Ice Drilling Program

Dartmouth – University of Wisconsin - University of New Hampshire

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Title:	**SCIENCE REQUIREMENTS: Sonde for Retrieving a Basal Ice Core During Clean Hot Water Drilling**	
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DOCUMENT APPROVAL	
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1	Requirements for approval	10-20-2020	Christner, Scherer, Tulaczyk

Science Requirements: Sonde for Retrieving a Basal Ice Core Using Clean Hot Water Drilling

Background:
The IDP Science Advisory Board identified in the IDP Long Range Science Plan 2019-2029 a priority need to create the IDP Science Requirements for clean sample acquisition for a drill capable of fast retrieval of a core from sediment-laden basal ice. The need to retrieve basal ice samples in aqueous environments is important for a number of scientific applications, including biological studies and grounding zone assessments, where it is very likely that the basal ice will contain entrained sediment. It is envisioned that this ice coring sonde would be associated with a hot water drill tbd, for example the Roving or other drill. The sonde for the Cal Tech hot water ice coring drill designed by Englehardt, Kamb, Bolsey (J. Glaciol. 2000) may make a reasonable starting point for hot water ice coring sonde design, except that it is known that the core dogs in that drill were not functional in dirty ice. Furthermore, in deployment at both the Kamb Ice Stream (Caltech) and at the Whillans Ice Stream grounding zone (WISSARD-UCSC), slow advance of the drill head through sediment-laden ice led to an unacceptable degree of melting of the ice cylinder within the annulus. A different coring head and sonde design is needed, possibly including aspects of a rotary drill head. The logistical requirements associated with use of the sonde should be minimized such that the drill system should be useful in remote locations, and it should be compatible with clean access protocols for subglacial exploration (e.g. National Research Council, 2007). From discussions organized by IDP with iterative discussions between scientists, IDP engineers and IDP staff, the following are the science requirements for a Sonde for retrieving basal ice cores appropriate for use with Clean Hot Water Drill systems.

Scientific Requirements

1. Target ice depth: depths ranging from 200 m – 1,500 m depth, matching the depth for the hot water drill associated with the science project.
2. Ice core diameter: appx 94 mm.
3. Hole diameter in accordance with the main hot water drill.
4. Ice core length: 2 m per section preferable; 1 m per section acceptable.
5. Target drilling rate through ice is the same as the hot water drill driving the sonde.
6. The coring sonde should be operable in surrounding ice temperatures the same as the hot water drill driving the sonde.
7. The coring sonde must be compatible with procedures that reduce introduction of chemical and microbes in the subglacial environment. Fluids and lubricants for the system should be food grade.
8. The sonde design should enable minimal time for unloading of the core on the surface between runs.
9. All electrical connections and control boxes should be sealed to function well in damp environments.
10. Core quality requirements:
    a. Priority is for retrieving basal ice that may be dirty, but potential to recover core over other segments of the borehole depth may also be desirable.
    b. The minimum ice core diameter retrieved should be appx 80 mm.
    c. The minimum continuous ice piece without breakage should be appx 50 cm.
    d. Should include traps for retaining and recovering melt-out particulates that are dislodged during drilling.
11. Air transport type: the sonde should be easily transportable by Basler or light ground traverse
12. The sonde system should be compatible with a hot water drill that could be pulled on a sled between adjacent holes.
13. The sonde should be easy to connect to the rest of the drill system.
14. The sonde for the coring system should be planned and designed to avoid freezing of lines overnight, whether the sonde is within the borehole or on the surface.
15. The sonde and associated cutters should be provided with instructions for use and parts for field maintenance.
16. Core packaging materials for the retrieved basal ice core (tubes, boxes, straps) shall be provided by the logistics provider.

Discussion:

Harwood, D. comments (3 Sept. 2020; revised 15 Sept.): The following comments and questions describe scenarios and basal-ice and borehole conditions that merit additional consideration in setting scientific requirements.

Comment/Question 1: The desired drilling/coring rate of 200 m in 6 hours is perhaps achievable (= 33 m/hr). Note that the SALSA borehole drilling advanced at 13.8 m/hr average rate through 1000 m to produce a 60 cm diameter hole. The debris-ice HWD coring system might require a 20 to 30 cm diameter hole: 20 cm diameter at the cutting head to cut the ice-core, and a 30 cm diameter borehole behind the sonde to aid recovery and prevent sediment falling in behind the sonde, preventing its recovery.

Note: Drilling rate is no longer prescribed in the science requirements.

Comment/Question 2: Does the 200 m in 6 hour rate consider 'trip-time' for return of each 1 to 2 meter segment of core to the surface? Shallower cores (200 – 500 m core depths) would be recovered at a faster rate than deeper cores (500 – 1000 m core depths). Thus, it might be better to set the desired specification for a cutting/coring rate to obtain a 2 m core segment, removing trip-time from the calculation (e.g., 2 m in 20 min). Alternatively, set the specification to include trip times to recover core at the surface, but with different rates for different depths (e.g., 100 - 300 m depth at a rate of 100 m/10 hrs; 300 - 500 m depth at 75 m/10 hrs; 500 – 700 m depth at 50 m/10 hrs).

Note: Drilling rate is no longer prescribed in the science requirements.

Comment /Question 3: One other variable to consider will be the amount of debris in the ice, and whether the debris is of relatively soft and uniform sedimentary particles (till pellets), or of particles of mixed hardness comprising sedimentary, igneous, and metamorphic pebbles and sand. Thus, the cutting speed will depend on this variable, with harder pebbles requiring longer coring cutting times, or longer melting times to allow these particles to melt out of the borehole wall.

Note: The Conceptual and Engineering designs for the sonde should specify the nature and amount of debris that the sonde will be able to handle.

Comment/Question 4: Hot-water coring through debris-ice, through an extended interval of debris-ice is likely to result in the unwanted accummulation of sediment at the bottom of the borehole, which might reach a thickness so that the ice core bit is no longer able to contact the ice. Thus, a different tool/approach should be envisaged to provide a means of 'clean-out' ahead of the sonde. Some of this debris will be raining down from above the sonde, as material falls from above. Sedimentary particles will continue to fall out of the ice, and suspended material will settle out of the water to the bottom of the borehole, during intervals when the sonde is returned to the surface, to recover each ice core. See next comment. It is anticipated that much of the debris accumulated in the bottom of the borehole will be recovered in the sonde's core-barrel on top of the ice core, as the first material to enter the core-barrel.

Note: Item 10d had been added by R.S.

Comment/Question 5: Material falling from the ice-borehole wall, from depths above the sonde will have the potential to jamb-in around the sonde, thus there will be a need to enlarge the borehole above and around the sonde's active cutting interval, to ensure retrieval. The rate of cutting/coring should also consider the time to enlarge the ice borehole around and above the sonde's cutting front. Sufficient heat will be available from hot-water flowing through the sonde and out the cutting head, but the rate of downward advance of the corer, and the rate of lateral enlargement of the borehole will need to be considered in parallel.

Note: This should be considered when the Engineering Requirements are written.

Comment/Question 6: For scientific value and for operational considerations, the top of the sonde should include an open screen/mesh 'basket-sieve' to collect materials that fall out of the ice from the borehole above the sonde, or are suspended in the borehole water. These particles of variable sizes will have the potential to jamb in and around the sonde, trapping it, and also accumulate in the bottom of the borehole, hindering ice core recovery. These particles will also have scientific value and should be recovered. A screen/sieve (~5 mm size), attached to the top of the sonde could catch and contain some of this debris and filter some suspended material in the borehole water during a trip of the sonde up the borehole to the surface, to recover the ice core.

Note: This should be considered when the Engineering Requirements are written.

Comment S. Tulaczyk: It might not be feasible, but oriented ice cores may be desirable for scientists studying ice fabric.

Comment M. Albert: The requirements could be improved when the range of particle sizes can be defined.