of the ice sheet. The results showed that the amplitude of snow temperature fluctuation decreases with depth, and the peak and trough of temperature fluctuation in phase lags more than 100 days when conducting downward from surface to 10 m depth. The 10 m snow temperature is close to the mean annual air temperature, and the near-surface snow temperature is anomalously warmed by 1℃ than the estimated near-surface air temperature from the ground temperature inversion in the plateau area. Modelling experiments presented that the observed snow temperatures at different depths are good agreement with simulated results. The temperature profiles in winter and summer or spring and autumn are opposite but not completely symmetrical, and imply the regional characteristics of "short summer, long winter".

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Session Classification: Session 6

Contribution ID: **23** Type: **Oral**

New capability to recover intermediate depth cores from the sea floor beneath floating ice platforms

Wednesday, 2 October 2019 11:20 (20 minutes)

Abstract
Much of the direct geological evidence for the instability of Antarctica's ice sheets and shelves in past warmer climate regimes is now hidden beneath thick floating and grounded ice. The ANDRILL project showed the scientific rewards of deep geological drilling through the Ross Ice shelf, but was on a logistical (>250 tonnes of equipment) and financial (USD30M) scale that is not sustainable on a year-by-year basis by most national Antarctic programmes. In contrast, deployment of short gravity and piston corers requires less resources but they are unlikely to penetrate sediments more than few metres thick and likely no older than the Last Glacial Maximum.
The new capability described below is intended to provide a drilling capability that can recover core from depths of 100 –200 m below the sea floor, or beneath a grounded ice sheet, with a footprint that is logistically supportable by many Antarctic national programmes. The system is designed to be integrated with an existing hot water drilling (HWD) system that can penetrate 1000 m thick ice.
Minerals industry-based coring technology has recovered high quality core from sea floor sediments during several inshore Antarctic drilling operations since 1975. Wireline tools have been developed and improved since then to allow good recovery of core from a range of settings. These include hydraulic piston coring for soft sediments and rotary diamond coring for indurated rock. However, the challenge is to make a system sufficiently light and compact that it can be operated by a small rig integrated with our current HWD infrastructure but still recover a scientifically useful length of core. A small rig has limited pull back and this is a limiting factor for the length of drill pipe and casing that can be deployed. Therefore, we propose to use an ice and sea riser that combines light weight Glass Reinforced Epoxy (GRE) casing with thin walled steel casing. This will reduce system weight, enabling us to use a smaller rig and greatly reducing operational costs. Stress analysis of the GRE casing has been carried out for several drilling scenarios with differing ocean current flows, water depth and ice shelf (the drilling platform) thickness and movement. The results show the concept is feasible, within the limits of the rig and environmental site parameters. The projected limits to coring depth below sea floor and core diameter are constrained by:
• Maintaining an open hole through shelf ice will require proportionally more time and resources to be committed to hot water drilling as the ice shelf thickens. Ultimately this will limit the amount of time the rock drill is able to utilise the hole and thus time for sea floor coring.
• Even with lightweight casing and drill pipe, the "pull back"capability of the drill rig will ultimately limit the length of drill string that can be used for coring.

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Session Classification: Session 5

Contribution ID: **24** Type: **Oral**

Drilling the new 5G-5 branch hole at Vostok Station for collecting a replicate core of old meteoric ice

Tuesday, 1 October 2019 09:00 (20 minutes)

Recent studies have shown that stratigraphically disturbed meteoric ice bedded at Vostok Station between 3318 and 3538 m dates back to 1.2 Ma BP, and possibly beyond (Lipenkov et al., 2019). As part of the VOICE (Vostok Oldest Ice Challenge) initiative, in the 2018/19 austral season, a new deviation from parent hole 5G-1 was made at depths of 3266-3291 m with the aim of obtaining a replicate core of the old ice. The deviation operation was performed using the standard KEMS-132 electromechanical drill routinely used for deep ice coring at Vostok, without significant changes in its initial design. Here we describe the method and operating procedures for replicate coring at a targeted depth in an existing slant hole, which imply using a cable-suspended electromechanical drill. A design of the drill cutter head suited to the deviation operation is presented. The performance characteristics and the experience of drilling two branch holes, 5G-2 and 5G-5, at Vostok are described and discussed.

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Session Classification: Session 3

Contribution ID: **25** Type: **Oral**

Design and analysis of a hydraulic tension sensor for ice drill and deep water applications

Thursday, 3 October 2019 14:20 (20 minutes)

Monitoring the tension in cables is significant in some ice drill and deep water applications. Take our RECoverable Autonomous Sonde (RECAS) for example. It is able to melt a hole to ice sheet bottom and is able to move upwards. A winch is installed inside RECAS to release and recover the cable, whose tension needs to be monitored in real time in order to control the behavior of the winch. As far as we are concerned, there aren't any commercial tension sensors that are able to fulfill such tasks as the cable is surrounded by deep water. Traditional tension sensors are mostly made of strain gages, which are not suitable for deep water applications as the pressure will disable the normal deformation of the gage. In this paper, a newly designed deep water tension sensor is proposed. The tension on the cable is transmitted through a hydraulic system to a pressure sensor (the theoretical schematic diagram is attached to this abstract). The effect of high pressure in deep water can be minimized by subtracting the environment pressure measured by another pressure sensor. In addition, in order to fit the narrow space in ice holes, the tension sensor is designed to be compact while its measuring range reaches up to 1000kg. Detailed force transmission and media characteristic analysis are carried out. The calibration platform, together with the calibration method is introduced. The tension sensor is tested in high pressure and low temperature environments and its accuracy is proved to be fairly good.

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Session Classification: Session 7

Contribution ID: **26** Type: **Oral**

HOTROD: Prototype melt-tip for rapid ice-sheet drilling

Monday, 30 September 2019 16:00 (20 minutes)

HOTROD is a prototype melt-tip drill for rapid sampling of ice-sheet temperatures. The relatively low-cost melt-tip, which has thermistors embedded along its integrated tether cable, is intended for single-use deployment. This means the melt-tip is not recovered following insertion of the temperature sensors. The main shaft of HOTROD is 120 cm in length and 5 cm in diameter. Forward heating elements, embedded in a 60° copper cone forming the melt-tip nose, draw 5 KW of power. Analogous 5 KW aft heating elements, embedded in a copper flange, protrude 0.75 mm from the main shaft. This aft flange yields a minimum borehole diameter of 6.5 cm. Lateral heating, via a lower wattage (< 1 KW) coiled heating braid, prevents freeze-in of the main shaft. Real-time monitoring of embedded thermocouples allows the forward and aft primary heating elements to be alternatively powered, by a single 5 KW power source. This offers the potential to avoid both freeze-in and overheating. Assuming a heat-transfer efficiency of 40 % between the melt-tip and the surrounding ice, we anticipate penetration rates of between 5 and 10 m/hr in pure ice, depending on effective borehole diameter and heating element performance. For relatively easy deployment, the entire HOTROD apparatus, including a 6.4 KW generator with 21-day gasoline supply, weighs < 600 kg. Initial ice-sheet testing of HOTROD will take place in May 2020 in West Greenland. Our minimum goal is to re-measure the 125 m deep temperature profile initially measured at Camp VI (69.70°N, 48.27°W, 1595 m) in 1950. Our maximum goal is to achieve a drill depth of 500 m. Open-design development of the HOTROD melt-tip by the Geological Survey of Denmark and Greenland is funded by the Villum Foundation.

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Session Classification: Session 2

Contribution ID: **27** Type: **Oral**

Shallow ice core drillings at South East Dome, Greenland in 2015 and 2020.

Tuesday, 1 October 2019 15:40 (20 minutes)

We conducted a 90.45 m ice core drilling in a high accumulation area of the southeastern Greenland Ice Sheet in 2015. The drilling site (SE-Dome; 67.81°N, 36.37°W, 3170m a.s.l.) is located 185km north of the Tasiilaq. We used a helicopter, Bell 212 for transportation. Two and two flights of Bell 212 were required to fly in and out SE-Dome. We used a light weight of electromechanical drill developed in Hokkaido Univ. In 2020, we are going to drill a 300 m ice core in SE-Dome to assemble a database of aerosol deposition for 250 years. Logistics of ice drilling in 2015 and a plan of next drilling in are presented in this paper.

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Session Classification: Session 4

Contribution ID: **28** Type: **Poster**

Ice core drilling complications: shallow dry hole electromechanical ice coring.

Tuesday, 1 October 2019 17:44 (4 minutes)

Most of complications during ice coring related to: 1) selection of a drilling technology, drilling protocol, and operators mistake 2) selection of drilling site and time of the year, 3) drill performance at specific conditions 4) unforeseen drilling conditions, 5) drilling system malfunction.
Presented materials describe problems that were observed during dry borehole (BH) shallow depth (<300 m) ice core drilling of polar, temperate and polythermal glaciers. Some of the problems took place upon drilling ice loaded with dust and pebbles. Most of complications related to drilling at relatively high temperatures and operation of drill at above the melting point air temperature.
Major subjects of the presentation:
- organization of an ice coring operation,
- penetration protocol, penetration problems,
- borehole vertical stability,
- kerf cleanup,
- causes of a drill stuck, dry and fluid unstuck techniques,
- borehole closure and borehole reaming,
- slipping antitorque,
- hard core break.

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Session Classification: Session 4

Contribution ID: **29** Type: **Poster**

High resolution in situ density profiling of snow-firn-ice sequences.

Monday, 30 September 2019 17:04 (4 minutes)

Most of density quantification methods require a sample, its preparation and few measurements. Procedures are laborious, slow and time consuming. Due to vertical and horizontal density variations a single vertical density profile has significant uncertainty. Multiple profiling allows increase precision of mass balance measurements. Field and laboratory measurements show that melting-penetration rate of the HP is proportional to density of a porous or solid ice formations. Continuous and high depth resolution density profiling of snow-firn-ice sequences (SFIS) was conducted with a low power, non-coring thermal-electric drill - hot point (HP) and electronic interface that registered penetration rate The penetration rate of the HP drill converts to density instantiations. Average rate of vertical profiling with the HP is above 10 m h-1. Resolution of density measurements using HP is about 5% of its value and vertical resolution can be as high as a few millimeters. We present calorimetric method for fast, continuous, in situ density profiling of a SFIS and application results obtained in Polar Ural, Svalbard, Greenland and Elbrus glaciers.

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Session Classification: Session 2

Contribution ID: **30** Type: **Oral**

Shallow depth lightweight ice coring: progress and new developments.

Thursday, 3 October 2019 09:00 (20 minutes)

Since 1975 about dozen of dry hole electromechanical (EM) ice coring drills were developed. Most of the drills were used in polar regions and a few in polar and high altitude glaciers ice coring operations. Main differences between ice coring operations in polar regions and in high altitude glaciers are: logistics, air and ice temperatures, particles concentration in ice and physical capacities of the drilling team. Therefore, the major requirements for drilling equipment for operations at high altitude are lightweight, low power and high ice core production rate (ICPR).
About 5500 m of ice cores were obtained with the EM drill developed at Byrd Polar Climate Research Center at the Ohio State University. The drill demonstrate capability to reach 310 m depth in dry borehole at average 4.8 m/h production drilling rate. The drill was successfully used in polar and temperate glaciers.
The next development step is the Ultralight ice coring system (ULICS) for most logistically difficult operations in high altitude glaciers. ULICS weight less than 30 kg including power source and capable to reach 200 m depth. It includes thermal (42 mm core) and dry hole EM drills (75 mm core).

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Session Classification: Session 6

Contribution ID: **31** Type: **Oral**

Rapid intermediate depth ice sampling with electromechanical coring drill.

Thursday, 3 October 2019 09:20 (20 minutes)

High production rate ice coring systems allow for fast ice sampling in intermediate depths. Several ice coring operations in Greenland and Antarctica ice sheets and in high altitude glaciers demonstrate ability of the dry hole electromechanical (EM) ice coring drills rich depth of a few hundred meters in a short time. The highest average production drilling rate (aPDR) of 4.79 m/h in 310 m deep borehole (BH) was achieved in Guliya glacier (Tibet, 2015). Depending on drilling conditions decent and acceptable quality ice cores were obtained down to 140-180 m depth. In Guliya BH at least one 0.1-0.3 m long section of the ice core was obtained down to 310 m. The rest of 0.8-1.1 m long samples was presented by irregular shape ice chunks. In polar glaciers below 100-140 m samples mainly composed of 3-10 mm thick disks.
Modification of drilling protocol of the BPRC EM drill allows reduction of surface time for 40%. Then aPDR at 300 m depth will be close to 7 m/h while in 600 m deep BH the aPDR is about 6.5 m/h. Ice sampling with EM coring drill down to 1000 m possible with hoist system modifications, 20 h/day operation in ice temperatures below -40C. The major limitation of the dry hole drilling is rheological BH closure. Estimates shows that at -55C ice temperature depth of 600 m can be reached in 93 h without BH reaming. Sampling down to 1000 m will require 2-3 reaming (total about 8 h) and total 170 h operation.

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Session Classification: Session 6

Contribution ID: **32** Type: **Oral**

Glacial-bedrock interface drilling and sampling

Monday, 30 September 2019 13:20 (20 minutes)

Since 1957-58 IGY only few penetrations through glacial ice-bedrock interface took place. Essential progress in ice drilling and new scientific goals stimulate development of drilling and sampling technique of rock-imbedded ice and sub-glacial bedrock. There are two objectives: 1) penetrate through natural obstacle and continue ice coring and 2) sampling of glacier-bedrock interface materials. Considering ice coring operation the penetration through the obstacle requires drilling of the same diameter borehole as in above glacier ice. The glacial interface sampling in limited depth interval can be achieved by smaller diameter drilling instrument compared to an ice coring drill. Industrial drilling provides essential information about rock drilling to determine torque, specific pressure on the bit, cutting speed and parameters of the kerf flushing. At the same time, industrial drilling currently do not operate with cable suspended drills. Therefore, specific knowledge and new sub-glacial drilling technique development are also required. Here we present summary of our laboratory drilling experiments of ice-rock composites and granite samples. The last was done by standard industrial drill bits and thin 127 mm outer diameter coring drill bit. In addition, we discuss concept of cable suspended lightweight drill for rock and ice-rock composites drilling-sampling system. The system can use conventional ice coring superstructure and power system.

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Session Classification: Session 2

Contribution ID: **33** Type: **Oral**

Drill system for the third deep ice coring project around Dome Fuji, Antarctica

Tuesday, 1 October 2019 14:00 (20 minutes)

The second deep ice coring project at Dome Fuji, Antarctica reached a depth of 3035.22 m on 26 January 2007. The age of the ice core bottom was 720,000 years.
In response to IPICS 'OLDEST ICE', the third deep ice coring project is underway to obtain ice cores older than 800,000 years. We are currently developing and producing a new deep drill system. Various problems that were encountered in the 2nd drilling operation have been resolved, but there were no major design changes in the machine itself. The JARE drill features a simple design that has an ice chip transport mechanism with an Archimedean pump and a booster, a chip chamber with many small holes for stable cutting/screening, and an adverse current prevention system of chips during drill ascent. We will report separately on communication and control systems between the surface and the drill as development progresses. The drilling fluids examined were silicone oil and butyl acetate. At Dome Fuji, the temperature dips to lows of −50 ℃ even at a depths of 600 m. Since kinematic viscosity of silicone oil is about 3 times larger than butyl acetate at such low temperature and expensive, butyl acetate is preferred. With regard to butyl acetate, there have been concerns about its influence on the human body. However, its composition list posses no serious issues. With experience from the 2nd deep drilling project, it was possible to work comfortably without a mask in temperatures of -15 to -25 ℃ at the drilling site, with strong ventilation and regular cleaning of the drill chip, maintaining an almost dry floor. In addition, there will be an experimental change to the step cutter.

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Session Classification: Session 4

Contribution ID: **34** Type: **Oral**

Basic design for new electronics of the JARE deep drill and testing of the prototype

Thursday, 3 October 2019 09:40 (20 minutes)

The electronics of the JARE deep drill was previously manufactured through outsourcing and its basic design has already spent quarter century. The electronics of the drill should be installed in the pressure chamber. This implies that size of the electronics is restricted as smaller and difficult to manufacture. Therefore, it needs to be customized by incorporating and the required improvements, such as the addition of some sensor devices and revise of software were not so easy after the building.
Recently, small personal computers (PCs) have been commercially available for cheaper prices. In our proposed idea, a small PC was used as a computer in the drill. We also suggested building the electronics of the drill by assembling some commercial devices, such as the PC, specific types of sensors, motor controller, and the required devices for data acquisition and data communication. The proposed electronics of the drill can be customized after development and is cost-effective.
During the design of the proposed electronics, decision of winch cable was necessary since it was employed to provide the electric power supply and data communication. We decide to use same winch cable with previously our use since spare of it is stocked in Antarctica. Type of the winch cable is armoured cable which consist from the outer wires and inner seven conductor cables. The outer wires and five of the conductor cables were used for power supply, while two of the conductor cables were used for data communication. The voltage of the electric power supply was DC200V during the drilling to rotate the motor and DC24V for the electric devices. Therefore we also employed a secondary cell and an electrical relay to manage these two voltage levels.
Commercial devices such as a stick type PC, AD convertor equipped digital input-output, RS485 transmitter-receiver, electrical relay, and secondary cells constitute the basic design of the proposed electronics. A prototype of main part of the drill electronics was made by assembling these devices. Size of this prototype is smaller than 85 mm in diameter. Therefore, it can be inserted into the pressure chamber of the drill. Temporal control software was developed to check the validity of the prototype. The results confirmed that the prototype functions well. Therefore, we proceeded to apply this design concept for the proposed electronics of the JARE deep drill.

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Session Classification: Session 6

Contribution ID: **35** Type: **Oral**

Cable communication through the winch conductor cables for the JARE deep ice core drill - Evaluation of RS485 serial communication using an experiment and a numerical simulation-

Thursday, 3 October 2019 10:40 (20 minutes)

Data communication between the surface and the drill computer is necessary for deep ice core drilling. The contact force, inclination, and temperature of the drill are important for the drilling operation. These values were measured using the sensors in the drill and transmitted to the surface computer through the winch cable. The winch cable, which is 3000 m or more in length for enabling the deep drilling, was used for the data communication. The winch cable was also used for hanging the drill and providing the electric power supply to the motor and the drill electronics. We used the armoured which consists with outer wires and seven conductor cables. Only two of the seven conductor cables were used for data communication, because the cables were mainly used for power supply purposes. To design drill electronics, it is necessary to determine method of data communication.

We considered RS485, which is one of the serial communication interfaces, for achieving data communication, as this interface is simple and widely used in the industry. However, the maximum length of the RS485 communication is 1200 m for industrial applications. Therefore, evaluation of this interface for use in longer winch cables was performed using experiments with winch wires and a numerical simulation of the electric circuit.

In the first experiment, the string characters were transmitted from the transmitter and received by the receiver of the RS485 through a 700 m winch cable on the drum. The matching of the string characters between the transmitter and the receiver was validated by changing the communication speed, baud rate. The string characters matched up to a baud rate of 115200 bps. This baud rate limit was in accordance to that of the RS485 in the industrial applications. At higher baud rates, a non-match was observed in some of the string characters received. Therefore, the transmitted and the received waveforms were monitored using an oscilloscope. The transmitted waveform demonstrated rectangular pulses, while the received one demonstrated some metamorphose at higher baud rates. The received metamorphosed waveform could be expressed using the numerical simulation of an electric circuit with applied voltage pulses at the transmitter. The simulation was performed on the 3000 m cable to estimate the probable upper limit of baud rate to purchase a new winch cable. A new winch cable with a length of 3500 m was used to conduct the testing again. The string characters were sent and received, as the baud rates were changed, and the received waveforms were monitored. It was discovered that the upper limit of the baud rate was 19200 bps and the received waveforms agreed well with our estimation.

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Session Classification: Session 6

Contribution ID: **36** Type: **Oral**

Bench Tests of Mechanical Ice Core Drilling

Thursday, 3 October 2019 14:00 (20 minutes)

Bench tests of core drilling in ice with various filling liquids were performed during the seasonal shift period of the 64th Russian Antarctic Expedition (December 2018 - January 2019) with the use of Borehole 5G drilling facilities. Experimental studies were done using the test bench developed at the St.Petersburg Mining University, that was first applied in 1994 prior to drilling Borehole G5 with the KEMS-132 mechanical drilling assembly. The test drilling was done with kerosene, with a mixture of kerosene and freon, and with organosilicon fluid. The primary objective of these tests was to assess the possibility of end-of-hole flushing and collection of cuttings in a filter unit with organosilicon fluid used as a filling liquid. This fluid is planned to replace the kerosene-and-freon mixture in drilling a new access hole to study Subglacial Lake Vostok.
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Session Classification: Session 7

Contribution ID: **38** Type: **Oral**

Analysis of Challenges Encountered in Deep-Hole Ice Drilling

Tuesday, 1 October 2019 09:20 (20 minutes)

While drilling deep boreholes in Antarctica and Greenland researchers from many countries have faced serious challenges already at the depths over 2500 m, while below 3000 m these complications turned so dramatic that further penetration was almost impossible. This phenomenon was even given its proper name, i.e. 'warm ice drilling issue', as with increasing depth the ice temperature is rising. Ice melting due to cutting was considered as the main reason for this phenomenon. Analysis of 5G Deep Borehole drilling at Vostok Station shows that the main cause of such complications is formation of freon hydrates on the surface of drill cuttings causing their adhesion.
Acknowledgments
The authors are grateful for the logistic support provided by the Russian Antarctic Expedition. This work was conducted with the support of the Russian Foundation of Fundamental Research No. 18-55-16003\18.

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Session Classification: Session 3

Contribution ID: **39** Type: **Oral**

Penetration Technology for Investigation of Subglacial Lake Vostok

Tuesday, 1 October 2019 11:00 (20 minutes)

The results of operations to penetrate into the subglacial lake proved that with the differential pressure of -0.2 MPa, lake water ingresses into the borehole through the annular clearance between the drilling assembly and the borehole walls, rising up to 15 meters above the drilling assembly. While rising through the annular space, the water mixes up with the filling liquid. This creates an emulsion due to freon presence in the borehole, which acts as a surfactant. In order to enhance environmental safety during investigations of Subglacial Lake Vostok, it was decided to drill a new access borehole using organosilicon fluid as the filling liquid. Decreasing the level of water that ingresses into the borehole upon its completion requires that the diameter of the lower section of the borehole is increased at least 2-2.5 times before the penetration into the lake.
Acknowledgments
The authors are grateful for the logistic support provided by the Russian Antarctic Expedition. This work was conducted with the support of the Russian Foundation of Fundamental Research No. 18-55-16003\18.

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Session Classification: Session 3

Contribution ID: **40** Type: **Oral**

EGRIP –a deep ice core drilling camp in Greenland: New concepts and new construction methods.

Tuesday, 1 October 2019 10:40 (20 minutes)

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 have been constructed using snow as the only construction material and balloons to create underground caves. 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.

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Session Classification: Session 3

Contribution ID: **41** Type: **Oral**

Recoverable autonomous thermal sonde for subglacial lakes exploration: electronic control system design

Thursday, 3 October 2019 16:20 (20 minutes)

Recent evidence reveals that a large number of subglacial lakes exist beneath the Antarctic ice sheet. Exploring the subglacial lake is of great interest to the science community. RECoverable Autonomous Sonde (RECAS) will provide an exploration tool to measure and sample the subglacial lake environments while the subglacial lake remains isolated from the glacier surface and atmosphere. This paper presents the electronic control system design of RECAS, which is the key aspect of the sonde.

The electronic control system can be divided into three subsystems: the 'surface system', the 'downhole control system'(DHCS) and the 'power transfer and communication system'(PTCS). The PTCS transfers data and power between the surface and the DHCS via a coaxial cable.

Because the cable is coiled inside the sonde on an electric-motor-powered coil, the size of the cable should be as small as possible. To this end, the power is supplied at 2500 V a.c. and converted to 220 V a.c. by toroidal transformers installed in the probe. Then the 220 V feed is directly provided to the thermal drill bits and the lateral heaters, and converted to low voltage for the on-board electronics and the coil motors. To further minimize the size of the cable, the cable consists only of two power lines. The data is transmitted over the power lines using the power line communication (PLC) technologies.

The core part of the DHCS is a main control board. It has three types of functions: (1) sonde status monitoring; (2) sonde motion control; (3) subglacial water sampling and in-situ analyzing. To monitor the sonde status, the main control board acquires data from sensors which measure conditions such as temperatures of important areas, cable tension, sonde attitude, voltages and currents of the key components, etc. The sonde motion is controlled by regulating the power applied to thermal drill bits and the lateral heaters. Meanwhile, the rotation direction and speed of the coil motor are controlled according to the sonde moving direction and the cable tension, forming a feedback control loop. When the probe enters the subglacial lake, the main control board triggers the water samplers to sample the water, and the sensors to analyze water parameters, such as pH, conductivity, temperature and pressure. In addition, we also have a high-definition video camera to record the underwater environment.

The surface system is a PC-based supervisory control system that communicates with the DHCS, sending control commands and receiving data from the downhole. It also has a data link to an Iridium modem so that a human can monitor or even intervene the sonde remotely.

The laboratory tests have been carried out, which validated the feasibility of the electronic control system. The RECAS prototype tests are scheduled on the summer of 2019.

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Session Classification: Session 7

Contribution ID: **42** Type: **Oral**

Drilling the coldest firn

Thursday, 3 October 2019 13:00 (20 minutes)

The coldest firn on the East Antarctic plateau is the best modern analogue of glacial firn to study firnification and pore close off. In the austral field seasons 2012/13 and 2016/17 a total of six 200 m lang shallow cores were drilled in the area between Kohnen Station, Dome Fuji and the former US Plateau Station. The drill sites cover the temperature range between -45℃ and -60℃ (former US Plateau Station)and the accumulation range between 80 and 20 kg/m3. Two sites were supported by plane and three by overland traverse (OIR traverse). The cores were drilled dry. The core quality was generally excellent down to a depth of 120 m depth. Below 130 m depth fractures along the cores were frequent most likely caused by the too long core catchers designed for drilling in firn. A 200 m core was drilled in a week by a team of 4/5 persons. Presented and discussed are our experiences how to drill shallow ice cores in remote sites on the East Antarctica plateau during the short austral field season by plane and overland traverse support, respectively.

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Presenter: KIPFSTUHL, Sepp (AWI)

Session Classification: Session 7

Contribution ID: **43** Type: **Oral**

Control System Designs for Ice Coring Drills

Thursday, 3 October 2019 13:20 (20 minutes)

The control system for ice coring drills present many design challenges due to the harsh environments in which the components must operate. This is further complicated by the need to send power and communicate over long winch cables with small conductors. An increasing amount of components can be purchased off-the-shelf, however custom electronics are still often required to provide communications and motor control over long winch cables. Modern motor controllers provide precise motor control in a compact and lightweight package, but often introduce electrical noise into the system that must be addressed with proper filtering and cable shielding. This presentation provides an overview of the control systems to be used with the U.S. Ice Drilling Program' s (IDP) new shallow Foro 400 Drill and the in-development deep Foro 3000 Drill.

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Presenter: Mr JOHNSON, Jay (University of Wisconsin-Madison)

Session Classification: Session 7

Contribution ID: **44** Type: **Oral**

Drilling the South Pole Ice Core (SPICEcore)

Tuesday, 1 October 2019 09:40 (20 minutes)

The Intermediate Depth Drill (IDD), designed and built by the Ice Drilling Design and Operations group (now IDP), was used to drill a 1,751 meter deep ice core during the 2014-2015 and 2015-2016 field seasons at the South Pole for the South Pole Ice core (SPICEcore) project. A team of 10 people worked 6 days per week, 24 hours per day, in 3 shifts to recover the 98 mm diameter ice cores, up to 2 meters in length per run. Dry drilling was completed to 160 meters and casing was set to 130 meters. Wet drilling, using Estisol 140 drilling fluid, was performed to the final depth. In this presentation, drilling operations, techniques, performance, and challenges will be discussed.

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Session Classification: Session 3

Contribution ID: **45** Type: **Poster**

4-Inch Drill to Foro 400 Evolution

Monday, 30 September 2019 17:36 (4 minutes)

The 4-Inch Drill, designed and built by the Polar Ice Coring Office (PICO), has long been the work horse of the U.S Ice Drilling Program (IDP) for ice core recovery to 300 meters. While the 4-Inch Drills are still in use, the systems are aging and in need of replacement. To address the continued demand for robust and lightweight shallow ice coring drills, IDP has developed the new Foro 400 Drill. The Foro 400 Drill maintains desirable attributes of the 4-Inch Drill sled and tower design and pairs them with a shorter, 1-meter core length version of the IDP Intermediate Depth Drill (IDD) sonde. This provides for part interchangeability between systems while realizing a 40% weight savings over the 4-Inch Drill system. A newly designed control system provides finer winch control and an improved cable tension and payout display. Along with the drill development, special shipping cases have been designed to reduce weight and improve packing by providing specific storage places for each component.

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Session Classification: Session 2

Contribution ID: **46** Type: **Oral**

Development of the Foro 3000 Deep Ice Core Drill

Tuesday, 1 October 2019 11:20 (20 minutes)

Beginning in program year 2016, Ice Drilling Design and Operations (now IDP) began working with the Ice Drilling Program Office, science community representatives, and the Antarctic Support Contract personnel to conduct an analysis on using the Deep Ice Sheet Coring (DISC) Drill for the next U.S. deep ice coring project versus using an adaptation of the Intermediate Depth Drill (IDD), now referred to as the Foro 3000 Drill. In May 2017, IDP completed a Conceptual Overview document outlining necessary changes to the IDD to enable drilling to 3000 m. The report ultimately helped inform IDPO, NSF, and the science community's decision to move forward with fabrication of the Foro 3000 Drill in advance of the next deep drilling project. Final detailed designs have since been completed and fabrication of the new winch and tower are in process. Design and fabrication of a new down-hole electronics package has also begun. This presentation will discuss the changes being made to the IDD system design to expand its capability to reach 3000 m depth.

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Session Classification: Session 3

Contribution ID: **47** Type: **Poster**

Passive Replicate Coring Concept for Ice Coring Drills

Monday, 30 September 2019 17:24 (4 minutes)

Replicate coring systems (RCS) provide a means for additional core samples with high scientific value to be collected from an existing borehole. Considerable conservation of resources can be realized by the implementation and deployment of core replicating technology which is integrated into an established drilling/coring system. A long range (>3km) core replicating system has been designed and successfully deployed with the Deep Ice-Sheet Coring (DISC) Drill system to retrieve cores at five separate deviation points. The DISC Drill produced 122mm diameter core and the RCS produced 108mm diameter core. This particular RCS provided operators with complete autonomous control of position and inclination for initiating a deviated path including on the uphill side of the parent borehole. Adapting this technology to the Hans Tausen (HT) type drill design with 98mm diameter core, specifically the U.S. Ice Drilling Programs'(IDP) Intermediate Depth Drill (IDD) and the in-development Foro 3000 Drill, is not feasible without completely redesigning the drill systems due to the electronic and mechanical complexity of the technology. Design for a new RCS can realize a relative simplification by allowing deviations at any azimuth. By permitting deviations to be made on the downhill side of a parent borehole, steering capabilities may be excluded.

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Session Classification: Session 2

Contribution ID: **48** Type: **Oral**

Sub-glacial Drilling at Pirrit Hills, Antarctica

Monday, 30 September 2019 11:40 (20 minutes)

The Agile Sub-Ice Geological (ASIG) Drill system was first used at Pirrit Hills, Antarctica during the 2016-2017 field season, when IDDO (Ice Drilling Design & Operations, now IDP) retrieved 8 meters of granite core from under 150 meters of ice. This is the first time that a rock core more than a meter long has been retrieved from beneath glacial ice. A previous borehole was abandoned due to probable hydro-fracture of the surrounding ice near the bedrock surface at approximately 100 meters depth. This presentation describes drill system performance in the field at Pirrit Hills, lessons learned from this experience, and results from some recent analyses of the drilling process.

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Presenter: Mr KUHL, Tanner (University of Wisconsin-Madison)

Session Classification: Session 1

Contribution ID: **49** Type: **Oral**

Rapid Air Movement Drill Upgrade

Tuesday, 1 October 2019 17:00 (20 minutes)

Significant upgrades to the Rapid Air Movement (RAM) Drill were developed and tested in 2018 by the U.S. Ice Drilling Program (IDP) for the U.S. National Science Foundation (NSF). The design of the system leverages the existing infrastructure of the RAM Drill to greatly reduce the logistical burden of deploying the drill while maintaining the ability to drill an access hole in firn and ice to 100m in 20 minutes or less. In this presentation, characteristics of the drill are described, along with a description of the drill performance in the testing at Raven field camp in Greenland.

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Presenter: Mr GIBSON, Christopher (University of Wisconsin-Madison)

Session Classification: Session 4

Contribution ID: **50** Type: **Poster**

Drill Tents

Monday, 30 September 2019 17:32 (4 minutes)

Efficient operation of drill equipment in the field can quickly be thwarted by bad weather. A structure to protect equipment and operators during poor weather conditions can significantly reduce the amount of down time during expeditions. However, structures are often a logistical burden and time consuming to erect. A lightweight tent, designed in collaboration with Fabricon, LLC, was successfully deployed to Antarctica during the 2018-2019 field season with the IDP Blue Ice Drill. The tent, weighing a total of 97 kg, withstood winds of approximately 50 knots. The tent was constructed simultaneously with the drill system and took approximately eight hours to complete. This poster presents details of the structure as well as adaptions to the tent that will allow it to be implemented with many of the U.S Ice Drilling Program's suite of drills.

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Session Classification: Session 2

Contribution ID: **51** Type: **Poster**

IDP Hot Water Drills

Monday, 30 September 2019 17:12 (4 minutes)

The U.S. Ice Drilling Program (IDP) has developed several hot water drills to support U.S. National Science Foundation (NSF) funded research projects. Recent upgrades to the IDP Small Hot Water Drill leverage a design proven in the field for over two decades. The Sediment Laden Lake Ice Drill (SLLID) is designed to be portable over lake ice by just two people and capable of creating access holes through up to 6 meters of silty ice. The IDP has also supported the development of the Hotsy-add-on drill and has created a detailed conceptual design of a Scalable Hot Water (ScHWD) Drill. This poster presents details of both the design of the drills and their performance in the field.

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Session Classification: Session 2

Contribution ID: **52** Type: **Poster**

IDP Rock Coring Drills

Tuesday, 1 October 2019 18:08 (4 minutes)

Two drills capable of coring rock beneath ice have been developed by the U.S. Ice Drilling Program (IDP) for the U.S. National Science Foundation. The design of the systems leverages existing exploration drilling equipment to create drills capable of recovering ice and rock core. The Agile Sub-Ice Geological (ASIG) Drill is capable of collecting ice cores at any target depth and up to 10 meters of rock beneath as much as 700 meters of ice. The IDP Winkie Drill is capable of collecting ice cores at any target depth up to 100 meters and up to 10 meters of rock core. The systems were developed and tested from 2016 through 2019. The new drill systems integrate several new mechanical sub-systems including custom packer and casing systems, fluid filtration systems to remove both ice and rock cuttings, and custom drill bits. The systems were successfully deployed in multiple Antarctic seasons recovering, in total, tens of meters of rock core from depths to approximately 150 meters beneath the ice. This poster presents details of both the design of the drills and their performance in the field.

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Presenter: Mr BOECKMANN, Grant (University of Wisconsin-Madison)

Session Classification: Session 4

Contribution ID: **53** Type: **Poster**

Prototype Ice Well

Monday, 30 September 2019 17:16 (4 minutes)

The U.S. Ice Drilling Program (IDP) has the need to efficiently develop and operate drilling equipment. A prototype ice well has been created at the University of Wisconsin as a significant step in addressing this need. The well provides a column of ice approximately 15m deep and 25cm in diameter at temperatures as low as -20℃. The well provides significant cost savings to the program by providing an efficient facility for testing drill equipment and by minimizing logistical burdens of field testing and training. This poster provides technical details of the system and performance as well as a proposal for future development.

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Presenter: Mr GIBSON, Christopher (University of Wisconsin-Madison)

Session Classification: Session 2

Contribution ID: **54** Type: **Oral**

P-RAID: a bottom-of-the-hole subglacial bedrock sampler

Tuesday, 1 October 2019 13:40 (20 minutes)

The British Antarctic Survey (BAS) Rapid Access Isotope Drill (RAID) is an innovative new class of electromechanical ice drill. Once the bedrock is reached, it can now be fitted with a percussive head (P-RAID) to deliver a bottom-of-the-hole rock sampling capability.

This head uses a local control loop to manage weight-on-bit downhole, with a decoupled rotary-percussive drill mechanism and a passive core retention architecture.

The results of the test programme to date, including an initial Antarctic shakedown, will be outlined, along with our plans for the next drilling and bedrock recovery campaign at Sherman Island.

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Presenter: Mr TIMONEY, Ryan (University of Glasgow)

Session Classification: Session 4

Contribution ID: **55** Type: **Oral**

The Skytrain ice core drilling project

Tuesday, 1 October 2019 11:40 (20 minutes)

In the 2018/19 austral field season, we successful drilled an ice core to bedrock at a depth of 651 m on Skytrain Ice Rise situated at the south of the Ronne Ice Shelf, Antarctica. The team of six (for much of the season) comprised five driller/logger staff, and one person to manage the camp. The full project took place over a single field season, including setting up and tearing down of the camp and drilling infrastructure. Working in shifts of 4 hours in a 16-hour day, the bedrock was reached after 42 days of drilling. This makes it the slowest of our comparable drilling projects (for example the similar depth Fletcher drilling project took 39 days) and the reasons for this are discussed. Drilling took place from the surface using a tilting tower winch mounted on a wooden platform inside a Weatherhaven tent with a slot to accommodate the tower in the upright position. The borehole was fluid filled with a traditional Exxsol D60 fluid, which is lighter than ice density, but sufficient for a single season drilling project. This fluid was largely removed from the borehole at the end of the drilling using a bailing system. The intention was to provide a dry borehole to deploy a new design rock drill to penetrate the basal rock (described in another abstract), then to measure the borehole temperature (also described in another abstract). Problems met during the operation, and solutions, will be discussed.

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Presenter: RIX, Julius (The British Antarctic Survey)

Session Classification: Session 3

Contribution ID: **56** Type: **Oral**

SLUSH: Hybrid electromechanical-thermal drilling system for penetration of Europa ice

Thursday, 3 October 2019 14:40 (20 minutes)

Introduction: Europa is a primary target in the search for past or present life because it is potentially geologically active and likely possesses a deep global ocean in contact with a rocky core underneath its outer ice shell. Theory and observation indicate that the icy surface shell is approximately 3-30 km thick, depending on models [1, 2].
Reaching Europa Ocean: To reach the subsurface ocean, where life may be most prevalent, a probe would need to penetrate the icy formation while moving the excavated material behind it. This operation can be achieved via two methods: thermal (melting) or mechanical (cutting). Mechanical systems break the icy material efficiently, but transport ice chips inefficiently. Thermal systems have an effective chip removal approach, but a power intensive ice-melting step. The Search for Life Using Submersible Heated (SLUSH) drill is a hybrid, thermo-mechanical drill probe system that combines the most efficient aspects of these two techniques [5].
SLUSH is 5 m long, 57 cm diameter probe with a heated drill bit in front, antitorque cutters on the side, and several tether bays on top (Figure 1). The probe is partially flooded –only critical subsystems are inside a pressure vessel; this allows the probe to sink rather than float.
SLUSH utilizes a mechanical drill to break the formation, and partially melts the fragments to enable the efficient transport of material behind the probe. The resulting slush behaves like liquid despite being partially frozen, enabling a significant reduction of the power required for melting the full volume of ice. Further, because a mechanical approach generates higher penetration rates, SLUSH can reach the ocean in a much shorter time than a pure melt probe. Once SLUSH passes through the hazardous cryogenic ice, it could use a purely thermal approach to melt through the warmer ice without the need for mechanical cutting.
SLUSH incorporates the Kilopower reactor for both thermal and electrical needs. The fission reactor can be turned on/off and is self-moderating, significantly simplifying thermal management. The probe is physically connected to a surface lander by a communications tether, housed in several spool bays that are left behind in the ice once the spool is depleted. This allows each tether section to be purpose-designed. For example, the top section, which may see 150 kPa shear stresses on a diurnal cycle, will be reinforced with Kevlar. Leaving the spools behind also shortens the probe length as it descends, making penetration more efficient.
While Kevlar reinforcement and the refrozen channel left behind by the probe may provide protection from the diurnal stress environment, if the tether does break, broken sections can be used as "Tunable Tether"for communication. RF and acoustic communication could potentially provide a backup communication by incorporating transceivers into each spool section.

Figure 1. Conceptual design of SLUSH

Acknowledgments: This work is funded by NASA's PICASSO and SESAME Programs.

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Session Classification: Session 7

Contribution ID: **57** Type: **Oral**

The BEAMISH hot water drill

Monday, 30 September 2019 09:20 (20 minutes)

During the 2018-19 Antarctic field season, the British Antarctic Survey (BAS) BEAMISH project drilled three holes through the Rutford Ice Stream, West Antarctica, accessing and instrumenting its bed through 2152m of ice, the deepest hot water drilled access holes yet created. This was the culmination of almost 20 years of preparation and planning and following on from unsuccessful drilling attempts during an earlier project in 2004-05. Lessons learnt from this and the Subglacial Lake Ellsworth project drilling, informed the design and development of the BEAMISH hot water drill. The system was built on extensive experience with the BAS ice shelf hot water drill and utilises many identical components and processes. New systems and processes were developed for BEAMISH to aid critical aspects of deep access drilling, including extensive water recovery techniques and monitoring capabilities. The modular design of the BEAMISH drill offers many benefits in its adaptability, redundancy and minimal logistic foot print, which can accommodate the modifications needed for future deep, clean access hole creation.

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Presenter: Mr ANKER, Paul (British Antarctic Survey)

Session Classification: Session 1

Contribution ID: **58** Type: **Poster**

Enhancement of the BEAMISH hot water drill for clean subglacial access operations

Tuesday, 1 October 2019 17:56 (4 minutes)

The success of the British Antarctic Survey (BAS) BEAMISH project in 2018-19 demonstrated the viability of the BEAMISH hot water drill (HWD) system in creating access holes through over 2150m of the Rutford Ice Stream. The proven ability to gain access to subglacial environments at depths exceeding 2 km opens the way to accessing subglacial lake targets. The identification of such a target by Centro de Estudios Cientificos (CECs), Chile, has led to collaboration with BAS to access Subglacial Lake CECs, in central West Antarctica. The isolated nature of this lake requires a 'clean' drilling process to minimise contamination and disturbance of the subglacial environment during access, requiring modification of the BEAMISH HWD to meet these challenges. Drawing on previous work carried out for the unsuccessful Subglacial Lake Ellsworth (SLE) project, the modular nature of the BEAMISH HWD allows the integration of the pumping, filtering and water treatment systems developed for SLE. Following the same stewardship protocols developed for that project will allow the new drill to access Lake CECs cleanly. The lake lies beneath approximately 2650 m of ice requiring a new main drilling hose and an associated increase in water pumping and heating power, whilst the 2000 m altitude of the Lake CECs site requires the use of new diesel generators.

Primary authors: MAKINSON, Keith (British Antarctic Survey); ANKER, Paul (British Antarctic Survey)

Presenter: ANKER, Paul (British Antarctic Survey)

Session Classification: Session 4

Contribution ID: **59** Type: **Oral**

subglacior drilling probe : lesson learn

Monday, 30 September 2019 11:20 (20 minutes)

After the devlopment of the SUBGLACIOR drilling probe, we get the oportunity to try this tool a few times close to the Antarctic Dome C station. We will present here the reasults of these three testing seasons.

Primary authors: Mr ALEMANY, olivier (IGE - CNRS); Mr PIARD, luc; Mr POSSENTI, philippe; Mr GRILLI ROBERTO; Mr CHAPPELLAZ, jérôme; Mr LEFEBVRE, eric; Mr TEST, gregory; Mr ROMANINI, daniel

Presenter: Mr ALEMANY, olivier (IGE - CNRS)

Session Classification: Session 1

Contribution ID: **60** Type: **Oral**

Deep subglacial access: an assessment of past hot water drilling failures and recent successes

Monday, 30 September 2019 09:40 (20 minutes)

Following the failed 2012 attempt to access Subglacial Lake Ellsworth in West Antarctica, using a specially designed hot water drill, a programme review was undertaken. An international board of experts assessed the reasons for the failure, and made recommendations on the modifications necessary to facilitate successful deep (>2 km) subglacial access using the technique of hot water drilling. The lessons learnt were substantial and over four Antarctic field seasons, various hot water drilling equipment and procedural modifications were tested and optimised, successfully delivering numerous access holes through Filchner-Ronne Ice Shelf. On January 8th, 2019, the culmination of this work was demonstrated on Rutford Ice Stream, West Antarctica, when the British Antarctic Survey led BEAMISH project successfully hot water drilled a 2152 m deep subglacial access hole, reaching the sediments beneath the ice stream. A further two holes, at different sites, were then drilled over the following 5 weeks. Here we discuss the points raised by the review board and present the advances required for recent successes and for the future research of subglacial lakes beneath thick continental ice sheets.

Primary author: MAKINSON, Keith (British Antarctic Survey)

Co-author: Mr ANKER, Paul (British Antarctic Survey)

Presenter: MAKINSON, Keith (British Antarctic Survey)

Session Classification: Session 1

Contribution ID: **61** Type: **Poster**

An enhanced percussion hammer mechanism for a subglacial sediment corer

Monday, 30 September 2019 17:44 (4 minutes)

Subglacial sediments are of great interest to the science community. They can contain physical, chemical and biological information that can reveal changes in ice sheet history and identify and characterise life in those environments. However, retrieving sediment cores from up to 1000's of metres beneath the ice surface, through hot water drilled access holes, at remote field locations, presents numerous challenges. Motivated by the need to minimise weight and corer diameter, simplify assembly and operation, and maximise sediment recovery, British Antarctic Survey designed a percussion corer that was built by UWITEC. Here we outline the percussion corer design for use through subglacial access holes and then detail the new auto release mechanism that provides clearer feedback of its operation to the surface and improves the efficiency of the percussion hammer. Where englacial sediments are present in the access hole wall, measures to mitigate against material jamming the hammer mechanism are presented. Using a winched single rope for both the corer and hammer mechanism, this system has successfully operated at depths of up to 2150 m.

Primary author: MAKINSON, Keith (British Antarctic Survey)

Co-authors: ANKER, Paul (British Antarctic Survey); Dr SMITH, James (British Antarctic Survey); Prof. HODGSON, Dominic (British Antarctic Survey); Mr ASHURST, Dan (British Antarctic Survey)

Presenter: MAKINSON, Keith (British Antarctic Survey)

Session Classification: Session 2

Contribution ID: **62** Type: **Oral**

Agile Sub-Ice Geological Drill Development

Monday, 30 September 2019 14:00 (20 minutes)

The Agile Sub-Ice Geological (ASIG) Drill was developed by U.S. Ice Drilling Program (IDP) for the U.S. National Science Foundation. The design of the system leverages existing exploration drill equipment to create a drill capable of recovering ice core at any targeted depth up to 700m and 10m of rock core beneath up to 700m of ice and firn. The system was developed and tested in 2015 and 2016. Several new mechanical sub-systems were designed for the drill including a custom packer and casing system, a fluid filtration system to remove both ice and rock cuttings, and custom drill bits. This presentation describes the requirements for the drill and the design of the drill to meet those requirements.

Primary authors: Mr GIBSON, Christopher (University of Wisconsin-Madison); Mr KUHL, Tanner (University of Wisconsin-Madison); Mr JOHNSON, Jay (University of Wisconsin-Madison); Mr JETSON, Joshua (University of Wisconsin-Madison); Mr BOECKMANN, Grant (University of Wisconsin-Madison)

Presenter: Mr GIBSON, Christopher (University of Wisconsin-Madison)

Session Classification: Session 2

Contribution ID: **64** Type: **Oral**

The BAS Rapid Access Isotope Drill, a new lightweight ice sheet reconnaissance tool.

Tuesday, 1 October 2019 16:40 (20 minutes)

The British Antarctic Survey (BAS) Rapid Access Isotope Drill (RAID) is an innovative new class of electromechanical ice drill, which has recently been used to drill the deepest dry hole drilled by an electromechanical drill. The record breaking depth of 461.58m was drilled in just over 104 hours at Little Dome C. The drill is described as well as modifications since it was last used. Borehole temperature and stable water isotope results from Little Dome C are presented.

The next drilling season at Sherman Island is outlined with the addition complexity of reaming during the drilling process due to borehole closure at this relatively warm site.

Future developments are presented, including the ability to obtain a subglacial rock sample once the bedrock has been reached (P-RAID), borehole logging and a large version of the drill, BigRAID.

Primary author: RIX, Julius (The British Antarctic Survey)

Co-authors: Dr MULVANEY, Rob (British Antarctic Survey); Mr ASHURST, Dan (British Antarctic Survey); HONG, Jialin (Polar Research Center, Jilin University, Changchun, China); HARKNESS, Patrick (University of Glasgow); Dr WORRALL, Kevin (University of Glasgow); Mr TIMONEY, Ryan (University of Glasgow); Dr MARTIN, Carlos (The British Antarctic Survey); Dr RITZ, Catherine (Institut des Geosciences de l'environnement); Dr FREZZOTTI, Massimo (ENEA); Ms ROWELL, Isobel (Cambridge University)

Presenter: RIX, Julius (The British Antarctic Survey)

Session Classification: Session 4

Contribution ID: **65** Type: **Poster**

Using Distributed Temperature Sensing to measure borehole temperature.

Tuesday, 1 October 2019 17:48 (4 minutes)

A fibre-optic Distributed Temperature Sensing (DTS) instrument has been deployed into a number of ice boreholes in order to measure the temperature profile. The advantage of the DTS is that glass in the fibre itself becomes the temperature sensor and a relatively cheap length of fibre-optic cable can be used to measure temperature continuously along its length. As temperatures are measured throughout the cable's length, cables can be frozen in place and true undisturbed temperatures obtained. We describe the weaknesses of the of-the-shelf DTS instrument used and ways to overcome them. A method is described in order to obtain well calibrated borehole temperatures. Using this method we present borehole temperature profiles from the TALDICE, Little Dome C and Skytrain Ice Rise boreholes.

Primary author: RIX, Julius (The British Antarctic Survey)

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Presenter: RIX, Julius (The British Antarctic Survey)

Session Classification: Session 4

Contribution ID: **66** Type: **Oral**

Sub-glacial Drilling using the IDP Winkie Drill

Monday, 30 September 2019 14:40 (20 minutes)

The IDP Winkie Drill have deployed to two Antarctic field seasons. The first successful deployment was to the Ohio Range during the 2016-2017 field season where it recovered subglacial bedrock from five boreholes ranging in depth from 12.0 to 28.3 meters using the standard AW34 coring tools. Access boreholes were created with modified Kovacs 2-inch augers. The drill was deployed to the Ong Valley in 2017-2018 and successfully collected two mixed media cores from the surface to depths of 9.5 and 12.4 meters. The Ong Valley cores were collected with over-sized barrels resulting in cores of 71.7 mm. This presentation describes the system performance and results of the expeditions, as well as lessons learned.

Primary author: Mr BOECKMANN, Grant (University of Wisconsin-Madison)

Co-author: GIBSON, Christopher (University of Wisconsin-Madison)

Presenter: Mr BOECKMANN, Grant (University of Wisconsin-Madison)

Session Classification: Session 2

Contribution ID: **67** Type: **Poster**

A new Kevlar-armored cables for cable-suspended ice drills

Tuesday, 1 October 2019 17:52 (4 minutes)

Various thermal and electromechanical ice drills are suspended on armored cable that provide power to the downhole unit and transmit signals to the surface. As a general matter, steel wire armored cables are used. These cables have usually 4 to 7 conductors and outer diameter in the range of 4.5-9 mm. The weight of such cables is 0.09-0.35 kg/m and maximum bending radius (under tension)of the curve of the inner edge of the bends shall be at least 12 times the external diameter of the cable. To make cable lighter and more flexible, series of new Kevlar-armored cables were developed and tested. The cable consists of two 1.28 mm2 conductors that can be used as power and signal lines at the same time. All the conductors are isolated by polytetrafluoroethylene (PFA) jackets. The strength member is made from 0.65-mm diameter Kevlar lines that have either net or double-spiral pattern. To hold Kevlar lines in order, the outer layer of cable is produced from polyamide fabric cover net. Outer diameter of the different-type cables ranged from 5.7 to 6.2 mm. Permissible bending radius is as low as 17-20 mm. The maximal breaking force under straight tension is 16 kN while under bending tension with wheels 40 mm in diameter it reduced to 10.5 kN. Cables weigh only 0.055-0.065 kg/m. All cables were tested for mechanical and electrical properties. The first laboratory tests with prototype of RECoverable Autonomous Sonde RECAS-200at an ice-drill testing facility that can simulate drilling conditions as close as possible to the natural environment throughout the year are scheduled on the summer of 2019.

Primary author: Dr ZHANG, Nan (Polar Research Center, Jilin University, Changchun, China)

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Presenter: Dr ZHANG, Nan (Polar Research Center, Jilin University, Changchun, China)

Session Classification: Session 4

Contribution ID: **68** Type: **Poster**

Side-wall ice corer

Monday, 30 September 2019 17:40 (4 minutes)

In order to obtain short additional core samples from intervals of specific interest (tephra layers, basal ice, shearing zones, etc.), the simple wireline side-wall thermal coring system is proposed. The corer includes driven unit, bendable core barrel, and thermal coring head. The side-wall coring system can be precisely positioned in the zone of interest. To this end, it can be equipped with an optical televiewer or laser dust logger that, combined with core inspection from the parent hole, will fit the sample into an existing stratigraphy. The first prototype of the corer is intended to work in dry parent hole with diameter of 130-135 mm, but future modification will allow to recover samples from the wet boreholes as well. Of course, the system is designed to acquire a smaller core sample than is possible with the replicate coring drill: the inner and outer diameter of the drill head are 30 and 40 mm, respectively, and the expected depth of the side-wall hole is up to 0.4-0.5 m. Nevertheless, we believe that the retrieved ice core samples are suitable for different studies. In this presentation, we present first testing results of thermal head and bendable core barrel.

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Presenter: Prof. TALALAY, Pavel (Jilin University)

Session Classification: Session 2

Contribution ID: **69** Type: **Oral**

The development of the RADIX rapid access drilling system

Tuesday, 1 October 2019 16:20 (20 minutes)

Rapid drilling of an access hole in ice sheets can complement the prospection of potential deep drilling sites and serve to locally explore an ice sheet. RADIX is a rapid access system for an access hole of 20 mm diameter optimized for minimal resources and logistics demand. It is based on a coiled drilling system. The drilled ice cuttings are available for analysis. The drilling speed is about 10 mm/s, resulting in less than 4 days of continuous drilling for a 3000 m hole. We present the experience of a 4-year testing phase and the current system as will be deployed to Little Dome C, Antarctica.
A battery operated 15-mm diameter downhole sonde has been designed and constructed for logging. Hole inclination, azimuth, temperature and dust content of the surrounding ice are transmitted to the surface through an optical fiber cable.

Primary author: Dr SCHWANDER, Jakob (University of Bern)

Co-authors: Prof. STOCKER, Thomas (University of Bern); Prof. FISCHER, Hubertus (University of Bern); MARENDING, Samuel (University of Bern); WALTHER, Remo (University of Bern); JOST, Jürg (Spacetek Technology); MORET, Hanspeter (University of Bern)

Presenter: Dr SCHWANDER, Jakob (University of Bern)

Session Classification: Session 4

Contribution ID: **70** Type: **Oral**

The brittle ice zone in polar ice cores

Monday, 30 September 2019 13:40 (20 minutes)

The brittle ice zone (BIZ) is a persistent challenge for deep and intermediate-depth polar ice core projects. Increasing ice overburden at depth pressurizes trapped air bubbles, resulting in fracture of ice cores as they are drilled brought to the surface. Only at depths/pressures where air bubbles fully transition to clathrates is this breakage relieved. Ice core fracturing has negative downstream impacts in sampling and analysis, causing contamination and degrading scientific results. The international ice core community has encountered the BIZ at many sites; data from 18 polar locations was documented and published after discussions beginning at the 7th International Workshop on Ice Drilling Technology. The BIZ begins at a mean depth of 545 +/- 162 m (1 standard deviation), extending to depths where ductile clathrate ice is reached: an average of 1132 +/- 178 m depth. Due to variations in ice thickness and snow accumulation rate, ages at depth in the BIZ range from as young as 2 ka before present (BP) at Dye-3, Greenland to >160 ka BP at Taylor Dome, Antarctica. At intermediate depth ice core sites, up to 90% of the paleoclimate record can be compromised. Exploring the effects of temperature and pressure on the BIZ reveals complex relationships between firn densification and BIZ depth, qualitatively supporting expected thinning of the BIZ at lower temperature due to shallow clathrate stability in such environments. BIZ results published in 2014 are updated here to include ice coring completed in the last five years.

Primary author: Dr NEFF, Peter D. (University of Washington)

Presenter: Dr NEFF, Peter D. (University of Washington)

Session Classification: Session 2

Contribution ID: **71** Type: **Oral**

Five drills across four decades: large-volume ice coring for atmospheric gas concentration and isotopic studies at the high-accumulation DE-08 site, Law Dome, Antarctica

Tuesday, 1 October 2019 14:40 (20 minutes)

The record of past atmospheric gases preserved in ice at the "DE08"site, located 16 km east of the summit of Law Dome, East Antarctica, has been the subject of analysis since the late 1980s. Three ice coring projects have been completed at this location, all exploiting the benefits of high local snowfall rates—1.2 m ice eq. a-1 at DE08. Such snow accumulation rapidly traps gases, resulting in narrow gas age distribution (~8-9 a), and also rapidly advects ice to depths where it is shielded from cosmic ray bombardment. This shielding reduces in-situ 14C production and enables studies of radiocarbon-containing atmospheric trace-gases trapped in the ice (e.g. 14CO, 14CH4). First, in 1987, an Australian team used a custom thermal drill to extract cores to 234 m depth (195 mm ø) at DE08 for the purpose of developing paleoatmospheric reconstructions. DE08-2, located approximately 300 m southeast of the DE08 site, was drilled in 1993 by an Australian-French team using a French electromechanical drill (100 mm ø) and reached 243 m depth. In the 2018-2019 Antarctic summer season, a joint Australian-US team recovered ice cores from six separate boreholes at "DE08-OH,"located 900 m northeast of the original DE08, for the purpose of reconstructing past atmospheric 14CO, which provides insight into past atmospheric oxidative capacity dictated by the hydroxyl (OH) radical. One core to 100 m depth was recovered using the Badger-Eclipse drill (81 mm ø) and the borehole subsequently sampled with the CSIRO firn-air sampling device; two cores to 95 m depth were recovered using the Blue Ice Drill (241 mm ø); and three cores to 240 m depth were recovered using the 4-inch drill (104 mm ø). All of these ice cores were extracted without the use of drilling fluid, and as such provide lessons in dry ice coring to depths >200 m, where deteriorating core quality is experienced due to increased ice overburden pressure. We examine drill performance and sample quality from all DE08 drilling projects, with an emphasis on recent findings from three parallel, 240 m-depth boreholes (~4 m horizontal spacing) recovered using the US 4-inch electromechanical drill.

Primary authors: Dr NEFF, Peter D. (University of Washington); KUHL, Tanner (University of Wisconsin); Dr ETHERIDGE, David M. (Commonwealth Scientific and Industrial Research Organisation); Dr PETRENKO, Vasilii (University of Rochester); Dr SMITH, Andrew M. (Australian Nuclear Science and Technology Organisation); Mr BOECKMANN, Grant (IDP, University of Wisconsin-Madison); Mr CROSIER, Edward (University of Rochester); Mr THORNTON, David (Commonwealth Scientific and Industrial Research Organisation); Dr JONG, Lenneke M. (Australian Antarctic Division); Ms LABUDDA, Sharon (Australian Antarctic Division); Dr CURRAN, Mark (Australian Antarctic Division); Dr VAN OMMEN, Tas (Australian Antarctic Division)

Presenters: Dr NEFF, Peter D. (University of Washington); KUHL, Tanner (University of Wisconsin)

Session Classification: Session 4

Contribution ID: **72** Type: **Poster**

A novel approach to process brittle ice for continuous flow analysis of stable water isotopes

Tuesday, 1 October 2019 17:28 (4 minutes)

Ice core handling comes with many challenges, especially in the brittle ice zone. Here we present a technique to process longitudinally broken ice pieces (slant breaks) for continuous flow analysis (CFA). This technique involves shaving ice either side of the break (slant or normal) and refitting the pieces before melting them, instead of cutting out the slanted break and creating a discontinuity. Preserving the break allows for more of the ice to be analysed using CFA techniques. We use the Roosevelt Island Climate Evolution (RICE) ice core stable isotope CFA dataset as proof of concept, demonstrating our technique by comparing duplicate core segments that were melted with and without slanted cuts. Although the cleaning process did remove some material and slightly smooth some of the data, there was no loss of major features. We were able to include ~3m of ice, or about ~1% of the 261m brittle ice, that would have been unable to be incorporated into the CFA analysis. This equates to ~1300 years record scale as it was in the deeper, more compressed part of the core.

This technique was developed at the GNS Ice Core Facility, located in Lower Hutt, New Zealand which was opened in 2007. The facility includes: two storage freezers operating at -36℃ which are utilised to store approximately 2000 metres of core material, a working cold laboratory set at -20℃, and a class 1000 clean laboratory (room temperature). The site also has additional frozen container storage: two 20 ft reefers and one 40 ft reefer that is CO2 cooled and able to perform at -40℃. The clean lab is equipped with an ice melt set-up: upright freezer for melting core and clean hoods for discrete sample collection. For CFA analysis we have a laser spectroscopy system and for discrete water chemistry (major ion component) analysis we have an ion chromatograph which can measure ions to the low ppb level. The campus also includes a stable isotope laboratory that can be utilised for ice core analysis.

Primary authors: PYNE, Rebecca (GNS Science); KELLER, Elizabeth (GNS Science); CANESSA, Silvia (GNS Science); BERTLER, Nancy (GNS Science, Victoria University of Wellington); PYNE, Alex (Victoria University of Wellington, New Zealand); Mr MANDENO, Darcy; Dr VALLELONGA, Paul (University of Copenhagen); SEMPER, Stefanie (GNS Science); Dr KJÆR, Helle Astrid (PICE-Physics of Ice, Climate and Earth); HUTCHINSON, Ed (GNS Science); BAISDEN, W. Troy (GNS Science)

Presenter: PYNE, Rebecca (GNS Science)

Session Classification: Session 4

Contribution ID: **73** Type: **Poster**

DiElectric Profiling with rapid access drilling: in-situ DEP in the borehole

Monday, 30 September 2019 17:48 (4 minutes)

Dielectric profiling (DEP) is a fast, non-destructive method to precisely scan the dielectric properties of an ice core in as high depth resolution as a few millimetres. Initially being proposed to acquire conductivity profiles, the method has been extended to also interpret relative permittivity and ultimately determine the firn's density and its pure ice phase's conductivity by inversion of the measured properties with the specifically developed mixing model DECOMP. The conductivity profile itself exhibits time markers from volcanic eruptions and facilitates, by integrating the density along depth, the calculation of average accumulation rates in between these time markers. The modelling of synthetic radar traces is another application of dielectric profiling data, that establishes a high precision link between the icecore and geophysical ground penetrating radar surveys in the vicinity of the drilling site. In the light of these applications the aim to log the dielectric properties directly in the borehole has been out there for a few decades. Mainly motivated in acquiring records without missing data due to core breaks and to even better extent the depth scale beyond sections of possibly missing core sections. Along with the development of rapid access drilling, where no ice core but only cuttings are taken, there is an even more urgent desire to acquire the high quality electrical data directly from in-situ measurements in the borehole.
The traditional DEP method, as described in the literature, uses commercial auto-balancing-bridge devices to measure the electrical circuit properties of the DEP capacitor with the icecore as a dielectric filling. The commercial devices typically have 19"rack size dimensions and extensive circuit design would have been required to adapt the electronics to fit into a typically 100 mm diameter tube of a borehole logger. We developed a lock-in amplifier based electronics with a small circuit layout and successfully tested it in an icecore DEP device . We will inter-compare the records with the results of an auto-balancing-bridge based measurement and estimate the expected measurement performance of our new lock-in amplifier circuit. The electrostatic theory to determine the borehole-wall ice properties has been described before and allows to predict the precision of the ice parameters as measured in a borehole log. We will also lay out the mechanical and electrical design to build and operate a borehole DEP in a dry and a liquid filled hole.

Primary authors: Prof. WILHELMS, Frank (Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung & Department of Crystallography, Geoscience Centre, University of Göttingen); RIX, Julius (The British Antarctic Survey); Mr LIPPMANN, Erich (LGM); Mr FRENZEL, Andreas (Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung); Dr KIPFSTUHL, Sepp (Am Handelshafen 12 27570 Bremerhaven Germany); Dr HÖRHOLD, Maria (Am Handelshafen 12 27570 Bremerhaven Germany); Mr MOJTABAVI, Seyedhamidreza (Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung); Dr MULVANEY, Rob (British Antarctic Survey); Prof. LAEPPLE, Thomas (Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung)

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Session Classification: Session 2

Contribution ID: **74** Type: **Poster**

Hot water drill and borhole measurment . Argentière glacier Alpes

Tuesday, 1 October 2019 17:32 (4 minutes)

We will present the results of a field campaign planned in September 2019.
The goal is to drill 5 holes (250m deep) with a new hot water drill system. Hole will be equipped with a inclinometer string an piezometer

Primary author: PIARD, luc (cnrs)

Presenter: PIARD, luc (cnrs)

Session Classification: Session 4

Contribution ID: **75** Type: **Oral**

University of Copenhagen Ice Core Drilling Operations Since 2013 and Future Outlook

Monday, 30 September 2019 13:00 (20 minutes)

Since the last update at the Seventh International Drilling Workshop on Ice Drilling Technology, in Madison, WI USA in September of 2013, the drilling group at the University of Copenhagen (UCPH) has been responsible for several shallow, intermediate, and deep drilling operations in both Greenland and Antarctica. The deep drilling program, EastGRIP, placed near the onset of the North East Greenland Ice Stream (NEGIS), began in 2016 and is ongoing with the goal of reaching bedrock near 2700 m by 2020. The intermediate depth program at Renland, Greenland (RECAP – 584 m) was completed in 2015 and two intermediate depth programs together with the Australian Antarctic Division: Aurora Basin North, Antarctica (ABN –303 m) and Mt. Brown, Antarctica (299 m), were completed in the 2013-14 and 2017-18 field seasons respectively. Several shallow drilling campaigns for partners associated with EastGRIP and RECAP have occurred concurrently with those projects, and a shallow drilling mission into the warm glaciers on Disko Island, Greenland was done in the Spring of 2018. The UCPH collection of Hans Tausen type drills and the Danish shallow drill were adapted to each purpose which will be highlighted in this presentation, together with a look at the new and familiar challenges experienced at each drilling operation.

Primary author: COPENHAGEN DRILL GROUP (Niels Bohr Institute)

Presenter: COPENHAGEN DRILL GROUP (Niels Bohr Institute)

Session Classification: Session 2

Contribution ID: **76** Type: **Oral**

Deep Ice Core Drilling at EastGRIP, Greenland

Tuesday, 1 October 2019 13:00 (20 minutes)

In this presentation we will describe the four seasons spent for set-up and drilling at EastGRIP, including a description of some new innovations and their effect on drilling performance and core quality. The first challenge at EGRIP was adapting the drilling to the sub-surface trenches that were created using a so-called balloon technique, which has some advantages over traditional trench construction techniques, but also creates an environment that presents new challenges for installing drilling and maintaining infrastructure. The core handling at EGRIP was optimized for the protection of brittle ice using a rigid core extraction system assembled in a temperature controlled environment in order to minimize both mechanical and thermal shock to the cores. Core quality through the brittle zone at EGRIP was much improved over previous deep drillings in Greenland. Other highlights and challenges include the attempt to develop a new communication protocol between surface and downhole electronics sections via GRIDCOM modems (which was ultimately abandoned), the development of new motor control and control software, the demonstration of directional drilling, which was achieved in an effort to control borehole inclination and provides a potential means for replicate coring, and the use of a chips melter for drill fluid recycling. EGRIP also served as a training and testing grounds for teams and hardware to be used for the coming Beyond EPICA-Oldest Ice project in Antarctica.

Primary author: COPENHAGEN DRILL GROUP (Niels Bohr Institute)

Presenter: COPENHAGEN DRILL GROUP (Niels Bohr Institute)

Session Classification: Session 4

Contribution ID: **77** Type: **Oral**

Estisol Drilling Fluid Handling and Recycling Using a Chips Melter at EGRIP, RECAP, and ABN-North Ice Core Drilling Projects

Thursday, 3 October 2019 11:40 (20 minutes)

For the recovery and reuse of drilling fluid from the chips produced in ice core drilling a melting procedure has been introduced at the EGRIP, RECAP, and ABN projects. The aim is to maximize the efficiency of drill fluid recovery through complete separation of the drilling fluid from liquid water, which would be an improvement over traditional methods relying on centrifugal force for fluid separation from the frozen ice chips. While fluid-water separation using Estisol-140 was straight forward and complete (RECAP and ABN projects), melt separation for the EGRIP drilling fluid mixture of Estisol-240 and Coasol was more problematic. When heated, a small percentage of water remained in solution with the drill fluid, requiring a subsequent refreezing step to remove the last traces of water, and likewise traces of drill fluid remained in solution with the water phase, which were harder to remove. In this presentation we review these experiences, and look ahead to the next deployment of our melt system for the Beyond EPICA-Oldest Ice core project in Antarctica beginning in 2021.

Primary author: COPENHAGEN DRILL GROUP (Niels Bohr Institute)

Presenter: COPENHAGEN DRILL GROUP (Niels Bohr Institute)

Session Classification: Session 6

Contribution ID: **78** Type: **Oral**

Directional Drilling for Inclination Correction and Potential for Replicate Coring at EGRIP

Wednesday, 2 October 2019 09:00 (20 minutes)

During EastGRIP season 2017 we observed a rapidly growing borehole inclination, which culminated at ≈ 5,5° in a depth of 550m. In order to correct for this inclination a leaf spring was mounted on the outer glass fiber core barrel, near the drill head of our 2-m core-barrel version of the Hans Tausen Drill to provide a sideways force as close to the cutters as possible. To rectify the inclination, the drill must be rotated such that the spring is facing upwards requiring that the position of the outer core barrel relative to the direction of the inclination be known. The drill electronics houses a 9-axis orientation sensor (BNO055), used for monitoring the relative inclination during drill operation. The inclination is calculated using the data from the tri-axial 14-bit accelerometer. Since acceleration is measured in three directions, it is possible to tell the orientation of the coordinate system of the sensor, relative to the borehole inclination. As the sensor remains stationary inside the pressure tube, and the outer core barrel is locked together with the pressure tube, it is possible to tell which way the spring is oriented relative to the borehole inclination, and thereby to orient it facing "upwards"relative to the gravitational acceleration in order to exert a force downwards on the drill head. This forces the drill into a direction which is more true to the direction of gravity. This method proved to be very effective in terms of changing direction of the borehole inclination. From 570m depth to 730m, the spring was oriented correctly, rectifying the borehole by ≈ 0.1 degree per 5 m. At 730m the drill was assembled incorrectly in a way that the spring force increased the inclination instead of decreasing it. When this was discovered, it was corrected for, and the inclination decreased again, thus demonstrating the ability to change inclination both in the direction of, and opposite to gravity. A similar approach could then be used in attempts exit an existing borehole to retrieve replicate cores for specific depth intervals, or in the case of continuing a drilling around a stuck drill sonde from which the cable has been removed.

Primary author: COPENHAGEN DRILL GROUP (Niels Bohr Institute)

Presenter: COPENHAGEN DRILL GROUP (Niels Bohr Institute)

Session Classification: Session 5

Contribution ID: **79** Type: **Oral**

A New Hot Water Drill System for Antarctic Ice Shelf Investigation

Wednesday, 2 October 2019 09:40 (20 minutes)

Mass loss of ice shelf is of great significance to a better understanding of the ice sheet dynamics and a more precise prediction of global sea levels. However, the melting processes and ocean currents beneath the ice shelf remain poorly understood. The hot water drill, a highly efficient drill technique, provides an opportunity to investigate the physical and chemical processes beneath the ice shelf. With the financial support from the Ministry of Science and Technology of China, a new hot water drill system has been successfully developed. Drilling test results show that the average drilling speed is >30 m h-1, and the diameter of the obtained borehole is >35 cm. The length of the main hose is 2200 m. In the following years, the hot water drill will be employed on Amery Ice Shelf to penetrate the ice at 9 sites with thickness varying from ~600m to 1800m (near the grounding line). Through the borehole, seawater and sediment beneath the ice shelf will be sampled. The ice core will be recovered from three layers of the ice shelf (i.e., the upper, middle and lower layers). In addition, CTD and ADCP will be installed beneath the ice shelf. Besides, the automatic weather station, surface mass balance observation system and the GPS will be set up near the drilling site. The data logging to a local disk will be performed, and the disk will be replaced annually.

Primary author: Prof. LI, Yuansheng (Polar Research Institute of China, Shanghai, China)

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Presenter: Prof. LI, Yuansheng (Polar Research Institute of China, Shanghai, China)

Session Classification: Session 5

Contribution ID: **80** Type: **Oral**

Programmable deployed borehole measurement system for hot water drilled ice holes

Wednesday, 2 October 2019 09:20 (20 minutes)

Authors: Carson McAfee, Sean Quirk, Keith Makinson, Julius Rix, Paul Anker and Alex Brisbourne

Abstract:
A programmable borehole measurement system was deployed in hot water drilled ice holes during the BEAMISH project to drill to the bed of the Rutford Ice Stream in Antarctica. Capable of operating remotely, this system reached depths of 2150 meters and measured hole diameter, depth and angle. Additionally this system was fitted with three cameras (two side and one downward facing) to monitor sediment and glacier bed conditions. There were several project constraints. The first was constructing an instrumentation system small enough to fit the ice hole diameter, allowing only 17.5 cm width for the instruments. The second was ensuring the system could operate for the full period of deployment without surface intervention. The measurement system needed to operate autonomously after leaving the surface as there was no live data feed available from the drill line. To do this the instruments were coded to only operate during preconfigured times or depths via a central master unit. The system was successful but needed some refinement to the software and battery systems. There is also the possibility of including additional sensors to expand the measurement capabilities. Some of the results are presented and reviewed.

Primary authors: Mr MCAFEE, Carson (BAS); Mr QUIRK, Sean (BAS); Mr MAKINSON, Keith (BAS); Mr RIX, Julius (BAS); Mr ANKER, Paul (BAS); Mr BRISBOURNE, Alex (BAS)

Presenter: Mr MCAFEE, Carson (BAS)

Session Classification: Session 5

Contribution ID: **81** Type: **Oral**

Wet drilling with a modified 82mm ECLIPSE drill

Tuesday, 1 October 2019 13:20 (20 minutes)

A modified 82mm ECLIPSE ice coring drill was used to drill to 260m on the Antarctic coast near the Princess Elisabeth Station during the 2018-2019 season. The drill was modified to operate in Estisol fluid, including the use of a booster pump, pressure seals, and borehole bail. Switching between dry and wet operation can be accomplished in minutes. Core quality through the troublesome 100m level was good. We will discuss the drill design and operation, including core log, penetration rates, drill maintenance, core handling, and planned future improvements. The presentation will include a short video.

Primary authors: GROS, E (Icefield Instruments Inc.); INOUE, M (ULB, Belguim); WAUTHY, S (ULB, Belgium); GOOSSE, H (UCL, Belgium); WAVER, N (U. Colorado); SUN, S (ULB, Belgium); CURRAN, M (AAD, Australia); BERCLAZ, C (International Polar Foundation); POTVIN, E (Icefield Instruments Inc.); BLAKE, E (Icefield Instruments Inc.)

Presenter: BLAKE, E (Icefield Instruments Inc.)

Session Classification: Session 4

Contribution ID: **82** Type: **Poster**

Field-portable ice core saw

Monday, 30 September 2019 17:08 (4 minutes)

We present a field-portable ice core saw capable of both horizontal and vertical cuts, with adjustable feed rate, adjustable cutting height, fast retraction speed, and feed clutch. The design is a moving-saw design, and includes emergency stop and a remote control. Accessories such as ECM can be mounted on the saw. The design is currently being used at the National Centre for Antarctic & Ocean Research, India, and the University of Calgary, Canada.

Primary authors: POTVIN, Emmanuel (Icefield Instruments Inc.); GROS, Etienne (Icefield Instruments Inc.); BLAKE, Erik (Icefield Instruments Inc.)

Presenter: BLAKE, Erik (Icefield Instruments Inc.)

Session Classification: Session 2

Contribution ID: **83** Type: **Oral**

Recoverable autonomous thermal sonde for subglacial lakes exploration: heating control system design

Thursday, 3 October 2019 13:40 (20 minutes)

Recent evidence reveals that a large number of subglacial lakes exist beneath the Antarctic ice sheet. Exploring the subglacial lake is of great interest to the science community. RECoverable Autonomous Sonde (RECAS) will provide an exploration tool to measure and sample the subglacial lake environments while the subglacial lake remains isolated from the glacier surface and atmosphere. The thermal sonde is driven by two electrically heated drill bits and lateral heaters, and recovered by using a winch mechanism to move the probe upwards. This paper presents the design of the heating control system in RECAS, which controls the sonde motion by regulating the electrical power applied to thermal drill bits and the lateral heaters.

To reduce the size of the cable, the power is supplied at 800 V a.c. to 2500 V a.c according different cable lengths. Then the high-voltage feed is directly provided to the thermal drill bits and the lateral heaters, and converted to low voltage for the on-board electronics and the coil motors. Because there is no off-the-shelf power regulator can be used at such high-voltage, we have to design a special heating control system to regulate the electrical power applied to thermal drill bits and the lateral heaters. The self-designed heating control system consists of two parts: a power regulating control module and a power switching module. The power regulating control module includes a voltage zero-cross detection circuit, aiming to turn off the a.c. voltage at the zero-cross point when the instantaneous current through the load is zero. The power switching module includes a high efficiency thyristor to regulate the power by turning on and off the load circuit. A temperature sensor is mounted on the thyristor and detected by the power regulating control module to provide an overheating protection. The control signal from the power regulating control module to the thyristor is opto-isolated.

The laboratory tests have been carried out, which validated the feasibility of the heating control system. The RECAS prototype tests are scheduled on the summer of 2019.

Primary author: YU, Haibin (Hangzhou Dianzi University)

Co-authors: Mr LI, Chong (Hangzhou Dianzi University); Mr TANG, Yongzhen (Hangzhou Dianzi University); Mr LI, Xiaodong (Hangzhou Dianzi University); Dr SHI, Jianguang (Hangzhou Dianzi University); Prof. SUN, Youhong (Polar Research Center, Jilin University, Changchun, China); Prof. TALALAY, Pavel (Jilin University); Dr PENG, Shilin (Hangzhou Dianzi University)

Presenters: YU, Haibin (Hangzhou Dianzi University); Mr LI, Chong (Hangzhou Dianzi University); Dr PENG, Shilin (Hangzhou Dianzi University)

Session Classification: Session 7

Contribution ID: **84** Type: **Oral**

Optical Cryobots and Other Novel Methods for Deep Ice Penetration

Thursday, 3 October 2019 16:00 (20 minutes)

We present the results of laboratory and field tests of several new technologies developed at Stone Aerospace during the past five years in response to NASA needs to advance technology readiness levels for planetary missions to icy Ocean Worlds. Each of the approaches we present were developed in response to a common problem: emulating a nuclear power source that will be used on a flight cryobot. The amount of power needed to penetrate tens of kilometers of cryogenic ice on an outer planet moon force the use of nuclear power (most likely in the form of a compact fission reactor). For terrestrial field testing a non-nuclear surrogate power source is needed that will emulate to a high level of fidelity the size and performance of a micro fission reactor. We investigated three uniquely different approaches to this problem. In Project VALKYRIE (2010-2016) a 5 kW industrial laser was used to beam power through a fiber optic thread to a remote cryobot. A beam dump, located the nose of the cryobot, was used to convert photons to heat and electricity. Jet pumps pulled melt water through a heat exchanger surrounding the beam dump and created an open-loop hot water drill. The system was tested on the Matanuska Glacier in Alaska and achieved descent rates of 1 m/hour at 5 kW input power for a 25 cm diameter vehicle operating in temperate ice, which closely followed theoretical predictions. In Projects SPINDLE and ARCHIMEDES (2015-2019), a second variation on this theme eliminated the beam dump and jet pumps and replaced them with focusing optics at the nose of the vehicle. The optics were designed to focus the beam approximately 4 vehicle diameters ahead of the nose of the vehicle. This approach led to a spectacular descent rate of 22 m/hour at 5 kW input power for a 5 cm diameter vehicle operating in temperate ice in laboratory tests. The design works because of an unusual disparity between the transmission coefficient of photons in ice versus liquid water at 1070 nm wavelength. At this wavelength nearly 100% of the power is absorbed by the ice ahead of the vehicle, thus minimizing sidewall losses. Lastly, we present results from Projects SPINDLE and THOR (2015-2022) that are developing means for radically improving the classical Philberth probe. We will describe novel high voltage AC power transmission means and methods for liquid resistive electrical-to-thermal power conversion used to drive a closed-cycle hot water drill. These methods allow for power dumps at the nose of a cryobot at unprecedented power density levels exceeding 600 kW/liter. We also discuss terrestrial applications for these drilling technologies and the logistics required for deployment of these drill systems to remote field sites.

Primary authors: STONE, William (Stone Aerospace); HOGAN, Bartholomew (Stone Aerospace); HARMAN, John (Stone Aerospace); SIEGEL, Victoria (Stone Aerospace); RICHMOND, Kristof (Stone Aerospace)

Presenter: Dr NEAL, Tanner (Stone Aerospace)

Session Classification: Session 7

Contribution ID: **85** Type: **Oral**

A flexible and powerful shallow drilling winch even extended to a 4000 m logging winch

Thursday, 3 October 2019 11:20 (20 minutes)

Glaciological research requires winch systems to deploy drilling, logging and sampling equipment. The requirements in terms of pulling force, winding speed and electrical power and data transmission over the cable vary in a wide range. We started off from a shallow drilling winch design with 250 m of commonly used 5.66 mm 4-conductor cable. For the new design we aimed to increase the static pulling force as high as possible to more than 1000 daN, e.g. when breaking the core. The winding speed should vary from a fraction of 1 mm s-1, when penetrating, to more than 1 m s-1, when paying out or reeling in while moving the drill between the surface and the bottom of the hole. State-of-the-art EC motors offer the required dynamic range of more than 10 octaves. As the cable contributes a major fraction of the cross weight, we elaborated on a design with a pluggable drum to adapt to the actually required cable length for the target depth within minutes by switching drums that carry different cable length. The system performed as expected with maximal static pulling forces exceeding 1300 daN, winding speeds exceeding 1 m s-1 with moderate loads of about 200 daN and thus outperformed regularly used older winch designs with collector motors by a factor of more than three. For deployment of oceanic instruments we desired a system with at least 1000 m of single conductor oceanographic instrumentation cable with 3.12 mm cable. After changing the Lebus® sleeves we fitted 1200 m cable on the drum and tested the spool at moderate loads of up to 200 daN. For the deployment of a sediment corer under an ice-shelf 1200 m of cable with a maximal breaking load of more than 1300 daN was desired and we fitted a 3 mm Dyneema cable with a maximal break strength of 1500 daN, which performed as expected. The pulling force requirement for logging deep boreholes of up to 4000 m is only a few 100 daN and winding speeds are less than 0.5 m s-1. We increased the winch drum and the frame to fit 4000 m of the abovementioned oceanographic instrumentation cable. Initial problems with the Lebus® spool due to deforming drum flanks from Aluminium as we experienced during a first test we are confident to solve with stainless drum flanks and little modifications to the overall system. We will present the design and considerations that guided us along the process and conclude that we are surprised by the flexibility of the system and have a powerful winch system for drilling applications in the range of 100 kg cross-weight and a logging winch in the range of less than 350 kg, which is also by about 100 kg lighter than previously existing systems.

Primary authors: TELL, Jan; WILHELMS, Frank (Alfred-Wegener-Institute); HÜTHER, Matthias (Alfred-Wegener-Institut); Mr BROY, Benjamin (Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung); Mrs SCHIWEK, Svenja (Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung); Mr LEMBURG, Johannes (Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung); GONG, Da (Polar Research Center, Jilin University, China)

Presenter: TELL, Jan

Session Classification: Session 6

Contribution ID: **86** Type: **Oral**

Greenland deep boreholes inform on sliding and deformation of the basal ice

Monday, 30 September 2019 10:40 (20 minutes)

Repeated measurements of the deformation of the deep boreholes on the Greenland ice sheet informs on the basal sliding, near basal deformation and in general on the horizontal velocity through the ice. Results of the logging of the boreholes at Dye3, GRIP, NGRIP, NEEM and Camp Century through the last 40 years by the Danish Ice and Climate group will be presented and discussed. The results on the flow will be compared with the information on ice properties, impurity load and bedrock entrained material from the deep ice cores and the radio echo sounding images near the drill sites.

The results show that the basal movement often happens in an impurity rich zone above the bedrock while pure basal sliding is limited even in the presence of basal water and significant basal melt.

Most of the deep ice core sites are located close to ice divides where the surface velocity is limited so significant basal sliding is not expected. Exceptions are the surface velocities at Camp Century and Dye 3, both being 13 m/yr.

Finally, the ongoing deep drilling at EGRIP will shortly be presented where we are drilling in the center of the North East Greenland Ice Stream (NEGIS).

Primary author: Prof. DAHL-JENSEN, Dorthe (University of Copenhagen)

Presenter: Prof. DAHL-JENSEN, Dorthe (University of Copenhagen)

Session Classification: Session 1

Contribution ID: **87** Type: **Oral**

System architecture of the upcoming BE-OI ice-coring-drill drive-chain

Thursday, 3 October 2019 11:00 (20 minutes)

The upcoming deep ice-coring project Beyond EPICA Oldest Ice (BE-OI) in Antarctica requires a robust and capable electrical drive-chain. The design goal was to increase the useable mechanical power of the drill motor as well as the data transfer between the surface and the downhole section by keeping the system as compatible as possible to existing dill systems.
The system consists of a brushless-direct-drive electrical motor with controller, a high voltage DC power supply and modem pair, which operates over a 4 km long steel armoured coaxial cable. Component tests was conducted by shallow coring of about 100 m at Neumayer 3 (2016) and 80 m EastGRIP (2017). Additionally a full drive-chain test deployment was performed in the EDML borehole up to 2600m depth in December 2018.

Primary author: Mr HÜTHER, Matthias (Alfred Wegener Institute for Polar and Marine Research)

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Presenters: Mr HÜTHER, Matthias (Alfred Wegener Institute for Polar and Marine Research); LEHMANN , Josef (Cipunet®)

Session Classification: Session 6

Contribution ID: **88** Type: **Poster**

Searching for the oldest ice in Antarctica using RES method: Review and Chinese contribution

Tuesday, 1 October 2019 17:24 (4 minutes)

Oldest ice with a potential climate record over 1.2Ma on Earth has significance in revealing reasons of Middle Pleistocene Transition (MPT, occurred between ~0.9 –1.2 Ma ago). The deep ice core at Dome C provided us the longest and high resolution record of paleo-climatic change in the past of 0.8Ma with eight glacial cycles, but it's not long enough to infer what caused the earth's glacial cycle changing from ~40ka to recent ~100ka during MPT. Searching for the oldest ice in Antarctica is now an international effort, and is also the main goal of International Partnerships in Ice Core Sciences (IPICS) established by SCAR. Modelling results show that the most likely places have oldest ice exist along ice divide of East Antarctic Ice Sheet, including Dome A, Dome C, Dome F and Ridge B. Radio-echo sounding(RES) is a well-established geophysical method to measure ice thickness, subglacial topography and internal ice layers. All these are critical parameters or boundary conditions for modelling.

In the past several years, Dome C was well surveyed by both airborne and ground-based RES with high-spatial resolution grid. Based on ice thickness and subglacial topography, as well as paleo-accumulation rate and basal conditions inferred from RES results, drilling site was almost selected, and two deep ice cores will be drilled soon by Australia and Europe respectively. In Dome F, airborne RES campaign has also been launched recently. Preliminary results show oldest ice may exist there. Anyway, ground-based RES is required in future.

In Dome A, China conducted ground-based RES in 2004/05 and 2007/08. A 30km * 30km area was surveyed in a very high resolution grid. According to ice thickness, bedrock topography and internal layers, the deep ice core drilling site was located, and ice core was drilled soon after that. However, extensive airborne RES from AGAP project shows basal melting and refreeze-on ice developed in Dome A region. Modelling results with new data give a possible ice age of ~0.5Ma - ~0.7Ma at bottom, but large uncertainty exists because of unknown geothermal heat flux and ice fabrics. Anyway, Dome A is still a very likely place having oldest ice. To further evaluate ice age and search for the oldest ice in Dome A, ice fabric was studied using multi-polarization radar data, and other potential places, for example valleys with not that thick ice, are being studied. Last year, China surveyed the Ridge B area firstly using recently deployed airplane with ice penetrating radar. The RES data can help to search for the oldest ice in this region in future.

Primary authors: Dr XIANGBIN, Cui (Polar Research Institute of China, Shanghai, China); Dr WOLOVICK, Michael (Beijing Normal University, Beijing, China); Dr TANG, Xueyuan (Polar Research Institute of China); Dr JINGXUE, Guo (Polar Research Institute of China, Shanghai, China); Prof. BO, Sun (Polar Research Institute of China, Shanghai, China)

Presenter: Dr XIANGBIN, Cui (Polar Research Institute of China, Shanghai, China)

Session Classification: Session 4

Contribution ID: **89** Type: **Poster**

TRIPLE-IceCraft - A retrievable melting probe for transporting scientific payloads

Tuesday, 1 October 2019 18:04 (4 minutes)

Within TRIPLE, initiated by the DLR Space Administration, Technologies for Rapid Ice Penetration and subglacial Lake Exploration are being researched. The TRIPLE scenario is divided into three components and aims to explore the subglacial ocean of the Jovian moon Europa. The first component is a melting probe which penetrates the icy shield and navigates to the ocean below. It anchors itself at the ice water boundary and releases the second component into the water: The nanoAUV, a small autonomous submarine, will explore the ocean, identify points of interests and take samples. The samples will be transported back to the melting probe and then processed and analysed by the AstroBioLab, the third component.

We present the concept of the TRIPLE-IceCraft, a melting probe which is currently in development. It will be a modular bus system for transporting standardized payloads through ice. The current design will be suitable for the transport of a scientific payload through several hundred meters of ice penetrating into an ocean or subglacial lake and later return to the surface. For the demonstration the TRIPLE-IceCraft aims for an analog scenario at the Ekström Ice Shelf in Antarctica in 2022.

Primary authors: HEINEN, Dirk (RWTH Aachen University, Germany); Prof. WIEBUSCH, Christopher (RWTH Aachen University, Germany); ZIERKE , Simon (RWTH Aachen University, Germany); ESPE, Clemens (GSI GmbH, Aachen); FELDMANN, Marco (GSI GmbH, Aachen); Mr FRANCKE, Gero (GSI GmbH, Aachen); SCHICKENDANZ, Lars (GSI GmbH, Aachen)

Presenter: HEINEN, Dirk (RWTH Aachen University, Germany)

Session Classification: Session 4

Contribution ID: **92** Type: **Oral**

Welcome

Monday, 30 September 2019 09:00 (20 minutes)

Welcome to the 8th International Ice Drill Symposium

Primary authors: Mrs DAHL-JENSEN, Dorthe (co-chair); Mr HANSEN, Steffen Bo (Co-chair)

Presenters: Mrs DAHL-JENSEN, Dorthe (co-chair); Mr HANSEN, Steffen Bo (Co-chair)

Session Classification: Session 1

Contribution ID: **93** Type: **Poster**

The five category approach for recommissioning equipment from extended storage.

Tuesday, 1 October 2019 18:12 (4 minutes)

This paper analyzes the problems of evaluating, refurbishing and updating drill equipment, specifically the IceCube EHWD drill, which has been in long term storage for years and is needed to be put into service for an upcoming project.
The approach developed was to prioritize tasks, into five categories: with the highest priority on bringing back as many experienced team members from the original IceCube project as possible, secondly, an onsite survey of equipment, and a complete inventory, third, getting back any mission critical equipment that was repurposed to other projects, fourth, testing of any components that age or long term cold soaking might be a factor of their integrity, fifth, as the original IceCube operating system is outdated modernizing the operating system is crucial for future operations.
Using this five category process for the drill systems recommissioning helps keep the project on budget, on schedule. By using this system the IceCube upgrade has already seen savings in power generation and support equipment purchases.
If this five category of evaluating equipment is used it will be able to save money and meet project schedules on any size project that uses complicated drilling equipment.

Primary author: Mr DULING, Dennis (PSL lab, University of Wisconsin)

Presenter: Mr DULING, Dennis (PSL lab, University of Wisconsin)

Session Classification: Session 4

Contribution ID: **94** Type: **Oral**

Dome A presentation

Wednesday, 2 October 2019 11:40 (20 minutes)

Dome A presentation

Primary author: Prof. TALALAY, Pavel (Jilin University)

Presenter: Prof. TALALAY, Pavel (Jilin University)

Session Classification: Session 5