STRUCTURAL AND STRATIGRAPHIC STUDIES OF THE NORTHERN ELLESMERE ICE SHELF

Ernest W. Marshall*

THIS paper reports on an aspect of the glaciological program carried out on the ice shelf of northern Ellesmere Island in 1954 that was not described previously by other members of the expedition.[1] The glaciological program of the expedition to northern Ellesmere Island was supported by the Snow, Ice and Permafrost Research Establishment, Corps of Engineers, U.S. Army, to correlate with structural and stratigraphic studies conducted on ice island T3 during the period May to November 1953. Glaciological investigations were conducted principally around Ward Hunt Island, where the largest remnant of the once more extensive ice shelf exists today. The structural and stratigraphic relationships of the various ice components of the shelf were investigated because the Ellesmere ice shelf is probably the primary source area of the ice islands of the Arctic Ocean. Also, the climatic history of the area during the past periods of ice shelf formation can be deduced from these studies.

Ice cores, 3 inches in diameter, were obtained with a manually operated hand corer at selected sites on the ice shelf (Fig. 1) and in adjoining fiords and ice fields. The aluminum corer, drill rods, and tripod were of a size and weight adapted for sledge transport (Fig. 2) and for back-packing where necessary. When taking shallow cores, down to depths of 10 to 15 feet in iced firn, the rods and corer were easily hand hauled. In deeper coring, to overcome the weight of the corer and rods plus a partial vacuum created beneath the corer, a manually operated hoist was used consisting of block and tackle suspended from an aluminum tripod (Fig. 3). With similar coring equipment aided by a gasoline driven winch, a hole was cored by hand to a depth of 106 feet on ice island T3 in 1953. Cores were collected on sledge and ski trips and tentatively classified as the core site by visual examination. While on extended sledge trips cores were brought back to the trail camp for examination. Selected portions were returned by sledge to the Ward Hunt base camp for detailed study; here thin sections of the 3-inch cores were examined and photographed in polarized light. Four ice types, iced firn, glacier ice, lake ice, and sea ice, were identified as components of the ice shelf

*Glaciologist, Snow, Ice and Permafrost Research Establishment, Corps of Engineers, U.S. Army.

[1]*See also* Hattersley-Smith, G. and others. 1955. "Northern Ellesmere Island, 1953 and 1954". *Arctic*, Vol. 8, pp. 3-36.

by means of their characteristic textures seen in the sections and by field observations during the period of bare ice.

These investigations indicate that the thick primary portion of the Ellesmere ice shelf is composed stratigraphically of three major ice units. Two of these units were observed, the third is postulated, and was not encountered at the surface or in cores down to the depth of 80 feet. Seismic measurements of the ice shelf by A. P. Crary, U.S. Air Force Cambridge

Fig. 1. Petrologic field examination and photography of thin sections of ice from M'Clintock Bay. Marshall examining 3-inch ice core obtained by aluminum hand auger.

Research Center, indicate a total thickness of approximately 150 feet (Hattersley-Smith and others, 1955, p. 28).

The upper unit of the ice shelf is a sedimentary section of granular iced firn with grain diameter averaging about 1 cm. Interstratified lenses of lake ice of typical columnar structure, represent local, and in some cases widespread, ponding of meltwater during the latest period of ice shelf formation. The annual accumulation of this iced firn section was found to be approximately 3 inches per year, on the basis of vertical changes in grain size, together with the stratigraphic position of dust layers. This upper unit was observed at depths of 80 feet. It rests unconformably upon a middle unit which is also composed of granular iced firn with associated lenses of lake ice, but which has been soaked by migrating sea water. The ice surface along the depositional unconformity is marked by a widespread, heavy dirt layer, and near land areas by patches of associated gravel and sharp, irregular, avalanched rocks. The insolation received by bedrock areas along the mainland and around islands protruding through the ice shelf, warmed up the surrounding air, and has caused the accelerated ablation of the upper iced firn unit, so that the middle ice unit with its heavy dirt layer is revealed. The sedimentary nature of the middle unit is most evident on the weathered granulated exposures of the salt water-soaked iced firn. Unweathered exposures do not show such evident

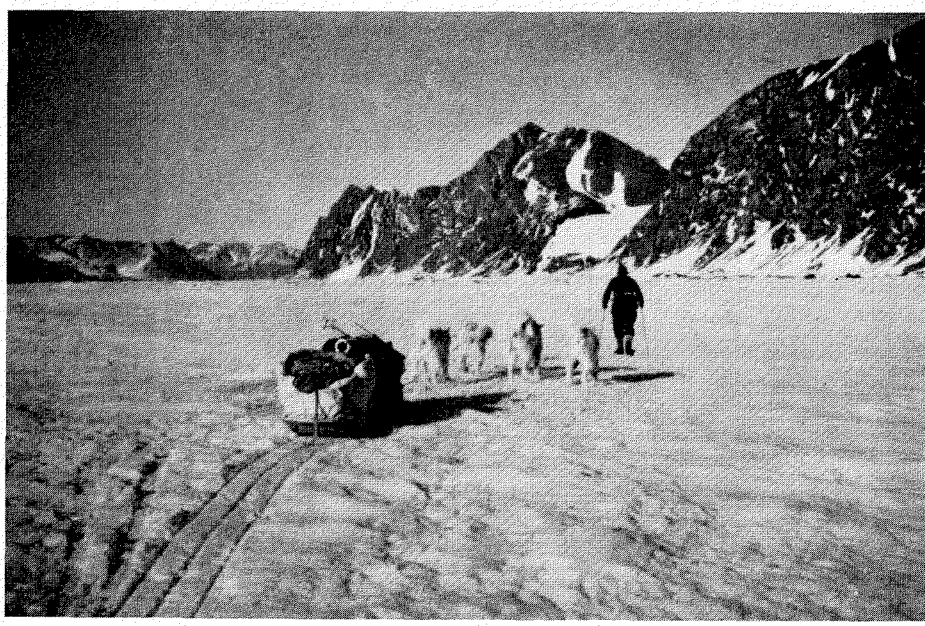

Fig. 2. Geologic and glaciological investigation of M'Clintock Bay by Christie and Marshall, June 1954. Food and scientific equipment carried on dog-hauled pulka.

stratigraphy. In most of the exposures the contact between the salt water-soaked and unsoaked iced firn coincides with the unconformity, but sometimes the salt water soaking of the iced firn extended above the unconformity into the overlying younger iced firn.

Since the lowest observed stratigraphic unit of the ice shelf fringing the coast is sedimentary, a primary basement or platform is postulated, upon which the oldest iced firn accumulated. Such basements exist at the margins of the ice shelf and in fiords behind, and serve as a platform for iced firn deposition during the cooler years of the present climatic cycle. This situation was observed in cores taken in the ice shelf re-entrant opposite Markham Bay, from which a section of shelf broke away in 1946 (Koenig and others, 1952, pp. 76–7). This re-entrant, refilled by the normal freezing of sea water and the rafting of sea ice, showed iced firn accretion in the upper 1 foot of core.

In some of the fiords behind the ice shelf which receive huge quantities of meltwater during the summer, the typical ice shelf structure has disappeared due to accelerated bottom melting and subsequent fragmentation. In these areas sea ice and lake ice structures cover the fiord and are a function of the salinity of the surface waters at the time of freeze up.

Evidence that glacier ice serves as a basement for iced firn accumulations was also found on the west shore of Markham Bay, where a local ice field

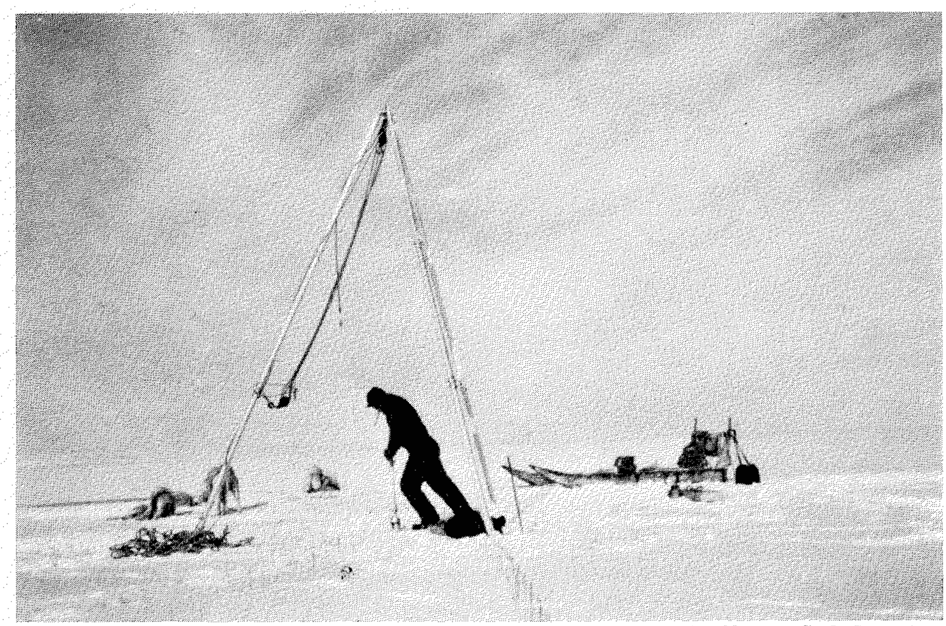

Photo: R. L. Christie, Geol. Surv. Can.

Fig. 3. Marshall coring on Ward Hunt Island ice field. Aluminum tripod breaks into 5-foot sections for ease of sledge transport.

merges with the ice shelf structure of the fiord. Portions of the ice shelf in Markham Bay have been destroyed by the ablation of meltwater, other portions have been thinned, and fractures due to tidal and wind stresses reveal ice cliffs 10 to 15 feet high, in which the ice structure could be seen. These exposures show a basement of glacier ice upon which there is up to 10 feet of iced firn. A study of aerial photographs, together with this field evidence suggest that frequently the basement accumulation was created by tributary glaciers coalescing within the fiords. Coring and surface observations in the Ward Hunt area of the ice shelf give no evidence that glacier ice is the primary basement of the ice shelf fringing this portion of the coast (Fig. 4). It is assumed that sea ice interfingering with the glacier ice or lake ice cover of the fiord provided the original basement. Thermal studies by Crary indicate that small increments of brackish or salt ice may possibly accrete on the bottom of the ice shelf (Hattersley-Smith and others, 1955, p. 30).

The initial shelf building period began with the formation and persistence of a platform of deposition upon which the iced firn gradually accumulated. As accumulation continued, the primary basement and the superimposed iced firn were depressed into the sea water, and salt water penetrated upward along intergranular channels to levels determined by the 28.5°F isotherm, the freezing point of the sea water. Both the total thickness of the iced firn deposited during the first period of shelf building, and the upper limit to which the salt

Fig. 4. Looking west across shelf ice to Ward Hunt Island from east side of mouth of Disraeli Bay.

water penetrated are unknown. Subsequent warming of the climate caused the complete ablation of the upper, unsoaked iced firn and unknown thicknesses of the section were penetrated by sea water. This ablation surface is marked by a major dirt layer due to dust layers deposited in the upper section of the iced firn and concentrated by ablation, in addition to wind blown material from adjacent land areas.

In the second, or latest period of shelf building new iced firn formed to a thickness of at least 80 feet, as proved by coring. These new accumulations were sufficient to depress the ice shelf even lower into the sea and the salt water migrating to the 28.5°F isotherm rose above the unconformity into the younger iced firn.

The present amelioration of the climate of the Arctic is indicated by the dirt layer now forming on the surface of the ice shelf as a result of prolonged ablation.

These structural and stratigraphic studies of the Ellesmere ice shelf have provided information on the structure of areas of potential ice islands and outlined the broad climatic conditions under which the present ice shelf formed. A maximum age of the northern Ellesmere ice shelf may be obtained from the Carbon 14 dating of drift wood found behind the ice shelf during the summer of 1954. The age of the organic-rich dirt from the unconformity could provide a date for the last great warming of the arctic regions. Stratigraphic and petrologic studies of ice cores collected from ice island T3 and the Ellesmere ice shelf now in progress at the Snow, Ice and Permafrost Research Establishment laboratories will provide more details of the formation, growth, and disintegration of ice shelves bordering the Arctic Ocean.

References

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Koenig, L. S., K. R. Greenaway, Moira Dunbar, and G. Hattersley-Smith. 1952. "Arctic ice islands". *Arctic*, Vol. 5, pp. 67-103.