Deep Core Drilling in Ice and Core Analysis at Camp Century, Greenland, 1961-1966

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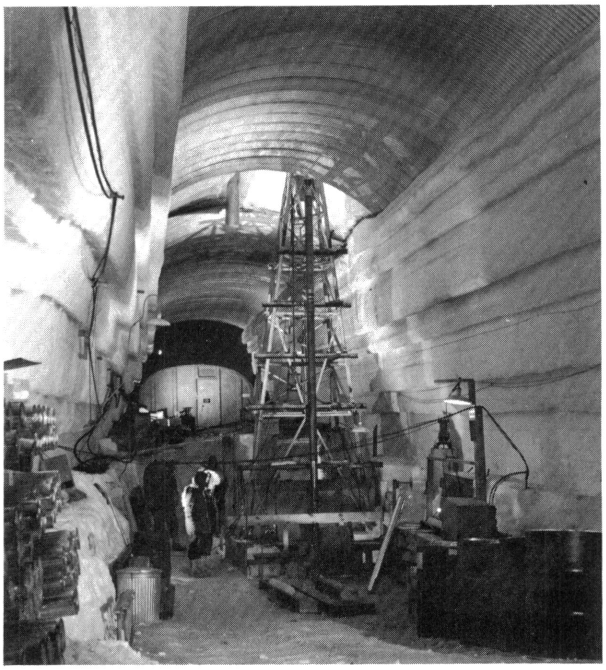
The results obtained from holes drilled by USA SIPRE (now USA CRREL), under the scientific leadership of Henri Bader, as part of the U.S. IGY glaciology program in Greenland and Antarctica, confirmed the desirability of continuous core drilling through the Greenland and antarctic ice sheets. Equipment and techniques for deep core drilling, core analysis, and drill-hole measurements were to be developed and tested in Greenland prior to their use in Antarctica.

By the summer of 1963, a thermal coring system, the CRREL drill, had been developed which can be used to drill holes in clear ice to a depth of 500 meters. Three of these drills have been made: one for drilling in Antarctica, one for the Canadian Polar Continental Shelf Project, and one for the Australian National Antarctic Research Expeditions. In the process of developing this equipment, three holes were drilled at Camp Century, Greenland (77°10′N. 61°08′W.). A 186-meter long core was recovered during the 1960-1961 season. A second hole was started in 1962 from which 238 meters of core were obtained. A third hole was started in 1963 and 264 meters of core were obtained. These holes were filled with fluid after the drilling had been completed. In 1964, the third hole was extended to 535 meters using the thermal drill in a fluid-filled hole. In 1963 the Electrodrill, an electromechanical coring drill, was used to extend the third hole to a depth of 1,002 meters. Continuous core was recovered.

In June 1966, drilling was resumed with the Electrodrill, which had been modified. On July 2, at a depth of 1,370.5 meters, ice containing silt bands and small pebbles was encountered. On July 4, after drilling through 16.9 meters of this material, the interface at the bottom of the ice cap was reached at a depth of 1,387.4 meters. The bottom material is frozen till; 3.55 meters of this material was recovered. The total depth of the hole is 1,391 meters.

For analytical purposes, the core quality is in general very good, improving to excellent at great depths. Near the bottom, unbroken cores up to 5 meters long were recovered. This entire profile is currently being studied in detail with immediate emphasis being placed on the sub-ice material. Several ice core studies (e.g., structural features, bulk density measurements, thick- and thin-section analyses, dissolved solids content, crystal size measurement, artificial radioactive reference horizons, and Pb^{210}-dating) have been completed, and others (e.g., an extensive investigation of ionic variations with depth, Si^{32} age dating, down-borehole CO_2 gas extractions for C^{14} dating purposes, volcanic dust index horizons, cosmic dust concentrations, atmospheric pollution studies, stable isotope investigations, compositional analyses of fossil atmospheres and climatological correlation of ice core data with historically recorded events) are planned or in progress. A comprehensive and detailed report on the stratigraphic analyses of an earlier 411-meter deep ice core from Site 2 in Greenland has been completed and will soon be available.



Thermo Drill Installed in Subsurface Trench at Camp Century, Greenland.

The diameter, inclination, and drift of the hole have been measured in addition to the depth-temperature profile. The minimum temperature was −24. 6°C. at 154 meters, and the bottom temperature was −13.0°C. The temperature gradient is linear in the bottom 300 meters, indicating a geothermal heat flow of 1.00 microcalorie/cm.^{2}/sec. Measurements next year may show whether the thickness of the ice cap is changing and if flow is occurring. The latter data can be compared with surface movement data being obtained by CRREL.

The Greenland core drilling has been completed and the equipment is en route to Antarctica, where preparations for core drilling to bedrock will be started in November 1966.

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Glaciology of the Ross Ice Shelf

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An analysis has been carried out of data obtained by University of Michigan field parties during the 1959-1960, 1960-1961, and 1961-1962 seasons, including the movement, regime, and morphology of the principal valley glaciers flowing into the Ross Ice Shelf. The surface velocity of Liv Glacier, measured over a period of two years by a New Zealand survey team, was found in close agreement with measurements made during a five-day period in 1962.

Ice movement, strain, temperature, and snow accumulation studies have been carried out near the western and southern margins of the Ross Ice Shelf. Rates of movement, measured on the pinnacled ice (the part of the Ross Ice Shelf lying to the south and west of McMurdo Station), are from 1 meter/year to 20 meters/year. This contrasts with the main part of the Ice Shelf off Cape Crozier, where velocities of more than 700 meters/year are found. It is evident that under present conditions, the moraine and organic material carried by ice flowing northwards from Minna Bluff takes many thousands of years to traverse the 70 kilometers to the ice front. The ice itself which flows from Minna Bluff never does reach the ice front; it is lost by melting from the upper surface and replaced by new ice forming on the lower surface of the Ice Shelf.

A Sonic Device for Measuring Thickness Changes at the Bottom of Floating Ice

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The device consists of a commercially available transducer for generating and receiving sound signals of about 400 kc./s. The output is displayed on an oscilloscope which allows a sound path of 2 meters to be resolved within ±0.1 centimeter. The transducer is kept in a fixed position (relative to the interior of the ice) at the end of a polyvinyl chloride tube which is lowered through a 10-centimeter hole in the ice at an angle of 30° from the vertical. The transducer is mounted at the same angle with the tube and "looks" vertically up at a spot which has not been disturbed by the drilling.

Two transducers were installed under sea ice of 3-meter thickness near Ice Island T-3 in November 1965 at a depth of about 1.5 meters below the ice bottom. They functioned satisfactorily until March 1966 when a propane gas explosion destroyed the instrument shelter and all cable connections. Fortunately, the oscilloscope was not in the shelter at the time.

In order to eliminate temperature drift of the oscilloscope, a third transducer, whose signals are reflected by a pin at a distance of exactly one meter, was kept in the water and used to calibrate the sound path before taking a reading of the ice echo.

During the whole time of observations there were small, irregular daily thickness changes of generally < 1 centimeter which may be associated with changes in the skeletal surface layer of growing sea ice. Between December 2 and January 17, however, the thickness decreased by 10 centimeters. After that, the ice grew steadily until March. The relationship of these changes to the temperature profile in the ice and the velocity of the relative water current is presently being evaluated.

It appears that the device described here would be suitable for measuring ablation and accretion at the underside of thick, floating ice masses such as ice islands or ice shelves, particularly the Ross Ice Shelf whose energy exchange with the underlying sea water has been a point of speculation for some time. For that application, it would be necessary to drill a vertical hole and mount the transducer on an appropriately designed arm