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Polar Continental Shelf Project

Titles and Abstracts of Scientific Papers
Supported by PCSP

No.1

compiled by
G.D. Hobson and J.Voyce



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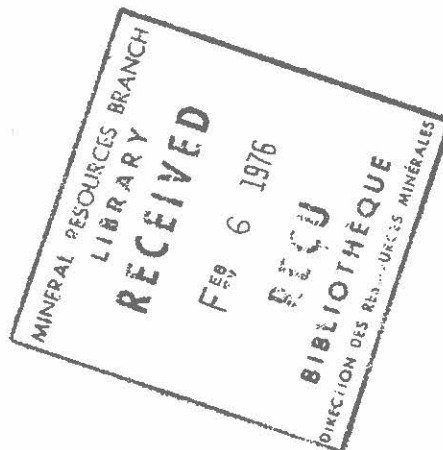
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PREFACE

In the beginning, it was decided that the Polar Continental Shelf Project would not proliferate scientific journals. Many studies under many disciplines would be undertaken or supported by PCSP and scientists would be allowed the freedom to select where they would publish the results of their investigations. It was assumed that the scientist knew where he would get the best exposure and gain the most respect amongst his colleagues. Therefore, it was decided that PCSP would not initiate a series of publications under its own flag. The only request PCSP has made to scientists is that they submit copies of their publications to the PCSP office.

You now have in your hands the first PCSP publication in the form of a bibliography. Through this medium we hope to allow those interested in the Canadian Arctic to become aware of the scientific efforts of many individuals and agencies. We hope that this itemization of scientific literature may be the starting place for new research in the Arctic and a worthwhile and useful compilation of what has been undertaken in the past.

The material in this bibliography has been set out by discipline with an author index. We readily admit that there may be some dispute amongst our colleagues as to where some papers should be filed, but in our wisdom we have tried to make an intelligent allocation. If there is no abstract to an original paper it has been impossible to include it in this bibliography. The abstracts have been reproduced with all the mistakes and eccentricities of the original publication; we hope that we have not added any new ones. We have made no changes in the literary or editorial style of the original abstracts although, as an aside, it is our opinion that many editorial changes, spelling corrections, etc. could have been made.

We point out also that we can see shortcomings in the layout of this volume before it goes to press, but we have chosen to ignore them at this time in our desire to get this volume into your hands. They will be changed in subsequent volumes.

It is our hope that this bibliography will be of use. We have already started to accumulate items for the second volume, and we would appreciate being made aware of publications we have missed and publications to come in the future.

December 14, 1973

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ARCHEOLOGY

- 0001 MCGHEE, R. - 1971
Excavation at Kittigazuit; *The Beaver*, Autumn, pp. 34-39.
- 0002 SEBISTY, J.J., PARSONS, D.E., and
ARNOLD, K.C. - 1964
Examination of metal relics found on Meighen Island, N.W.T.; *Mines Br. Can.*, Report I.R. 64-67, 15 p.
Two corroded tin-plate containers from one camp site, date unknown, and a third can from beside a cairn of known date were submitted by the Geographical Branch, Department of Mines and Technical Surveys to the Physical Metallurgy Division for metallurgical examination of the tin-plate in an attempt to establish the probable date of manufacture of the containers.
The steel used in the unknown containers was identified as of acid Bessemer grade. The basis steel sheet apparently was manufactured by the hot pack-rolling method followed by hot-dip chloride flux. Use of zinc chloride flux indicated that the tin-plate had been manufactured since 1910 and suggested that the containers were more probably left by Stefansson in 1916 or by Dr. Krueger in 1930 than by Dr. Cook in 1908.
- 0003 TAYLOR, W.E. - 1964
Archaeology of the McCormick Inlet site, Melville Island, N.W.T.; *Arctic*, vol. 17, No. 2, pp. 126-129.

BIOLOGY

- 0004 BARR, W., BARRETT, P.E., HUSSELL, D.J.T.,
KING, R.H., and KOERNER, R.M. - 1968
Devon Island programs, 1967; *Arctic*, vol. 21, No. 1, pp. 44-50.
- 0005 BARRETT, P.E., HUSSELL, D.J.T., and
WHILLANS, I.M. - 1969
Devon Island programs, 1968; *Arctic*, vol. 22, No. 2, pp. 158-160.
- 0006 BLISS, L.C. - 1972
Devon Island I.B.P. Project, High Arctic Ecosystem, Project Report 1970 and 1971; *Dept. Botany, Univ. Alta.*, 413 p.
The Devon Island Project began its field studies in May, 1970, two to three years after most other IBP ecosystem studies were initiated. The Truelove Lowland (75°40'N, 84°40'W) was chosen because of its relatively rich flora and fauna for a High Arctic area, its established camp of the Arctic Institute of North America and the resulting background research of the past 10 years, and the nearness of the area to Resolute Bay, Cornwallis Island for logistic support.
A series of lowlands along the northeast coast of Devon (Sverdrup - 26 km², Sparbo-Hardy - 86 km², Skogn - 13 km², Truelove - 43 km²) are the only ones in this part of the Island that contain relatively extensive plant cover and thus a food and shelter base for a diversity of animals. Plant cover and animal diversity are greater in those

lowlands with more scattered lakes (Truelove and Sparbo-Hardy). Similar areas in central Bathurst Island, Sherard Bay on Melville, Mould Bay on Prince Patrick, protected valleys on Axel Heiberg, Fosheim Peninsula and Lake Hazen areas of Ellesmere, and the upland southern coast of Melville Island are most of the major areas within the High Arctic (mostly north of 75°) with an adequate vegetation cover to support year-round populations of muskox, Peary's Caribou, and a variety of smaller mammals and birds. Rough estimates indicate that these areas comprise less than 3% of the approximately 400,000 km² land and ice area within the Canadian High Arctic.
The Truelove Lowland (43 km²) and Truelove Valley (3.6 km²) are a rather compact unit; isolated on the west and north by 24 km of shoreline and on the east and south by steep cliffs that rise 250 to 300 m to a plateau. Human and large mammal movement to lowlands northeast and southwest of the Truelove can go by sea ice 9-10 months of the year but in summer are restricted to going over the edge of the plateau. Thus a unique feature is its rather precise topographic limit. The south side of the Truelove Inlet and valley mark the edge of a depressed fault block on which some resistant granite outcrops occur, especially near the Truelove River delta and the northeast (Fig. 1). These outcrops comprise about 12% of the lowland including some that are calcareous. The remainder of the lowland consists of 22% lakes, 15% raised beach ridges, and 51% sedge and grass dominated meadows. The beach ridges, approximately 3,000 to 9,500 years old, and the lowland in general, result from isostatic rebound following ice retreat (Barr, 1971). Barr estimates total uplift to be 107 m and that for the first 1,000 years after deglaciation, uplift averaged 4.05 m per 100 years. The rate decreased steadily after the initial uplift and today appears to be matched by eustatic sea level rise.
The Lowland contains three large lakes, Water Lake (107.5 ha) adjacent to the beach ridge where the Base Camp is located, Char Lake (118.0 ha) to the southeast, and Phalarope Lake (179.5 ha) to the southwest. There are an additional 10 medium size and many small lakes and ponds. The Truelove River, which originates at the Devon Icecap, approximately 20 km inland, lies along the southern border of the lowland. It is not known at this time what influence it has on the lowland climate, especially during June break-up. The Gully River which flows north from a mid-point along the east cliff-face is a much smaller stream. Small streams also interconnect the lakes and in general drain to the west.
The biological diversity is considerable for a location at this latitude. There are approximately 95 species of vascular plants (Barrett, personal communication) 91 species of mosses and 170 species of lichens (Richardson, personal communication). Lichens predominate on the drier beach ridge surfaces and within the rock outcrops while mosses dominate in the sedge meadows and along streams. The greatest diversity of vascular plants occurs in the rock outcrops and drier meadows. The vascular flora of beach ridges (ca. 15 species) and the plateau (ca. 12 species) is much smaller. There are 17-18 species of breeding birds nesting in the lowland. Many

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species are insectivores but there are also herbivores (Snowy owl and Peregrine falcon). Mammal diversity is relatively large for terrestrial High Arctic areas. The only mammal not present is Peary's Caribou but these animals occurred in the recent past. The species present include collared lemming, arctic hare, and muskox as herbivores; and shorttail weasel, arctic fox, and arctic wolf as carnivores. The latter two species are present for only a relatively few days per year (25 to 100) on the Lowland. The large lakes, which are not being studied, contain arctic char, some more than 50 cm in length.

The Lowland ecosystem is being studied through an integrated, multidisciplinary approach. It was established at the start of the study that the two major habitat types, sedge meadows and beach ridges are central to the location and functioning of many species. Through a systematic inspection of a series of meadows and beach ridges, a representative one of each was selected and designated as the Intensive Study Site. Within each site a 5 x 5 m grid network was established and divided into areas for: observation only (controls), non-destructive sampling, and destructive sampling. A sufficient number of destructive sampling plots were established in 1970 to permit the random selection of plots for each of the four years of planned research. The intensive research programs for meteorology, soils, energy and water flux, plant production (both cryptogam and vascular), photosynthesis, invertebrates, decomposition and surface manipulation were all established on plots within these two habitats. It was recognized that a number of meadows and beach ridges must be investigated for the data collected to be representative of the biological diversity within the population of meadows and beach ridges. To this end, where appropriate (meteorology, soils, plant production, invertebrates, lemming) a series of meadows and beach ridges were chosen for less detailed study and were designated as Extensive Study Sites.

Details on the actual grid pattern (see Peters and Walker soils report) and the location of the intensive and extensive program for each study can be found in the respective reports. Because of the importance of the rock outcrops to lemming, weasel, fox and several bird species, it was agreed to study two or three of them in an extensive program during 1972 and 1973. In order to tie together the total biology and habitat types in the lowland, it was recognized that detailed aerial photography needed to be flown and a stereoscopically corrected orthographic map prepared. This will permit accurate mapping of many lowland features, biologic and topographic. Details of this project are included in this report.

The major objectives of the project are:

1. To determine the system's efficiency in capturing and utilizing energy;
2. To determine the environmental and biological limiting factors for the growth and development of key animals and plants;
3. To develop models of population numbers and standing crop (weight, calories, nitrogen) for the major biological components of the Lowland System;
4. To determine the limits of degrading and restoring plant-soil portions of the system by various manipulations;
5. To develop dynamic understanding and models of High Arctic Ecosystem function and the limits to its functioning induced by natural and artificial stresses.

This report of the first two years of research includes information on the major components of the system: 1) abiotic (geology, meteorology, permafrost, soils, CO₂, energy and water fluxes); 2) history of the vegetation; 3) primary producer (vascular plants, lichens, mosses); 4) production processes (photosynthesis, nitrogen fixation); 5) consumers (herbivores, insectivores, carnivores); 6) decomposers (soil microflora and microfauna); 7) manipulation studies (simulated grazing, fertilization, and soil surface manipulations); and 8) data synthesis, systems analysis and modelling. New units added in 1972 are hydrology, invertebrate bioenergetics, and primary production in rock outcrops. The basic objective is an understanding of the terrestrial portion of this High Arctic system.

No portion of this report may be reproduced without specific approval of the Project Director. Information contained herein may be cited, recognizing that the data are preliminary. This report is printed as an interim summary prior to the completion of the project in 1974.

0007 BLISS, L.C. - 1972
Devon Island, Canada, High-Arctic Ecosystem;
Biological Conservation, Elsevier Pub. Co. Ltd.,
pp. 229-231.

0008 BLISS, L.C. - 1972
I.B.P. High Arctic Ecosystem study, Devon Island;
Arctic, vol. 25, No. 2, pp. 158-161.

0009 BLISS, L.C., and TEERI, J.A. - 1971
Devon Island Programs 1970; *Arctic*, vol. 24, No. 1,
pp. 65-67.

0010 BLISS, L.C., and WEIN, R.W. - 1972
Ecological problems associated with Arctic oil and gas development; *Proc. Can. Northern Pipeline Res. Conf.*, Feb. 2-4, 1972, N.R.C. Assoc. Comm. Geotech. Res., Tech. Mem. 104, pp. 65-77.

The Canadian Arctic covers 2.5 million km², about 23 percent of the country. In this vast area there are great differences in topography, climate and biota. These point to the need for different land uses and land use regulations within an area and between areas. Vast areas of the Arctic Islands can be handled quite differently in exploration procedures than in the Low Arctic of northern Yukon and the Mackenzie Delta, yet small areas in the islands are comparable in terrain and biotic sensitivity to those of the Delta.

Data will be presented from some of the ecological research being conducted by government agencies, industry, and university groups to determine the environmental limits of Arctic exploration, oil and gas field development, and the impact of pipelines on arctic and subarctic ecosystems. Preliminary comparisons on seismic operations, use of summer and winter roads, revegetation trials and recovery of

vegetation from spillage of crude oil or diesel fuel can now be made with landscape units of the Delta and, in some cases, between the Delta and the Arctic Islands. Data will also be presented on the Devon Island IBP High Arctic Ecosystem study, including information on how a natural ecosystem functions and some of the limits to its manipulation.

0011 BURSA, A.S. - 1964

Kofoïdinium arcticum, a new Dinoflagellate;
Phycologia, vol. 4, No. 1, pp. 8-14.

A new species of dinoflagellate from the Arctic Ocean, *Kofoïdinium arcticum*, is described. Closely similar to the warm-water *K. velloides* Pavillard, it is nevertheless clearly distinct on the basis of several morphological characters. Although placed in the dinoflagellates, it differs structurally from typical members of the group. Its bipolarity is defined by the location of the cytostome which possibly corresponds functionally to the dorso-ventral area of other dinoflagellates.

0012 COLEMAN, R.W. - 1972

Certain aquatic plant-invertebrate interrelationships from Newfoundland, Canada; *Abstract*, 35th Annual Mtg., Amer. Soc. Limnology & Oceanography, March 19-22, Tallahassee, Florida.

From a biological survey of certain areas of Newfoundland in 1967 the following algae were collected: *Alaria* sp., *Blidingia minima*, *Chorda filum*, *Dictyosiphon lubrica*, *Enteromorpha intestinalis*, *Fucus distichus*, *Fucus distichus* subsp. *edentatus*, *Fucus spiralis*, *Fucus vesiculosus*, *Halosaccion ramentaceum*, *Monostroma fuscum*, *Pilayella littoralis*, *Polysiphonia urceolata*, *Porphyra umbilicalis*, *Rhodomela confervoides*, *Rhodymenia palmata*, *Scytosiphon lomentaria*, *Spongomorpha arcta*, *Ulothrix flacca* and *Urospora mirabilis*. The following invertebrates were collected: *Ulothrix flacca*, *Buccinum undatum*, *Galliopus laeviusculus*, *Caprella septentrionalis*, *Gamarellus angulosus*, *Gamarellus homari*, *Gammarus oceanicus*, *Gammarus serosus*, *Hyale nilssonii*, *Hyalella azteca*, *Idothea baltica*, *Ischyrocerus anguipes*, *Jaera* sp., *Lacuna vineta*, *Littorina littorea*, *Littorina saxatilis*, *Lunatia heros*, *Macoma balthica*, *Margarites groenlandicus*, *Mya arenaria*, *Mytilus edulis*, *Nucella lapilla* and *Nucella lapilla* forma *imbricata*. Interrelationships of these organisms are discussed and illustrated. Dr. R. Tucker Abbott, Dr. Robert K. Lee and Dr. Don Steele identified specimens.

0013 GRAINGER, E.H. - 1962

Arctic Unit of Fisheries Research Board of Canada field activities in 1960; *Polar Record*, vol. 2, No. 72, pp. 277-278.

The objectives of the Arctic Unit remain the assessment of fisheries and aquatic mammal resources in the Arctic Regions, and the establishment of a basis of biological information for their rational management. Knowledge of the zoogeography and ecology of aquatic species in the region is still incomplete, but it is evident that productivity is relatively low, and fisheries and marine mammal exploitation have been developed mainly on a small scale as an aid to local economies.

The present headquarters of the unit in Montreal are now inadequate and a new building is planned. In the field the unit operates two small vessels, the 49 ft. diesel ketch 'Calanus' and the 38 ft. exploratory fishing vessel 'Salvelinus'.

0014 GRAINGER, E.H. - 1965

Zooplankton from the Arctic Ocean and adjacent Canadian waters; *J. Fish. Res. Bd. Can.*, vol. 22, No. 2, pp. 543-564.

Zooplankton collections from the Arctic Ocean, the Beaufort Sea, and northwestern Canadian coastal waters are described, along with physical characteristics of the waters sampled. About 50 species are included.

The collections are compared with records from the central Arctic Ocean and other waters adjacent to the present region. The species are shown to fall into three groups. One is characteristic of the surface water of the Arctic Ocean, one of the Atlantic water and to a lesser extent the deep layer of the surface water of the Arctic Ocean, and one of the shallow peripheral seas of the Arctic Ocean.

The surface water group includes eight species which account for more than 95% of the copepod individuals found in the surface layer, and which appear to be the only copepods which breed in the surface layer of the central Arctic Ocean. The same species are the major constituents of the zooplankton found in the waters of the Canadian arctic, from the Arctic Ocean to Davis Strait. The deeper Atlantic species of the Arctic Ocean, more numerous as species but far less numerous as individuals than those of the surface water, occur only very rarely in the surface layers, show no evidence of breeding there, and appear to be almost entirely absent from Canadian archipelago waters inside the shelf. Clear continuity of the Arctic Ocean surface fauna through the waters of the Canadian arctic is shown, along with the almost total exclusion from archipelago waters of the deeper Atlantic fauna. This intrusion of Atlantic species into the waters of arctic Canada appears to be almost entirely restricted to the southeast part of the region, especially Hudson Strait and adjacent waters.

Development rates of two copepods in the Arctic Ocean, *Microcalanus pygmaeus* and *Calanus glacialis*, are discussed.

0015 GRAY, D.R. - 1970

The killing of a bull muskox by a single wolf; *Arctic*, vol. 23, No. 3, pp. 197-199.

Although there are many reports in the literature describing successful attacks of the wolf (*Canis lupus*) on muskoxen (*Ovibos moschatus*), the following observation of a single, male wolf attacking and killing a lone bull muskox is, to my knowledge, unique (see Hone and Tener for a review). The killing was observed from a distance of approximately 1 mile, using a 15 x 60 spotting scope, during a study of the behaviour of muskoxen (*Ovibos moschatus wardi*) on Bathurst Island, Northwest Territories.

0016 GRAY, D.R. - 1973

Social organization and behaviour of muskoxen (*Ovibos moschatus*) on Bathurst Island, N.W.T.; unpub. Ph.D. Thesis, Univ. Alberta, 212 p.

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The social organization and behaviour of a free-living high arctic population of muskoxen (*Ovibos moschatus*) was studied during summer and winter. The study population size was lowest in early summer and rose to about 100 in early winter. Limited resightings of tagged muskoxen suggest frequent movements between the study area and other grazing areas on the island. Few solitary bulls and no calves or yearlings were observed between May 1968 and May 1970. Sex ratios in herds approximated equality and few single-sex herds were seen. The activity cycle for muskoxen consisted of alternating periods of feeding and resting-rumination of about 150 minutes duration. Activity within most herds was synchronized but large winter aggregations did not show this same synchrony. Some animals remained together as a single herd or part of several different herds for up to three months. Other herds were less stable with much mixing, joining and splitting of herds occurring. During most daily feeding movements leadership was not evident but certain individuals did influence other herd movements.

Grooming and drinking were infrequent. Feeding behaviour in winter was variable, depending on snow conditions, but usually consisted of removing snow cover by pawing. In winter herds grazed in broad valleys rather than on wind-swept hillsides. No evidence of grouping during winter storms was noted.

A linear dominance hierarchy was present among the bulls of herds studied intensively. Displacements from winter feeding craters and the initiation and outcome of butting and charging interactions were closely related to the dominance position of the individuals. Broadside displays and gland-rubbing displays were usually performed by dominant bulls. The dominant bull acted as herd leader in situations of disturbance and during some herd movements. Joining of two herds occurred with no overt interactions, after dominance or threat displays by a dominant bull or after a clashing fight between two dominant bulls. Behaviour patterns seen during between-herd interactions also occurred in interactions with caribou, humans and attacking wolves. Behaviour patterns apparently unique to the muskox are the rubbing of the preorbital gland against the foreleg and the pressing together into a line or rough circle as a defence against predators.

During the expected rutting season, no copulations were seen. Muskox bulls performed sniffing, lip-curling and foreleg kicking and only rarely, mounting behaviours. Many courtship behaviours were performed by dominant bulls. Cows did not appear receptive. The sex ratio in herds remained the same and no harem-formation or tending-bond behaviour was observed. An increase in completeness of courtship behaviour and the presence of calves in 1971 indicate a return to a breeding condition in the population.

0017 HEYLAND, J.D. - 1972

Vertical aerial photography as an aid in wildlife population studies; *1st Can. Symp. Remote Sens.*, pp. 121-136.

The advantages and disadvantages of visual censuses of wildlife populations are discussed. It is noted that oblique photographs have limited use in census procedures and are most useful for panoramic, illustrative purposes. It is suggested that vertical photography provides the best method of censusing many animal and bird populations. Vertical photography of the population of Greater Snow geese, during the spring and fall migration periods along the St. Lawrence River, has made it possible to accurately census the geese, distinguish young from adults, to separate family units, to determine ranges of brood sizes and mean broods, and to obtain age ratios. Experimental vertical photography has shown that several species of waterfowl, some terrestrial ungulates, narwhal, and beluga could probably be accurately censused using this technique.

0018 LEE, R.K.S. - 1973

General ecology of the Canadian Arctic benthic marine algae; *Arctic*, vol. 26, No. 1, pp. 32-43. The Canadian Arctic marine flora is basically a regional extension of Atlantic species. As the extreme environmental conditions of low temperature, low salinity and long periods of darkness intensify towards the western and northern parts of the Canadian Arctic, there is a marked reduction in the number of species. The protective cover of sea ice, together with the seasonal development of a low salinity layer from ice melt, hinders mixing between water layers, and nutrient replenishment is apparently a critical problem. Communities are generally small and isolated largely because of substrate limitations. A population may be extensive and dense, but this is attributed to the small number of species and the relative ineffectiveness of most of these in competing for the available space. Following seasonal ice melt, the intertidal habitat in colder regions remains unsuitable for algal growth, because of its exposure to a combination of adverse climatic and oceanographic conditions. The decreasing diversity of species, as the physical conditions become more adverse, together with the nearly complete absence of endemics, indicate a low level of adaptation, and the arctic communities are judged to be ecologically immature.

0019 LEE, R.W. - 1966

Ecological study of the Mould Bay marine algae; unpub. M.A. Thesis, Univ. Mass., 47 p. The influence of salinity, bottom type, and especially illumination on the distribution of the benthic algae in an ice covered arctic marine environment (Mould Bay, Prince Patrick Island, 76°N, 120°W) was studied in the summer of 1964. In this hitherto phycologically unexamined region of the Canadian Archipelago 31 species of attached marine algae were found, all of which are common to the Atlantic flora. After winter salinities of ca. 34 ‰, the majority of attached sublittoral algae were exposed to salinities as low as 15 to 20 ‰ in July and early August when runoff from melt was high. Three species of algae were found restricted to the upper sublittoral and littoral zones where the salinity was commonly less than 3 ‰.

On bottoms illuminated by more than 200 ft-c (daily average intensities) algae occurred equally on the three sedimentary bottom types (sand, firm mud, and soft mud) which predominate in Mould Bay. At intensities as low as 10-20 ft-c few species and little plant mass were recovered from the soft mud bottoms in contrast to the other bottom types.

Several actively growing attached algae were recovered from bottoms receiving ca. 8 to 15 ft-c in June and July. No plant life was found on bottoms illuminated by less than 5 ft-c. Assuming that the respiratory needs of arctic multicellular algae are satisfied by ca. 5 ft-c, photosynthesis alone might explain the observed growth of attached algae in Mould Bay. An estimation of the seasonal variation in submarine illumination at Mould Bay in 1964 is presented. It is suggested that an obligate photoautotrophic form of nutrition may be sufficient for algal growth and survival in spite of extremely low light intensities followed by almost total darkness for over half the year.

0020 MacDONALD, S.D. - 1970

The breeding behaviour of the rock ptarmigan; *The Living Bird*, Cornell Lab. Ornithology, pp. 195-238. All arctic birds seem to acquire a special beauty on their breeding ground, and once removed from it their plumage loses its brilliance and its evanescent vitality which is its characteristic. When we think of birds that are truly beautiful, few of us even consider the Rock Ptarmigan. Its basic white plumage of the cold months seems purely utilitarian, as does the drab, cryptically colored brown of the summer. To appreciate what a splendid creature the Rock Ptarmigan really is, one must see it in life in its arctic environment. The winter plumage, so flat and chalky white in museum skins, is vivid in the living bird. When the arctic sun is low, the delicate blues and pinks of the wind-sculptured snow impart to it an opalescent glow; against the blue of the sky or dark bare ground the ptarmigan can be dazzling white. The brown plumage against the tundra is truly a marvel of camouflage, and a simple description of the exquisite blending of soft, earth colors conveys a sterile image as compared with the bird in life.

Throughout the short arctic spring and summer the Rock Ptarmigan molts almost continuously and three distinct plumages are recognized (Salomonsen, 1950-1951). In early spring its immaculate whiteness matches the snow in the strong light of the arctic day. As the snow melts and extensive areas of bare ground appear, the appearance of patches of brown plumage on the bird keeps pace with the disappearance of the snow. Again, in autumn, the piebald plumage matches the piebald landscape; and as winter advances, the fresh white plumage, now flushed with pale pink, harmonizes with the new snow in the low light of the declining sun.

The Rock Ptarmigan (*Lagopus mutus*), a circumpolar grouse, is the most boreal of the three ptarmigan in Canada (Godfrey, 1966). There its breeding range extends to the edge of the Arctic Ocean. This paper deals with the life history and behavior of a high-arctic population on Bathurst Island, Northwest Territories, and is based on detailed

field studies from 18 May to 15 August 1968 and during May and June 1969. The colleagues and students who assisted me either one or both summers were: David F. Parmalee, Philip Taylor, David Gray, Pierre Lamothe, and C.G. Hampson.

0021 MacDONALD, S.D., AND PARMELEE, D.F. - 1962
Feeding behaviour of the Turnstone in Arctic Canada; *British Birds*, vol. 55, pp. 240-243.

This short paper has been written in response to the editorial comments following the interesting observations by D.G. Bell and Bernard King on "Turnstones feeding on bread" (*Brit. Birds*, 54: 325-326).

In 1955 we spent six months on northern Ellesmere Island, Northwest Territories, conducting field studies to obtain information for the National Museum of Canada on the breeding cycles of birds in the far north. The principal area of investigation was Fosheim Peninsula, two thousand square miles of mountains and tundra plain to the north of the 79th parallel. Base camp was the joint Canadian-U.S. Weather Station of Eureka (80°00'N, 85°56'W). During the season we recorded 23 species of birds, and obtained nesting data on all except three of these. One of the species studied in detail was the Turnstone (*Arenaria interpres*).

0022 MAYFIELD, H.F. - 1973

Black-bellied Plover incubation and hatching; *Wilson Bull.*, vol. 85, No. 1, pp. 82-85.

Black-bellied Plover incubation and hatching. - The Black-bellied Plover (*Squatarola squatarola*) has been little studied on its nesting ground in the Arctic. There has been some confusion about its usual incubation period, and so far as I am aware no one previously has watched the bird from a blind for any considerable time during incubation and hatching. Therefore, I am summarizing observations made in 1970 and 1971 mainly on two nests located in the interior of Bathurst Island, N.W.T., Canada.

0023 McALPINE, J.F. - 1961

Preliminary report on the insects of the Isachsen area, Ellef Ringnes Island, 1960; *Arctic Circular*, vol. 14, No. 4, 2 p.

0024 McALPINE, J.F. - 1964

Arthropods of the bleakest barren lands: composition and distribution of the Arthropod fauna of the northwestern Queen Elizabeth Islands; *Can. Entomologist*, vol. 96, No. 1-2, pp. 127-129.

The Northwestern Queen Elizabeth Islands, i.e., Meighen, Ellef Ringnes, Amund Ringnes, King Christian, Loughheed, Borden, Mackenzie King, and Brock, constitute the most barren part of the high arctic fell field. Within this group, the richest area is at Isachsen on Ellef Ringnes Island; there the relief is higher and the variety of habitats greater and richer than at any other place on any of these islands. Despite this relative richness, however, Isachsen has the coldest summer climate of any arctic weather station (July mean, about 38°F.) and the smallest arthropod fauna (55 species of spiders, mites, collembolids and insects, according to studies conducted there in 1960) of any locality investigated during the Northern Insect Survey.

BIOLOGY

0025 McALPINE, J.F. - 1965

Insects and related terrestrial invertebrates of Ellef Ringnes Island; *Arctic*, vol. 18, No. 2, pp. 73-103.

0026 McDONALD, I.J., QUADLING, C., and CHAMBERS, A.K. - 1963

Proteolytic activity of some cold-tolerant bacteria from Arctic sediments; *Can. J. Microbiology*, vol. 9, pp. 303-315.

A number of Gram-negative cold-tolerant bacteria capable of growth on agar at 0°C but not at 25°C were isolated from Arctic littoral and marine sediment samples. Eight of these organisms able to hydrolyze gelatin were chosen for study. Taxonomically these organisms consisted of an unidentified but closely related group of seven cultures and a single *Pseudomonas* strain. Culture supernatants of these Arctic organisms contained proteinases that hydrolyzed gelatin, casein, and β -lactoglobulin, but not bovine plasma albumin. When casein was the substrate, the proteinases were most active at pH 7.0 to 8.0 between 30° and 40°C and were inhibited by ethylenediaminetetraacetic acid. The proteinases were relatively heat-labile; the activity of the most heat-labile was reduced by 90% in 20-30 minutes at 40°C and that of the most heat-stable by 90% in 45 minutes at 50°C. Proteinases of the unnamed group of Arctic organisms were characterized by a low temperature characteristic and possession of high enzymic activity at low temperatures. Presumably such organisms can convert protein to simple nitrogenous compounds in the Arctic environment.

0027 MILLER, F.L., RUSSELL, R.H., and URQUHART, D.R. - 1973

Preliminary surveys of Peary caribou and muskoxen on Melville, Eglinton, and Byam Martin Islands, Northwest Territories, 1972; Prel. Report, *Can. Wildlife Service*, CWSC 1422, 51 p.

In 1972 the Northwest Territories Game Management Service advised the CWS that they were considering plans for harvesting Peary caribou (*Rangifer tarandus pearyi*) on Melville Island by Eskimos, and requested an evaluation of the possible impact on the caribou population. Because of the N.W.T. G.M.S. request investigations were begun there. Aerial surveys in 1972 were carried out by CWS on Melville Island and the adjacent islands of Eglinton (lat. 75°45'N, long. 118°30'W) and Byam Martin (lat. 75°20'N, long. 104°20'W).

The only extensive aerial survey of muskoxen (*Ovibos moschatus*) and caribou on the Queen Elizabeth Islands, N.W.T., was conducted by CWS in the summer of 1961 (Tener, 1963). Tener (1963) estimated that in July, 1961 almost half of the total Peary caribou on the Queen Elizabeth Islands were on Melville Island (lat. 75°30'N, long. 111°00'W).

0028 SAVILE, D.B.O. - 1961

Bird and mammal observations on Ellef Ringnes Island in 1960; *Natural History Papers*, Nat. Mus. Can., No. 9, 6 p.

Collared lemmings were plentiful and arctic weasels occasional. Peary caribou and ringed seal were

scarce. One white-faced musk-ox was doubtfully reported. Breeding birds, in decreasing abundance, included Snow Bunting, Brant, Long-tailed Jaeger, Rock Ptarmigan, Knot, Baird's Sandpiper, Glaucous Gull, and perhaps Hoary Redpoll. The breeding bird density near Isachsen was estimated to be ca. 0.15 adults per 10 acres. In sandy parts of the island the density must have been even less. It is thought that a high lemming population contributed to the breeding success of several birds through diversion of predation pressure.

0029 STIRLING, I., and JONKEL, C. - 1972

The great white bears; *Nature Canada*, vol. 1, No. 3, pp. 15-18.

The polar bear, like the muskox and Peary caribou, is a year-round resident of the Far North. Once thought to be in danger of extinction, it now appears to be safe throughout most of its range. In Canada, this range extends from the permanent pack ice of the Arctic Ocean and the high arctic islands to southern James Bay at the same latitude as Calgary. In fact, the area between Cape Churchill and the Nelson River in Manitoba is one of the largest and most concentrated polar bear denning areas in the world.

0030 TIDMARSH, W.G. - 1973

The Copepoda (Calanoida, Cyclopoida) of northern Baffin Bay and southern Nares Strait: Their distribution and aspects of their biology; *Arctic Inst. N. Amer.*, Sc. Rept. No. 3, 181 p.

Plankton samples collected at sixty stations in northern Baffin Bay and southern Nares Strait between 1968 and 1970 are analyzed. Thirty-six copepod species are identified. Their distributions are controlled by bathymetric and oceanographic features of these regions. Distributions of indicator species reflect the movement of water masses. Zoogeography is discussed. Six species belong to the Atlantic fauna; three are Atlantic expatriates. Thirty species belong to the Arctic fauna; six are Arctic Basin expatriates. Differences between the relative importance of several species in the Arctic Ocean and Baffin Bay communities are discussed.

Life cycles of nine species and adult female sizes of four species are analyzed and related to the presence of the North Water. The open water has a greater effect on reproduction than on growth in two herbivorous *Calanus* species. The effect is less marked in *Metridia longa* and is negligible in deeper living carnivores and omnivores.

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0004 BARR, W., BARRETT, P.F., HUSSELL, D.J.T., KING, R.H., and KOERNER, R.M. - 1968

Devon Island programs, 1967; *Arctic*, vol. 21, No. 1, pp. 44-50.

0031 BARRETT, P.E., and TEERI, J.A. - 1973

Vascular plants of the Truelove Inlet region, Devon Island; *Arctic*, vol. 26, No. 1, pp. 58-67. Ninety-three species of vascular plants are recorded from a 16 sq. mile coastal lowland on the northern coast of Devon Island, Northwest Territories. The

following taxa are apparently new records for Devon Island: *Cystopteris fragilis*, *Woodsia alpina*, *Equisetum variegatum*, *Poa alpigena*, *Carex amblyorhyncha*, *Draba oblongata*, *Saxifraga tenuis*, *Epilobium arcticum*, *Hippuris vulgaris*, *Pedicularis lanata*, *Puccinellia vaginata* var. *paradoxa*. These additions bring the total known flora of Devon Island to 115 species. The Truelove flora is part of the High Arctic biogeographic element of the Canadian Arctic Archipelago. However, a distinct element of species of more southerly distribution is present probably due to the moderating influence of the lowland environment.

0005 BARRETT, P.E., HUSSELL, D.J.T., and WHILLANS, I.M. - 1969
Devon Island Programs, 1968; *Arctic*, vol. 22, No. 2, pp. 158-160.

0032 BLISS, L.C. - 1971
Arctic and alpine plant life cycles; *Ann. Rev. Ecology & Systematics*, vol. 2, pp. 405-438.
Of the world's major biomes, tundras, including Antarctica and Greenland, occupy about 15% of the land surface. These treeless areas, above treeline (alpine) or beyond treeline latitudinally (arctic), contain relatively few plant species. The plants that are preadapted to tundras have been selected by environmental regimes that contain less biologically usable energy than in other biomes. Yet Hare (78) has shown that even in the Canadian Archipelago the Arctic is not a heat sink on a yearly basis, for solar radiation amounts to 35-40 kilocalories/year (0-5 kly/year in net radiation), compared with 15-20 kly/year at treeline in Alaska and Keewatin. While altitudinal and latitudinal treeline conforms quite well to the 10°C mean for the warmest month, Bryson (46) reports that the northern limit of trees also corresponds with the southern limit of the arctic frontal zone in summer. This dynamic boundary may be controlled by vegetational differences in albedo and surface roughness.
The functioning of plants, as influenced directly and indirectly by temperature, becomes central in determining the various strategies that have evolved to enable them to cope with these heat-deficient ecosystems. The purpose of this review is to bring together recent information and theories on the adaptive mechanisms which enable plants to survive and function in environments with cool, short summers and cold, long winters - save for tropical alpine environments where "winter" comes nearly every night - and, where possible, to relate these findings to the pattern of species and communities in different tundras.
Much research has been done in recent years on the floristics, plant communities, soils, ecophysiology, and now the ecosystems of different tundras. A few key books and articles that speak to this background of information are those of Schroeter (169), Sørensen (176), Polunin (150, 152), Bliss (31), Tikhomirov (189), Tranquillini (195), Billings & Mooney (27), Johnson (97), and Heal (79).
A renewed interest in arctic ecology has occurred with oil and gas discovery in Siberia, Alaska, and Canada in the past several years, interest which now focuses on the fragility of arctic ecosystems

and their ability to maintain themselves in a reasonably steady state with the impact of man and machines. A good deal of this concern centers on the ability of plants to reinvade disturbed sites, and thus studies of adaptive mechanisms and life cycle strategies become central.

0006 BLISS, L.C. - 1972
Devon Island I.B.P. Project, High Arctic Ecosystem, Project Report 1970 and 1971; *Dept. Botany, Univ. Alta.*, 413 p.
Abstract under 0006

0007 BLISS, L.C. - 1972
Devon Island, Canada, High-Arctic Ecosystem; *Biological Conservation*, Elsevier Pub. Co. Ltd., pp. 229-231.

0008 BLISS, L.C. - 1972
I.B.P. High Arctic Ecosystem study, Devon Island; *Arctic*, vol. 25, No. 2, pp. 158-161.

0009 BLISS, L.C., and TEERI, J.A. - 1971
Devon Island Programs 1970; *Arctic*, vol. 24, No. 1, pp. 65-67.

0010 BLISS, L.C., and WEIN, R.W. - 1972
Ecological problems associated with Arctic oil and gas development; *Proc. Can. Northern Pipeline Res. Conf.*, Feb. 2-4, 1972, N.R.C. Assoc. Comm. Geotech. Res., Tech. Mem. 104, pp. 65-77.
Abstract under 0010

0033 BLISS, L.C., and WEIN, R.W. - 1972
Plant community responses to disturbances in the western Canadian Arctic; *Can. J. Bot.*, vol. 50, No. 5, pp. 1097-1109.
Data are presented on several current studies being conducted in the Mackenzie Delta and the Arctic Archipelago in relation to oil and gas exploration. Tundra fires destroy most of the aboveground plant cover and result in significant increases in depth of the active layer. Fire stimulated the growth and flowering of *Eriophorum vaginatum* subsp. *spissum* and *Calamagrostis canadensis*. The recovery of dwarf heath shrubs from rhizomes was relatively rapid while lichens and mosses showed no early recovery. Crude oil spilled in different plant communities killed the leaves of all species, yet regrowth occurred on some woody species the same summer and more species showed regrowth the second summer. Oil spilled in early winter (October) and in wet sedge communities in summer appeared to be most detrimental. Percentage plant removal has been significantly reduced with changed seismic technology in the past 6 years. Native species, often from rhizomes, reinvade all lines though recovery on peats and by native grasses appears most rapid. Winter roads of compacted snow were less detrimental to wetland sedge communities than to upland dwarf shrub-sedge-heath ones. Upland sites, which were dry in summer, were more difficult to revegetate. The revegetation studies indicated that 100 kg/ha of elemental nitrogen and 200 kg/ha of phosphorus treatment was best and that early spring or late fall seeding was essential. About five perennial plus two annual

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grass species in varying mixtures grew best in the reseeded trials. The supply of available nitrogen appears to strongly limit plant growth of native species while phosphorus does not. Most of these nutrients are retained in the organic mat, thus any disturbance that destroys this mat will seriously modify normal nutrient cycling and greatly increase the need for fertilizer in revegetation.

In the High Arctic most soils are wet during snow melt and thus subject to surface disturbance by vehicles. In the polar deserts, silty and sandy soils dry rather rapidly and show less evidence of disturbance later in summer. Lowland areas where there is a more complete cover of plants on wet shallow peats or silty soils are subject to rutting throughout the summer as in the Low Arctic. With surface disturbance there is much less thaw of the permafrost than occurs in the Delta. The different plant community - topographic - soil - ground ice landscape units or systems respond differentially to the different surface disturbances tested to date. This is true in both the Low and High Arctic.

0034 COLEMAN, R.W., and FERGUSON, J.S. - 1972
Southern Northwest Territory, Canada willows; *Abstract*, 84th Session, Iowa Acad. Sc., April 28-29, Univ. Iowa.

The following willows were collected in the summer of 1966 from various areas of southern Northwest Territory, Canada; *Salix bebbiana* Sarg., *Salix glauca* L., *Salix interior* Rowlee and *Salix planifolia* Pursh. *Salix bebbiana* Sarg. was the commonest species of the study area, being reported in over 70% of the collections. Biological notes on these plants are discussed and illustrated. Dr. George W. Argus identified these specimens.

0035 ELCOCK, W., BARRETT, P., and TEERI, J.A. - 1972
Devon Island Programs 1971; *Arctic*, vol. 25, No. 2, pp. 155-158.

0036 ELCOCK, W., HOYER, M., BARRETT, P., and SCHULTEN, R. - 1973
Devon Island programs 1972-1973; *Arctic*, vol. 28, No. 1, pp. 81-82.

0037 HARE, F.K., and RITCHIE, J.C. - 1972
The boreal bioclimates; *Amer. Geog. Soc. N.Y.*, July, pp. 333-365.

Perhaps within the next decade - and certainly within what is left of this century - the Boreal forest of North America (Fig. 1) will be massively altered by economic invasion. Already the southern margin has suffered widespread cutting by loggers who practice their craft with the ruthlessness so typical of our continent's pioneers. The tundra to the north is threatened by the search for oil and natural gas. Communication lines increasingly thread the forest. The last great cohesive wilderness is about to be irreversibly altered. There is little time left to record its nature.

Several reasons, other than the imminence of human invasion, make this a good time to review the forest's status, and especially its links with climate. The two decades that have intervened since

an earlier study of this formation have seen extensive field investigations of its structure all around the pole, not least in North America. Fresh evidence is accumulating from satellite data, which reveal detail not accessible by any other technique. And the climatologist can now present a good estimate of the energy and moisture regimes in the Boreal zone. This review is directed toward the bioclimate, interpreting that term much as Dansereau does, with a spatial as well as a temporal component. We believe that regular links exist among climate, vegetation, and soil in this zone and that these links constitute complex zonal systems rather than simple linear controls of the living cover by climate.

0038 HATTERSLEY-SMITH, G. - 1961
North-western Queen Elizabeth Islands (Polar Continental Shelf Project and Geographical Branch, Department of Mines and Technical Surveys); in *Can. Geophys. Bull.*, No. 14, pp. 96-98.

0039 HILLS, L.V., and OGILVIE, R.T. - 1970
Picea banksii n. sp. Beaufort Formation (Tertiary), northwestern Banks Island, Arctic Canada; *Can. J. Bot.*, vol. 48, No. 3, pp. 457-464.
Picea cones of late Tertiary age, from northwestern Banks Island, Arctic Canada, are described and illustrated. Extremely good preservation allowed measurements on cone length and width, scale length and width, seed wing length, and bract length, width, and number of teeth. In addition, ratios such as scale length to width; seed length to width; seed length; and bract length to scale length are calculated. Comparison is made with extant species of *Picea* and it is concluded that the fossil is most closely related to *Picea glauca*. It is suggested that a *Picea glauca* type was ancestral to many Northern Hemisphere spruce.

0040 JANKOVSKA, V., and BLISS, L.C. - 1972
Pollen and macroscopic analysis of a peat mound profile, Truelove Lowland; in Devon Island I.B.P. Project High Arctic Ecosystem Project Report 1970 and 1971, Dept. Botany, Univ. Alta., pp. 105-112. Because of logistic difficulties and the general shallow nature of peats, Post-Wisconsin paleobotanical information from the High Arctic is scanty (Fredskild 1969, Hegg 1963). Peat depths in many lowlands are only 10 to 20 cm and in most upland areas less than 5 cm. The raised center polygons in the "Truelove Lowland with peats 1.5 to 2.0 m in thickness thus provide a unique opportunity for pollen analyses. Peat mounds, approximately 5 ha in area are located on the north side of Phalarope Lake, southwest of the AINA Base Camp. They have been subjected to continuous frost activity which reworked the area into a topographically distinct net of high centred peat polygons, 1-2 m high and with deep ice wedges. The diameter of the polygons ranges from 5 to 15 m maximum active layer depth is 20 to 25 cm.

0041 KUC, M., and HILLS, L.V. - 1971
Fossil mosses, Beaufort Formation (Tertiary) Northwestern Banks Island, Western Canada Arctic; *Can. J. Bot.*, vol. 49, No. 7, pp. 1089-1094.

Thirteen fossil mosses belonging to eight genera were extracted from a woody sapropel found in the upper Beaufort Formation, northwestern Banks Island, Western Canadian Arctic. All belong to extant species.

On the basis of the enclosing strata, moss fossils, and associated organic remains it is concluded that the sediments were deposited in a small, shallow body of water, in which lake sedimentation was both preceded and terminated by alluvial sedimentation.

0042 MASON, W.R.M., SHEWELL, G.E., and CODY, W.J. - 1972

A plant collection from the southern interior of Banks Island, N.W.T.; *Can. Field-Naturalist*, vol. 86, No. 4, pp. 363-367.

In the summer of 1968, the Entomology Research Institute, Canada Agriculture, with the cooperation of the Polar Continental Shelf Project, Department of Energy, Mines and Resources, put a two-man field party in the southern interior of Banks Island, the most westerly island of the Canadian Arctic Archipelago.

Although the objectives of the expedition were mainly entomological, opportunity was taken by both members to make plant collections as circumstances allowed. Since the 122 species collected are all from one inland site and include 14 additions to the island flora, the results are presented here. They raise the number of species known from Banks I. to 186.

0043 RITCHIE, J.C. - 1972

Pollen analysis of Late-Quaternary sediments from the Arctic treeline of the Mackenzie River Delta region, Northwest Territories, Canada, in Climatic changes in Arctic areas during the last ten-thousand years, *Acta. Univ. Oulanka*, vol. 3, Geol. 1, pp. 253-271.

The uplands immediately east of the delta of the Mackenzie River in northwest Canada are promising for investigations of late-Quaternary (Holocene) climate, particularly using palynological evidence. Firstly, they are traversed by the mean July position of the Arctic front and there is some evidence of a positive correlation between this broad climatic feature and the transition from northern boreal forest to tundra (Bryson 1966, Krebs and Barry 1970, Hare and Hay 1971). This particular segment of the forest-tundra transition is characterized by steep gradients of climatic factors. A further reason for anticipating informative paleoecological data is that the area was free of ice early in the late-Wisconsin (Mackay 1963, Fyles 1967), and these authors suggest that the northern segment of the Tuktoyaktuk Peninsula was probably beyond the northern limit of Wisconsin ice (Fig. 1, after Fyles 1967 and Glacial Map of Canada 1968). And finally, the abruptness of the transition from forest to tundra in this area (Fig. 1), reflecting the relatively small shifts in the positions of the Arctic front between summer and winter, with the resulting sharp gradient of climatic change, leads one to expect that changes in late-Pleistocene climate might be reflected clearly in pollen spectra from sections of primary sediment.

Mackay and Terasmae (1963) report the pollen stratigraphy of two truncated sections of bog peat, ^{14}C -dated at 8,000 and 7,400 years (a further basal sample from one of these sections has been analysed recently from a sample collected by Dr. M. Kuc, yielding an older date-11,500 \pm 160 GSC 1514; personal communication from Dr. Kuc). The pollen diagrams show slight changes in the assemblages from which the authors suggest a 'decidedly tentative sequence of climatic events'. In view of the clear evidence presented below of marked changes in pollen stratigraphy in sections of late-Pleistocene sediment recovered from adjacent sites, it is possible that the bog sites analysed by Mackay and Terasmae (op.cit.) were less sensitive in registering regional vegetation change than limnic repositories. Ritchie (1972) has shown from a survey of modern pollen spectra in the area that while surficial lake muds record the regional pollen rain with reasonable consistency between samples within vegetation zones, terrestrial moss polsters vary widely in response to very local effects.

0044 RITCHIE, J.C., and HARE, F.K. - 1971

Late-Quaternary vegetation and climate near the Arctic tree line of northwestern North America; *Quat. Res.*, vol. 1, No. 3, pp. 331-342.

Earlier studies in Alaska and northwest Canada have shown inconsistent evidence for the expected northward extension of the Arctic tree line during the Hypsithermal Interval. Only megafossil evidence has supported this suggestion; the palynological findings have been inconclusive. The Tuktoyaktuk Peninsula, in the Northwest Territories of Canada, offers critical sites for studies of late-Pleistocene ecology, because of its geological, biotic, and climatological features. Palynological and megafossil evidence is presented from sites on the Tuktoyaktuk Peninsula, indicating northward advance of the Arctic tree line during the period 8500-5500 B.P. Relative pollen frequencies of a core of lake sediment suggest a late-Pleistocene sequence as follows: 12,900-11,600 dwarf birch tundra; 11,600-8500 forest tundra; 8500-5500 closed-crown spruce-birch forest; 5500-4000 tall shrub tundra; 4000-present dwarf birch heath tundra. These results suggest that during the Hypsithermal Interval the Arctic Front (July position) was further north, over the Beaufort Sea, a displacement from its present position of about 350 km. The Tuktoyaktuk Peninsula, presently occupied by tundra, and dominated by the Arctic airstream in July, was apparently under forest, with warm, moist Pacific air during the Hypsithermal Interval.

0045 SAVILE, D.B.O. - 1960

Limitations of the Competitive Exclusion Principle; *Science*, vol. 132, No. 3441, p. 1761.

Under severe conditions in the arctic the physical environment frequently overrides biological competition, allowing essentially random occurrence of plants without distinct associations and with the frequent coexistence of related species that have extremely similar requirements. Furthermore, a mixed population may be so advantageous in reducing disease incidence as to offset competition.

0046 SAVILE, D.B.O. - 1961

The botany of the northwestern Queen Elizabeth Islands; *Can. J. Botany*, vol. 39, pp. 909-942. Ellef Ringnes Island has a confirmed flora of 49 vascular plants and five parasitic fungi. The adjacent islands have less diversity of habitat and probably have even poorer floras. There are no endemics and the plants are extremely depauperate. The summer climate at Isachsen is colder than at any other station in the Canadian arctic. Although there are no convincing indications that Ellef Ringnes I. was overrun by a Wisconsin continental ice sheet, it cannot have escaped being snow-covered. The light cover of snow and ice on the outer islands was quickly lost in the postglacial xerothermic, which enabled plants to spread along the periphery of the archipelago. The numerous plants that occur southwest and northeast of these islands but not in them indicate that postglacial cold periods, probably accompanied by at least partial snow cover of the outermost islands, have driven out many species. Nearctic refugia are discussed and it is indicated, by analysis of distribution patterns, that no refugia occurred in the Canadian arctic archipelago. The region has been colonized from the Peary Land refuge, the Yukon-Alaska refugia, and from south of the retreating ice sheets.

0047 SAVILE, D.B.O., and PARMELEE, J.A. - 1964
Parasitic fungi of the Queen Elizabeth Islands; *Can. J. Botany*, vol. 42, pp. 699-722.

Fifty-six species, subspecies, and varieties of parasites are recorded from 23 locations, most from Isachsen in Ellef Ringnes I., Jacobsen-McGill Base in western Axel Heiberg I., and Hazen Camp in northern Ellesmere I. Previously published reports are assembled. Climatology and biogeography, as they relate to the fungi, are briefly discussed. *Puccinia poae-nemoralis* ssp. *hyperctica* Savile, *Ustilentyloma pleuropogonis* Savile (sp. et gen. nov., Ustilaginaceae), and *Mycosphaerella oxyriae* Savile are named. *Clasterosporium caricinum* and *Columophora rhytismatis* are newly reported from the arctic.

0048 STUTZ, R.C., and BLISS, L.C. - 1973

Acetylene reduction assay for nitrogen fixation under field conditions in remote areas; *Plant and Soil*, vol. 38, No. 1, pp. 209-213. A method for intensively sampling soil for nitrogen fixation potential using acetylene reduction assay is discussed. Acetylene was generated from calcium carbide. Soil cores were incubated in Mason jars with specially adapted lids. Air samples from the jars were stored and transported over dry KOH in 10 ml serum vials. The method overcomes many problems associated with other sampling procedures, and produces statistically reproducible data.

0049 WILCE, R.T. - 1967

Heterotrophy in Arctic sublittoral seaweeds: an hypothesis; *Botanica Marina*, vol. 10, No. 3/4, pp. 185-197. Facultative heterotrophy is suggested as a means by which deep-growing, attached, perennial, high arctic marine algae adapt to their environment. As

background for this suggestion brief comparisons are made between the marine environments and algal vegetations of the high arctic and the New England and Canadian Maritimes.

The parameters of light and temperature are described for two high arctic areas; sea ice and snow conditions are presented for these regions, and for the general area north of 75°N. lat. in the Canadian archipelago.

Photosynthesis and respiration in high arctic marine algae are discussed in terms of the relevant literature. Photosynthesis is ruled out for these plants for many months of the year, if not completely. Energy values of light penetrating even to the relative shallow depths of 30-50 M. is extremely low and may be present at these depths for less than two months of the year. With temperature essentially constant at -1.5° to -1.75°C. cold adaptation is necessary; the question of seasonal dormancy is discussed.

Numerous references are cited that demonstrate the occurrence of facultative heterotrophy in pigmented unicellular algae. Some examples are described of seemingly impossible habitats for "photoautotrophs" in which populations of pigmented unicellular and filamentous marine algae have been found.

Sources of dissolved carbon which may serve as substrate for the suggested facultative heterotrophs in the high arctic marine habitats are listed. References are discussed which take both sides of the issue that active uptake of substrate in low (i.e., normal for seawater) concentration by pigmented unicells occurs under heterotrophic environmental conditions. It is concluded that facultative heterotrophy may be essential to benthic pigmented perennial algae which live under the stress of the deep-water high arctic marine environment.

CLIMATOLOGY

0006 BLISS, L.C. - 1972

Devon Island I.B.P. Project, High Arctic Ecosystem, Project Report 1970 and 1971; *Dept. Botany, Univ. Alta.*, 413 p. Abstract under 0006

0008 BLISS, L.C. - 1972

I.B.P. High Arctic Ecosystem study, Devon Island; *Arctic*, vol. 25, No. 2, pp. 158-161.

0050 HOLMGREN, B. - 1971

Climate and energy exchange on a sub-polar ice cap in summer, Part A, Physical climatology; *Meddelanden Fran, Meteorologiska Institutionem, Uppsala Univ.*, Report No. 107, 83 p.

The analysis is based on climatological and micro-meteorological measurements made mainly at an elevated observation-place (Ice Cap Station, 1.3 km above M.S.L.) in the area of superimposed ice formation on the northwest slope of the ice cap. Comparative measurements were temporarily made in different parts of the ice cap. The structure of the wind-field over the ice cap, especially in situations with katabatic winds, was investigated by means of pilot balloons.

In the middle of the summer the low-lying parts of the ice cap and the outlet glaciers are invaded by air of temperatures above freezing. Since the temperature of the ice cannot rise further than to melting-point, an advection inversion develops above the surface. Over the high-lying parts of the ice cap the air temperature in general stays well below freezing. Here the radiation climate is the factor which dominates the temperature stratification in the surface layer. At Ice Cap Station the conditions are intermediate in this respect; air temperatures above freezing were obtained in about 40% of all temperature readings at screen level in July. When discussing the climate on an ice cap one natural question arises: How does the snow surface affect the air temperature above it? Surface inversions of varying magnitude were represented by 75% of all profile observations during the period from about mid-May to the end of August. Lapse conditions in the surface layer generally prevailed in situations with air temperatures below freezing and overcast skies. With a clear sky there was a marked diurnal variation of the surface inversion. A small inversion was usually left also in the middle of a clear day in spite of a net incoming radiation flux of the order of 0.1 ly/min at the frozen snow-surface at that time. This state of affairs is closely connected with the other vertical energy fluxes at the snow-surface, viz. the latent heat transport and the energy transport in the snow. Because of the radiative properties of the snow, the temperature of the uppermost snow-surface is on the average a few degrees lower than the temperature at a small depth below the surface. The relatively low surface temperature favours inversions in the low layer also in situations with a net incoming radiation. During "radiation nights" the inversion amounted to between 5 and 10°C as measured between the 0.1 and 9.5 m levels of the meteorological mast. Katabatic winds - with an approximately downslope direction and with a wind maximum at a low level above the snow-surface - then caused a flow of cold air from the central parts towards the outskirts of the ice cap. The vertical extent of the cold air and also the speed of the katabatic wind increased with the distance from the top of the ice cap. As a consequence, in situations with strong inversions the air temperature at screen level on the top plateau was generally a couple of degrees higher than the screen temperature on the slopes at altitudes several hundred metres below the top plateau. Because of the turbulent structure of the katabatic wind and also because of the dynamical pressure-heating and the divergence of the sinking air the greater part of the surface inversion was confined to a shallow layer (<10 m) over the ice cap. The vertical extent of the flow with a downhill velocity component was of the order of a few dekametres. The speed of the katabatic wind as measured at the level of the wind maximum (3-8 m) at Ice Cap Station typically amounted to 4-6 m sec⁻¹ in the middle of "radiation nights". On steep slopes the speed of the katabatic flow was higher; a low drift was observed to be a normal feature in some areas of the ice cap during "radiation nights". The katabatic

force (acting on the air within the surface inversion) seemed to effectively increase the wind speed in the surface layer only as long as the wind speed was less than 8 m sec⁻¹ at the 10 m level. With stronger winds the surface inversion was destroyed and the katabatic force became insignificant. The katabatic winds had a negligible effect on the redistribution of snow over the ice cap. When the gradient winds were strong there were often long lee-waves superposed on the general flow over the ice cap. During these conditions super-gradient wind speeds in the surface layers were observed within a zone below the top region on the lee-side of the ice cap. The strong winds had important effects on the accumulation pattern on the ice cap. The climate on the ice cap tended to become increasingly moist and cloudy towards the end of the summer. The diurnal variation of the relative humidity was barely noticeable; in the mean values a weak maximum appeared at 18^h-21^h L.S.T. The diurnal variation of the water-vapour pressure was more marked with a maximum at about noon and a minimum at about midnight. During inversion conditions the katabatic winds caused a decrease of the humidity in the surface layer, which is reflected in the variations noted above.

The mean cloudiness as well as the frequency of fog showed a marked variation with wind direction at Ice Cap Station. The fog was mainly induced by the orographic lifting of the air; radiation fog, and for that matter advection fog, were rarely observed. When a surface inversion formed, the drying effect of the katabatic wind generally seemed to prevent the formation of radiation fog. After the main snow melt on the plateau-lands surrounding the ice cap a relatively great difference between the surface temperatures of the ice and the bare land appears. As a result of this Cumulus clouds indicating convergence in low layers often formed over the marginal zone of the ice cap. The convergence was caused by a katabatic wind from the ice cap and an anabatic wind from the plateau-land. The "edge effect" could in certain weather situations be very conspicuous: A ring of towering Cumulus clouds could encircle the ice cap while there were practically no clouds at all over the rest of the ice cap and the plateau-land.

0051 HOLMGREN, B. - 1971

Climate and energy exchange on a sub-polar ice cap in summer. Part B. Wind- and temperature-field in the low layer on the top plateau of the ice cap; *Meddelanden Fran, Meteorologiska Institutionem, Uppsala Univ.*, Report No. 108, 43 p. Observations of the vertical variation of wind speed in near-neutral stratifications show an increase of the roughness parameter z_0 from about $5 \cdot 10^{-5}$ to $1 \cdot 10^{-3}$ m when the wind speed at the 5 m level decreases from 6-7 m sec⁻¹ to 2-3 m sec⁻¹. The increase of z_0 is suggested to be related to the flow conditions at the rear of the snow dunes. Snow dunes were characteristic features of the surface relief in the observation area. A comparison of the vertical variation of wind speed with the "log-linear" equation by Monin and Obukhov gives average values of the parameter α' ($= K_H/K_M \alpha$)

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amounting to 6-7, when the stability, as expressed by the Richardson number, is less than ca 0.15. With increasing stability the deviations from a log-linear relationship becomes increasingly apparent. Furthermore, the vertical variation of temperature and wind speed in situations with very stable stratifications suggests that the similarity theory by Monin-Obukhov is not applicable, at least not for the local conditions. With great temperature differences between the upper and lower levels of the mast there are often indications of sharp inversions or thermo-clines at an intermediate level above the snow surface. Possible causes of the observed profile features, especially the influence of the local conditions, are discussed.

0052 HOLMGREN, B. - 1971

Climate and energy exchange on a sub-polar ice cap in summer. Part C. On the katabatic winds over the north-west slope of the ice cap. Variations of the surface roughness; *Meddelanden Fran, Meteorologiska Inst., Uppsala Univ., Report No. 109, 43 p.* When the surface consisted of fine-grained frozen snow in spring, the z_0 -values on the average amounted to ca 1.10^{-4} m. At the end of the ablation-seasons, when the surface consisted of large melting ice grains (diameter 1-3 cm), z_0 -values of ca 1.10^{-3} cm may be considered as representative. The surface at Ice Cap Station was inclined ca 2° to the horizontal. In situations with light winds aloft and a surface inversion amounting to more than a couple of degrees Celsius as measured between the 0.1 and 9.5 m levels of the meteorological mast it was generally found that a katabatic flow prevailed in the surface layer. Contrary to ordinary gradient winds in the surface layer the katabatic winds are characterized by a rapid decrease with height of the shearing stress; i.e. the component along the fall-line of the slope. Together with other properties of the katabatic winds (see below) this had important bearings on the turbulent structure and therefore also the structure of the inversions over the main part of the ice cap. During "radiation nights" with strong inversions a thermo-cline generally appeared at approximately the same height as the wind maximum in the vertical; the tendency to formation of thermo-clines was more pronounced over the sloping surface at Ice Cap Station than over the quasi-horizontal surface in the top region of the ice cap. The visual observations as well as the profile observations indicated that the turbulent mixing between the cold air below the thermo-cline and the warm air above was markedly reduced or extinguished. Since the thermo-cline reduced the vertical turbulent transport of heat and since the wind speed was relatively high (typically ca 3 m sec^{-1} at the 1 m level) the turbulence in the cold air next to the surface was relatively intense. The stratification in the lowest metre or metres could generally be described as near-neutral or moderately stable in situations when the total surface inversions amounted to more than, say, 10°C . The profile measurements showed that the vertical variation of wind speed and temperature approached a logarithmic law with decreasing height. Deviations

from an exactly logarithmic variation could, however, generally be observed below the 1 m level. The stability conditions in situations with katabatic flows and the magnitude of the forces influencing the air in the inversion layer over the sloping surface are discussed. An analytical description of the profiles in the lowest layer above the snow-surface is given together with equations for the vertical heat flux during inversion conditions. A comparison of the vertical heat flux determined over the quasi-horizontal surface of the top plateau with the heat flux obtained at Ice Cap Station is also included.

0053 HOLMGREN, B. - 1971

Climate and energy exchange on a sub-polar ice cap in summer. Part D. On the vertical turbulent fluxes of water vapour at ice cap station; *Meddelanden Fran, Meteorologiska Inst., Uppsala Univ., Report No. 110, 29 p.*

The vertical turbulent flux of water vapour E at the snow surface is calculated by means of three-hourly determinations of

1. wind speed at a low level (0.5-1.0 m)
2. water-vapour pressure at 1.5 m
3. temperature profiles for indirect determination of the temperature and water-vapour pressure at the snow surface.

The temperature of the snow surface is determined by extrapolation of temperature-profiles down to the snow surface. The method is "calibrated" by reference to the conditions over melting snow. Humidity profiles measured with Assmann psychrometers at different levels are also utilized in the analysis of the humidity-field in the layer below the 1.5 m level. The calculations of E are furthermore based on a formula for the vertical variation of K_M , which was developed in Part C. It is assumed that $K_M \approx K_E$ in the layer considered ($z < 1.5 \text{ m}$). This assumption should be reasonable bearing in mind that relatively indifferent stability conditions usually prevail in the lowest layer at Ice Cap Station also in situations with strong inversions. The discussion includes a comparison with a semi-empirical model suggested by Sverdrup. The variations of E in different weather situations are described. During the relatively warm summer of 1962 the net evaporation amounted to 0.4 cm (w.e.) . During the relatively cold summer of 1963 the net evaporation was 1.4 cm (w.e.) .

0054 HOLMGREN, B. - 1971

Climate and energy exchange on a sub-polar ice cap in summer. Part E. Radiation climate; *Meddelanden Fran, Meteorologiska Inst., Uppsala Univ., Report No. 111, 111 p.*

In spring practically all surfaces in the Devon Island region are covered with snow which is very pure and which has a high albedo (80-90%). In summer the snow is generally removed by melting except in the highest parts of the ice cap, where discontinuous melting occurs during short periods only. The radiation climate is subject to a profound change in connection with the snow melt on and outside the ice cap. The main topic of this paper is the relationship between the variations of the

radiation fluxes and the albedo at an observation-place on the north-west slope of the ice cap at an altitude of 1.3 km above M.S.L. and at a distance of ca 10 km from the margin of the ice cap. The radiation climate is described by means of measurements with the Angström pyrheliometer, two standard models of pyranometers (Eppley and Moll-Gorczyński), the Beckman & Whitley net radiometer and also photo-cells in combination with filters. The photo-cells are used for determinations of the albedo, the penetration of light into the snow pack, and the intensity of light from different parts of the sky. Considerable difficulties have been experienced in the analysis of the radiation data. Because of a failure with a recording potentiometer only instantaneous measurements of the radiation fluxes have been obtained. However, the instantaneous measurements were made regularly and are available in a relatively large number. The greatest troubles were caused by errors in the measurements with some of the standard instruments. In connection with the measurements of the direct solar intensity simultaneous calibrations of the Eppley and Moll-Gorczyński pyranometers were made. When applying Liljequist's method for calculation of the calibration constants for radiation from a clear and an overcast sky respectively it was found that the outputs of the Eppley pyranometer were subject to substantial errors. Various experiments were carried out to elucidate the causes of the errors and to determine the corrections required to get us usable results. All measurements with the Beckman & Whitley net radiometer were rejected in connection with a discussion of the sources of error. The values of the net radiation given here are therefore partly determined by indirect methods. As to the rest of the contents it may be mentioned that, because of the pure air ($\beta = 0.015$) over the ice cap, an opportunity is given to discuss the absorption by water vapour in an atmosphere which is almost free from light-scattering aerosols. In some respects the results of the pyrheliometric measurements given here differ from the results of previous measurements in the polar regions. A proposal is made to improve the Angström-Hoelper method for determining the turbidity parameters β and W .

0055 HOLMGREN, B. - 1971

Climate and energy exchange on a sub-polar ice cap in summer. Part F. On the energy exchange of the snow surface at ice cap station; *Meddelanden Fran, Meteorologiska Inst., Uppsala Univ.*, Report No. 112, 53 p.

Micro-meteorological measurements at an observation-place situated at 1.3 km above M.S.L. on the north-west slope of the Devon Island ice cap are utilized to study the interplay between the energy transfers above and below the snow surface in various weather situations. The calculations of the energy budget is checked by summing up all energy fluxes during three observation-periods covering the summers of 1962 and 1963. The difference between the sum of all energy sources and the sum of all energy sinks appeared to be of the same order of magnitude as the expected measuring errors.

By means of temperature-depth profiles observed at short time-intervals the mechanisms of energy transport within the frozen as well as the melting snow pack are discussed. Special attention is given to the development of melt-water streams because of their vital role in the ablation process: Among other factors the rate of melting is important for the formation of melt-streams. The evaporation was found to be small.

A necessary but not sufficient condition for more noticeable melting on a sub-polar ice cap is that the air temperature rises above freezing. Advection of warm air is the initiating (and also the maintaining) factor in the melting process. The total annual accumulation and the total annual ablation are of a small order of magnitude; less than ca 25 cm (w.e.) during the three budget years when the studies were undertaken. In fact, it was found that a few days with relatively strong melting could be of decisive importance for the outcome of the annual mass balance. The greatest energy incomes and also the greatest rates of melting (2-3 cm w.e. per day) were always observed on days with strong winds and advection of warm and humid air over the ice cap. This weather type typically appeared in connection with frontal cyclones causing advances of warm air from the south-to-west sector as seen from the ice cap. Air temperatures above freezing were furthermore generally observed, when extensive warm-cored anti-cyclones dominated the weather conditions during the main summer-period. However, the rates of melting in the high-lying areas of the ice cap were small during fine-weather periods.

Many of the cyclones approaching the Devon Island region belong to the so called Baffin Bay type (following an approximately south-to-north track along the western flank of Greenland). When these cyclones influenced the weather on the ice cap the air temperatures at the 1.3 km level were well below freezing. Glaciological observations by Koerner (1966) indicated that the cyclones over Baffin Bay in autumn and winter caused a marked increase of the accumulation on the east-to-south side of the ice cap. The Baffin Bay cyclones therefore seem to favour glacierization on Devon Island, no matter the season when they appear.

0056 HOLMGREN, B., and WELLER, G. - 1973

Studies of the solar and terrestrial radiation fluxes over Arctic pack ice; *Geophys. Inst., Univ. Alaska, ARPA No. 1783*, 11 p.

Our studies have concentrated on determining the physical characteristics of pack ice, clouds and aerosols as they affect the Arctic radiation regime. At Barrow, flights through stratus clouds with aircraft mounted continuous cloud particle samplers have determined number and mass densities, particle size distributions and ice crystal contents of these clouds over a wide temperature range. Simultaneously, light intensity and reflectivity measurements have been carried out to determine the optical properties of these clouds.

Aircraft-mounted photometers have provided measurements that have allowed deduction of aerosol profiles up to 13,000 feet; on two occasions these were extended up to 35,000 feet aboard flights by the

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NASA CV-990 aircraft to the Arctic Ice Dynamics Joint Experiment (AIDJEX) camp in the Beaufort Sea. Although the air is fairly "clear" over the Arctic Ocean, ice crystal and other aerosols are present, and are important in scattering incoming radiation. In addition to measurements of ice nuclei concentrations at Barrow, actinometric observations were made on numerous occasions at the AIDJEX camp, occasionally through ice crystal clouds advected from open leads.

Routine monitoring of components of the radiation balance have been carried out at Barrow, Ice Island T-3 and the AIDJEX camp. Coupled with this were studies of surface inhomogeneities, such as hummocks, snow dunes, leads and pressure ridges, and the effects of these features on the surface albedo and temperature. Of particular interest were the measurements over refreezing leads, both artificially made and natural ones, showing extraordinary modification of the radiation balance during the freezing process. Light extinction measurements in snow, ice and sea water, using photocells, allowed the construction of a typical extinction nomogram for these studies.

One important part of our work has been theoretical modeling in order to synthesize our observations of radiation fluxes and of surface and atmospheric radiation characteristics. For infrared fluxes we have developed a fairly elaborate model which allows computation of radiation transfers in an atmosphere with several cloud layers, for short wave fluxes we have so far developed a rough model which shows the effect of a thin cloud layer on the radiation balance of the earth-atmospheric system at various latitudes and seasons.

Our main research efforts were accounted for in the Annual Report (Technical Report No. 2), where the overall research objectives were also described. In the present report we comment on a few measurements which had not been subject to analysis when the Annual Report was written.

Our original intention was that this project should develop into a broad study of the radiation regimes of the Arctic which could be related to such considerations as the heat budget of the Arctic Ocean and the stability of the Arctic climate. We feel that our basic approach has been sound and that we have made progress in attaining our objectives. We regret that our research has ended prematurely.

0044 RITCHIE, J.C., and HARE, F.K. - 1971
Late-Quaternary vegetation and climate near the Arctic tree line of northwestern North America; *Quat. Res.*, vol. 1, No. 3, pp. 331-342.
Abstract under 0044

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0057 ANDERSON, N.M., and MAHAFFY, R.J. - 1969
A comparison of Decca and astronomical positions; *Polar Cont. Shelf Proj.*, internal report, 56 p.

0058 BOURNE, I.A., HAGG, E.L., and POAPS, G.E. - 1966
Problems associated with the use of the 1.7 Mc/s "Hi-Fix" navigation system near Alert, N.W.T.; *Polar Cont. Shelf Proj.*, internal report, 24 p.

0059 COLBY, L.R. - 1969
Report of the Polar Continental Shelf Project, Department of Energy, Mines and Resources, Trials of a CC7 air cushion vehicle in Canada, May-August 1969; *Dept. Transport*, Chapt. 6, pp. 36-62.
A Cushioncraft CC-7 hovercraft was tested in the area surrounding Tuktoyaktuk, N.W.T., between July 9th and 27th, 1969. The purpose of the tests was to determine the usefulness of the machine as a self-contained scientific research support vehicle on the arctic tundra and coastline, and also to assess the amount of damage to vegetation and terrain caused by the passage of a small hovercraft under summer conditions.

0060 COLBY, L.R. - 1971
Performance evaluation of a Cushioncraft CC7 hovercraft in the Mackenzie River Delta area; *Can. Aeronautics & Space J.*, vol. 17, No. 3, pp. 83-87.
During the period 9 July to 27 July, 1969, a Cushioncraft CC7 hovercraft was tested in the Mackenzie River Delta and surrounding district covering a distance of 702 mi. in Arctic summer conditions.

In general the craft performed well over water and on low flat land with vegetation up to two feet high. The CC7 had difficulty when travelling over fully developed high centre polygon fields and was unable to climb slopes greater than 1:7. For general overland travel the craft was found to be limited to reconnoitered routes.

Little evidence of destruction to the vegetation cover was found after 50 circuits had been completed around a selected course, across various types of tundra vegetation and terrain.

Several problems, which emerged early in the trials, were present throughout the test period and may have prevented a full evaluation of the potential capabilities of the vehicle. These problems included an unexpectedly high fuel consumption, low engine performance due to the clogging of filters with organic debris, and poor passenger visibility when the craft was in motion.

0061 COMPUTING DEVICES CANADA LIMITED - 1961
Report covering analysis of Polar Continental Shelf Projects Decca Navigator Lambda Chain 1961 operations; *Polar Cont. Shelf Proj.*, internal report, 83 p.

The report is based on data procured from (a) a stationary receiver, continuously and automatically recording pattern readings at the main base located at Isachsen on Ellef Ringnes Island, (b) Mobile receivers set up at various established control points located around the E. S. and W. coasts of Ellef Ringnes Island and (c) individual records maintained at the respective Master, Red and Green transmitting stations, the receiver maintenance base and by the various field parties.

Such a report cannot be conclusive. It is based on information obtained over a very small area of the Arctic and therefore can only theoretically be applicable to that area. However, the analysis of all data obtained in the Polar Shelf area will provide basic information of tremendous value for the prediction of low frequency radio aid accuracies and the study of propagation behaviour in the Canadian Arctic.

0062 EATON, R.M. - 1959

Decca lane identification, an analysis; *Polar Cont. Shelf Proj.*, internal report, 3 p.

0063 EATON, R.M. - 1964

Experience with Hi-Fix hyperbolic in the Canadian Arctic; *Polar Cont. Shelf Proj.*, internal report, 30 p.

0064 EATON, R.M. - 1965

Experience with Hi-Fix hyperbolic in the Canadian Arctic; *Supp. Inter. Hydrographic Rev.*, vol. 6, pp. 39-49.

Early in 1962 the Canadian Hydrographic Service supplied a Hi-Fix chain for the airborne hydrographic surveys carried out in the Canadian Arctic Archipelago by the Polar Continental Shelf Project. It was used there in hyperbolic form for a survey by spot echo sounding through ice in Penny Strait during 1962, and in 1963 for the regular survey of Hell Gate (figure 1) by the helicopter-towed echo-sounding technique described elsewhere 1. Normally, the Hi-Fix transmitter stations are manned by technicians or visited daily, but at Hell Gate the stations were run unmanned, and visited only for servicing at 1 to 2 week intervals. This paper describes modifications to the standard equipment, installation for unattended operation, trials to determine maximum range, the stability of the patterns, accuracy and position plotting. Although the Polar Continental Shelf Project has used Hi-Fix only for airborne surveys in the Arctic, the experience gained is thought to be relevant to hydrographic surveys by other craft and in other latitudes.

Where variable errors are discussed the largest likely figure is given, with perhaps 95% probability that the actual error will be smaller. The reason for this is that a hydrographic surveyor is concerned that the maximum error in position of any sounding shall not exceed a prescribed limit. In this connection he does not consider the probable error, which is not applicable to the single observation for a sounding fix, and which should not be applied to the mean of all the fixes of a survey, since the mariner using the chart relies on every printed detail.

0065 GOTRO, N. - 1962

Tellurometer speeds north mapmaking; *Public Wks. in Can.*, July.

0066 HUGGETT, W.S., and MORTIMER, A. - 1971

Observations obtained on a Magnavox satellite navigation receiver in high latitudes; *Env. Can.*, Mar. Sci. Div., Pac. Mar. Sc. Report 71-4, 34 p.

From observations made at the optimum latitude for the number of satellite passes per day, the percentage of useful passes and their degree of reliability are assessed. The degree of reliability that can be expected from a satellite fix for real-time navigation decisions, without the benefit of off-line data processing, is shown. Comparisons are made between satellite fixes obtained in Latitude 70°N. and Latitude 49°N. The criteria for rejecting fixes is also discussed.

0067 HUNT, F.P. - 1961

Report on tellurometer operation in the Canadian Arctic - 1959, 1960, 1961; *Polar Cont. Shelf Proj.*, internal report, 3 p.

0068 HUNT, F.P. - 1964

Hudson Bay Oceanographic Project: site survey and ground lay out for Decca Lambda transmitters on the western shore of Hudson Bay; *Polar Cont. Shelf Proj.*, internal report, 3 p.

0069 JOLLYMORE, P.G. - 1969

A portable digital sounding system for Arctic use; *Atl. Ocean. Lab., Bed. Inst.*, report BI 1969-11, 35 p.

The purpose of this report is to describe how a T.H. Giffit Co. Model STP-1 transceiver, and a Hewlett-Packard Model 3734A counter, have been made into a portable digital echo sounder for deep water soundings in areas where the water is covered by a thick layer of ice.

This project was undertaken to satisfy a request by the Polar Continental Shelf Project (P.C.S.P.) personnel for a sounder capable of determining water depth in excess of 100 fathoms, from the ice surface. Simplicity, light weight and proven reliability dictated the choice of components used to form the system.

0070 KERR, A.J. - 1959

Observations on the tellurometer used in sub-zero temperatures; *Polar Cont. Shelf Proj.*, internal report, 3 p.

0071 LINDSAY, D.G., COLBY, L.R., and ROOTS, E.F. - 1968

Report on tests carried out in connection with the 1968 Arctic voyage of Alexbow-equipped barge L.A. Learmonth; *Polar Cont. Shelf Proj.*, internal report, 18 p.

0072 O'NEILL, J., and ROOTS, E.F. - 1959

Report on RAT; *Polar Cont. Shelf Proj.*, internal report, 7 p.

The experiences of a Topographical Survey winter field party in northern Ontario, and of the Polar Continental Shelf Project field party on Ellef Ringnes Island, N.W.T., in connection with the use of the Canadair RAT, are described. It is concluded that, although the design has several commendable principles, there are serious undesirable features. The vehicle as presently constructed is too complex and not sufficiently robust for general field service on snow or soft ground.

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0073 PUIKKINEN, H.W. - 1973

Hydrographic surveying with air cushion vehicles, trials report: evaluation of modified retractable fixed strut echo sounder; *Polar Cont. Shelf Proj.*, internal report, 46 p.

This report is a compilation and condensation of the technical reports written by persons taking part in trials of the Depth Sounding System designed for Hovercraft SRN-5 and SRN-6.

0074 SCHAEFFER, R.L., BROOKS, E.N., and POWELL, A. - 1970

Trip to Franklin Bay, N.W.T., Canada to observe operation of an SR.N6 hovercraft; *Naval Ship Res. & Devel. Centre*, internal report, 43 p.

0075 YEATON, G. - 1970

Hovercraft operations in the Beaufort Sea; in Ninth Annual Hydrographic Conference, 27-29 January, Ottawa, pp. 263-271.

GENERAL

0076 AUTAIR - 1961

Report on helicopter operations for Polar Continental Shelf Project 1961; *Polar Cont. Shelf Proj.*, internal report by Autair Helicopter Services Limited, 33 p.

0077 COLLIN, A.E., and ROOTS, E.F. - 1960

Investigations of the Canadian Arctic Continental Shelf; *Polar Cont. Shelf Proj.*, internal report, 10 p.

The Department of Mines and Technical Surveys of Canada has embarked upon a continuing programme of survey and research in the continental shelf areas of Arctic Canada. The area to be investigated includes the continental shelf lying offshore from the Canadian Arctic islands and mainland between the borders with Greenland and Alaska, together with parts of the outer islands of the Arctic Archipelago and the straits and channels between the islands, and parts of the continental slope and adjacent portions of the Arctic Ocean basin. This programme, known as the Polar Continental Shelf Project, embraces the fields of oceanography, submarine geology, gravity, geomagnetism, seismology and seismic sounding, physical geography, glaciology, marine biology and related subjects, terrestrial botany and entomology, together with the topographic and hydrographic surveys fundamental to most of the other studies. Various branches and units of the Canadian government, including the Hydrographic Service, the Topographical Survey, the seismic, geomagnetic, and gravity divisions of the Dominion Observatory, the Geographical Branch, the Geological Survey, the Fisheries Research Board, and the Department of Agriculture are cooperating in the project.

With a programme so diverse in scope, operating in a vast region about which very little is known in many important scientific fields and where any kind of study encounters serious logistic and technical problems, the Polar Continental Shelf Project is attempting to bring various scientific disciplines to bear in concert upon some of the important

problems of the area. Thus several teams, making quite different types of studies, are working in the same area simultaneously, and are attempting to build up a balanced, many-sided picture of selected portions of this little-known part of the world. For this reason as well as because of practical considerations, the project is concentrating first on a systematic, relatively thorough study of a 350-kilometer-wide "block" of the continental shelf area in about the middle of the Canadian Arctic Ocean front. It is planned that subsequent "blocks" will be investigated in turn until the entire region has been covered. A reconnaissance party went to the area in 1959, and the first full-scale programme of survey and research got under way in March 1960. About 50 men are in the field at the present time.

0078 GANTCHEFF, G.S. - 1971

Study and investigation on the knowledge to 1971 of the effects of oil spills on the Arctic environment; *Polar Cont. Shelf Proj.*, internal report, 104 p.

One of the significant events in the history of Canada, and an event that may profoundly alter the course of development of the nation and its standing among other nations, has been the discovery of the possibility of very large deposits of petroleum in the Arctic regions. This possibility, which has yet to be proven, has nevertheless changed the attitude of the Canadian public, industry and government toward the northern part of their country. Large sums of private and public money have been invested or committed to a region that was previously ignored or given only token attention; the pace of exploration, investigation, and technological innovation designed to overcome operational problems of northern regions has been accelerated dramatically. With the growth of hopes for economic profits from the north there has grown a parallel concern that exploitation of the mineral wealth, and particularly the industrial and commercial activities connected with that exploitation, may have serious undesired effects on the environment of the north, and on the people who live there. There is reason to fear that unless the development of northern petroleum resources is undertaken with full understanding of the special environmental characteristics and processes of the north, the undesired effects may not only make the development excessively costly and ultimately self-defeating in the short or long term, but they may also work to the disadvantage of the local people and seriously impair the value of the land for other purposes. Together with other agencies of the Government of Canada, the Department of Energy, Mines and Resources is actively engaged in obtaining information on the environment of the northern regions, and on the manner in which this environment may affect, or be affected by, activities connected with the development, transportation, and use of northern energy and mineral resources.

Among the concerns about the effects of exploitation of petroleum deposits in the Arctic, one of the most serious is that of a large spill of crude oil and its effect on the marine or terrestrial environment and its ecology. There have not yet been any known large spills of oil in Arctic regions; this has been fortunate, but it has not given us any direct experience in the behaviour of large amounts of free oil

on the ice-covered ocean or on land underlain by permafrost. From a few small accidental spills, from limited controlled testing, and from theoretical considerations it would appear that because of low temperatures, lack of sunlight, and the presence of ice on the water or in the soil, the spreading behaviour, chemical and physical changes and effects, and biological consequences of a large oil spill in the Arctic would be quite different from one in temperate regions. Such information as there is on this subject is widely scattered, inconclusive, and sometimes contradictory. More information is urgently needed; this should come from systematic research, based on the fragmentary knowledge already gained.

With these considerations in mind, the Polar Continental Shelf Project of the Department of Energy, Mines and Resources commissioned Worldwide Natural Resources Management Company, Limited (NAREMCO) to compile all available information on the effects of oil spills on Arctic or low-temperature environments, plus information about the behaviour of oil in other conditions that might be extended or extrapolated to Arctic conditions. The terms of reference for the study were discussed and approved by a Departmental Committee on Oil Spills, which set up an ad hoc review group, consisting of representatives of the Inland Waters Branch and Marine Sciences Branch (both at that time branches of the Department of Energy, Mines and Resources) and the Polar Continental Shelf Project, to monitor the study. During the course of the study, NAREMCO submitted progress reports at regular intervals, and held extensive discussions with the monitoring group on the scope and emphasis of the investigations. While the study was in progress, the Inland Waters Branch and Marine Sciences Branch were transferred to the new Department of the Environment, but the monitor group remained in contact with the study.

0079 ROOTS, E.F. - 1959
Polar Continental Shelf Project; *Polar Cont. Shelf Proj.*, internal report, 3 p.

0080 ROOTS, E.F. - 1959
Interim report on field work, Polar Continental Shelf Project, March 1959; *Polar Cont. Shelf Proj.*, internal report, 16 p.

0081 ROOTS, E.F. - 1959
The Canadian Continental Shelf Expedition; *Polar Cont. Shelf Proj.*, internal report, 1 p.

0082 ROOTS, E.F. - 1959
Polar Continental Shelf Project; *Polar Cont. Shelf Proj.*, internal report, 4 p.

0083 ROOTS, E.F. - 1959
The Polar Continental Shelf Project, 1959; *Polar Cont. Shelf Proj.*, internal report, 6 p.

0084 ROOTS, E.F. - 1959
The Polar Continental Shelf Project, 1959; *Polar Cont. Shelf Proj.*, internal report, 8 p.

0085 ROOTS, E.F. - 1960
Polar Continental Shelf Project, 1960 season, report of progress; *Polar Cont. Shelf Proj.*, internal report, 4 p.

0086 ROOTS, E.F. - 1960
Polar Continental Shelf Project, 1960 season, mid-season summary report; *Polar Cont. Shelf Proj.*, internal report, 1 p.

0087 ROOTS, E.F. - 1960
The Polar Continental Shelf Project, 1959; *The Arctic Circular*, vol. 12, No. 3, pp. 32-38.

0088 ROOTS, E.F. - 1960
Canadian Polar Continental Shelf Project, 1959; *Polar Record*, vol. 10, No. 66, pp. 275-276.

0089 ROOTS, E.F. - 1962
Polar Continental Shelf Project, Progress and programme summary; *Polar Cont. Shelf Proj.*, internal report, 11 p.

0090 ROOTS, E.F. - 1962
The Polar Continental Shelf Project; *Polar Cont. Shelf Proj.*, speech to Roy. Geog. Soc., Jan. 8, 1962, 27 p.

0091 ROOTS, E.F. - 1962
Polar Continental Shelf Project; *Polar Cont. Shelf Proj.*, internal report, 7 p.

0092 ROOTS, E.F. - 1962
Polar Continental Shelf Project; in Government Activities in the North - 1961, Dept. Ind. Aff. N. Devel., Advisory Comm. N. Devel., pp. 38-43.

0093 ROOTS, E.F. - 1962
Canadian Polar Continental Shelf Project, 1959-62; *Polar Record*, vol. 2, No. 72, pp. 270-276.

0094 ROOTS, E.F. - 1963
Polar Continental Shelf Project; in Government Activities in the North - 1962, Dept. Ind. Aff. N. Devel., Advisory Comm. N. Devel., pp. 68-75.

0095 ROOTS, E.F. - 1965
Tentative list of field investigations, 1965 season; *Polar Cont. Shelf Proj.*, internal report, 15 p.

0096 ROOTS, E.F. - 1965
Summary of work done, 1959-65; *Polar Cont. Shelf Proj.*, internal report, 15 p.
In the following report the various activities of the Polar Continental Shelf Project are briefly summarized, by disciplines. The studies carried out wholly by the Project, or by Departmental agencies with a major contribution from the Department, are listed first, in alphabetical order. This is followed by a brief mention of miscellaneous or minor activities, and of researches of other agencies for which the Polar Continental Shelf Project has provided facilities or field support.

GENERAL

0097 ROOTS, E.F. - 1965

Canadian Polar Continental Shelf Project: 1963; *Polar Record*, vol. 12, No. 81, pp. 738-741. The object of the Polar Continental Shelf Project, which began operations in 1959, is to carry out a long-term investigation of the continental shelf to the north and west of the Canadian Arctic archipelago and of the waters above it, together with the islands of the archipelago when relevant, and the straits and sounds between the islands. From 1939 to 1963 work has been concentrated in the region between Meighen Island and Brock Island, extending about 200 km out to sea and the same distance back into the archipelago; but individual programmes have been carried out throughout all the Queen Elizabeth Islands and extended to Banks Island and northern Greenland. As the area of extensive research moves to the south-west, at the rate of about 150 km a year, it is expected that most of the specialized research will be carried out at widely separated centres chosen for their suitability for the purpose.

0098 ROOTS, E.F. - 1965

The limits of geography; *Geog. J.*, vol. 131, Part 3, pp. 444-446.

Over the years it has become the custom for the recipient of the Patron's medal to reply on behalf of all those whom the society has so graciously honoured at its annual meeting. One does not even ask leave of the other recipients to speak for them. - Their only recourse, it would seem, is to become a Patron's Medallist in turn and get their own back - a sort of striving to become Head Boy so that you can dole out the treatment that you once received from other Head Boys. Perhaps this is what is meant when the society states that these awards are intended to be a spur to further endeavour in our chosen fields.

0099 ROOTS, E.F. - 1965

Polar Continental Shelf Project; *in* Government Activities in the North, 1964, Dept. Ind. Aff. N. Devel., Advisory Comm. N. Devel., pp. 66-72.

0100 ROOTS, E.F. - 1966

Polar Continental Shelf Project; *in* Government Activities in the North, 1965, Dept. Ind. Aff. N. Devel., Advisory Comm. N. Devel., pp. 77-84.

0101 ROOTS, E.F. - 1967

Yukon Centennial projects - a variety of survey problems; *The Can. Surv.*, vol. 21, No. 3, pp. 250-259.

0102 ROOTS, E.F. - 1967

Polar Continental Shelf Project; *in* Government Activities in the North, 1966, Dept. Ind. Aff. N. Devel., Advisory Comm. N. Devel., pp. 57-63.

0103 ROOTS, E.F. - 1968

Canadian Polar Continental Shelf Project, 1966; *Polar Record*, vol. 14, No. 89, pp. 192-194. The responsibility of the Polar Continental Shelf Project is to carry out a long-term investigation of the continental shelf lying to the north and west of the Canadian Arctic Archipelago and of the

waters above it, together with the islands of the archipelago where relevant, and the straits and sounds between the islands. The investigation is to comprise mainly those fields of survey, and subjects of research, for which the Department of Energy, Mines and Resources is responsible in other parts of Canada, wherever such study is not more economically and efficiently pursued as a separate self-contained operation; but it is also designed to include, or to support, worthwhile researches in fields outside those normally supported by the Department, if such researches could not otherwise be carried out. Emphasis is placed on field research and on survey, but basic laboratory or theoretical research is carried on as needed to aid in the investigations, or in the interpretation of field data; and equipment or technique development or experimentation is undertaken as relevant. In addition, the facilities of the Project are made available, under certain conditions, to approved university and other non-Government research groups.

0104 ROOTS, E.F. - 1968

The Polar Continental Shelf Project - 1968; *Arctic Circular*, vol. 18, Nos. 1 and 2, pp. 24-25.

0105 ROOTS, E.F. - 1968

The role of logistics in northern research; *in* Proc. 2nd Nat. N. Res. Conf., Whitehorse, Aug. 26-27, pp. 65-77.

0106 ROOTS, E.F. - 1968

Polar Continental Shelf Project; *in* Government Activities in the North - 1967, Dept. Ind. Aff. N. Devel., Advisory Comm. N. Devel., pp. 48-53

0107 ROOTS, E.F. - 1969

Informal remarks; *in* Polar Plan Conference, Virginia, Sept. 29-Oct. 2, A.I.N.A., pp. 114-117.

0108 ROOTS, E.F. - 1969

The operation and management of Arctic scientific activities: lessons from the Polar Continental Shelf Project; *Abstract*, Soc. Expl. Geophys., Calgary, Sept. 14-18.

The Polar Continental Shelf Project, which has completed its tenth field season, is the largest sustained scientific activity attempted in the Arctic by western nations. Lessons from its experiences may apply to other Arctic technical activities.

The Project is a semi-independent operational group established to achieve a long-term investigation of the continental shelf and adjacent regions of Arctic Canada in cooperation with other government agencies and by conducting independent research as necessary. Its program is designed to be flexible and adaptable to the changing priorities of national policy and the requirements of industry. Over the past ten years the achievements of the Project in undertaking control surveys, regional studies and researches in many fields have justified the premise that a number of investigations sharing logistics facilities and management can be more economical and scientifically effective than the same activities carried out separately. The operations have provided experience in the technical, economic, and management problems

imposed by the Arctic environment. In comparison with temperate regions, logistics are more expensive, but not necessarily more difficult; operational management is more difficult, though not necessarily more expensive. The investigation of a new area passes through several stages: - exploration, reconnaissance, problem research, and development or testing -, each with its optimum tactics and organization. From the planning and management aspect, Arctic activities have three unusual and important characteristics: (1) the physical constraints of the environment may upset the traditional relationships between time, money, and results; (2) the cost of labour may not be related to the job but may be controlled by the effectiveness with which a southern social environment is transplanted or substituted; and (3) the natural environment is so delicate and the consequences of destructive human activity so severe that operational decisions must consider not only immediate results but possible long-term effects quite outside the subject of the operation.

0109 ROOTS, E.F. - 1969

Cold Water and Man; *in* Conference on Man in Cold Water, Montreal, May, pp. 1-7.

0110 ROOTS, E.F. - 1969

Polar Continental Shelf Project; *in* Government Activities in the North - 1968, Dept. Ind. Aff. N. Devel., Advisory Comm. N. Devel., pp. 97-102.

0111 ROOTS, E.F. - 1970

Polar Continental Shelf Project; *in* Government Activities in the North - 1969, Dept. Ind. Aff. N. Devel., Advisory Comm. N. Devel., pp. 104-110.

0112 ROOTS, E.F. - 1971

Polar Continental Shelf Project; *in* Government Activities in the North - 1970, Dept. Ind. Aff. N. Devel., Advisory Comm. N. Devel., pp. 62-65.

0113 VAN STEENBURGH, W.E. - 1961

The scientific exploration of Canada's Arctic Islands; *New Scientist*, No. 241, pp. 792-795. Since the war there has been a quickening of scientific activity in the archipelago of the Far North. Research stations and expeditions whose interests range from weather forecasting to archaeology are engaged there. The first drillings in search of oil and natural gas may begin in the islands this summer.

0114 VAN STEENBURGH, W.E. - 1963

The Polar Continental Shelf Project; *in* Symposium on Geophysics in Government, Can. Min. Met. Bull., May, pp. 19-22, and Trans. C.I.M.M., vol. 66, pp. 198-201.

The Polar Continental Shelf Project was initiated in 1959 to provide an administrative and logistic vehicle for research in the physical sciences of the land, sea and channel areas of the Arctic Archipelago. Most of the scientists are supplied on secondment from the professional branches of the Department. The yearly expeditions number some eighty scientists and sub-professional staff, and they are supported by a fleet of fixed-winged

aircraft and helicopters. Accurate positioning is obtained by the use of a Decca Lambda navigational system which is moved as the area of interest is shifted. The Project is designed to accommodate not only physical scientists, but to provide facilities for other scientists who may have an interest in the area under study.

The main research scope of the Project includes topographical surveys, hydrography, oceanography, geology, including marine sedimentary studies, gravity, magnetics, seismology, glaciology and geography.

0115 VAN STEENBURGH, W.E. - 1967

The Polar Continental Shelf Project; *Polar Cont. Shelf Proj.*, internal report, 16 p.

The Polar Continental Shelf Project was authorized by the Canadian Government, by Cabinet Directive, on April 5, 1958. It was designed to conduct general mapping, oceanographic, hydrographic, geological, geophysical, geographical and related studies, to be undertaken on the Arctic Ocean Continental Shelf, on the islands of the Archipelago, and in the channels. It was to act as a logistic instrument for all divisions of the Department of Mines and Technical Surveys (Energy, Mines and Resources) in conducting research in the Arctic regions of Canada. It was to supply logistic support and facilities to other agencies conducting research in the area.

GEOLOGY

0116 BARNETT, D.M., FORBES, D.L., and

WHYTOCK, J.K. - 1970

Generator Lake, Baffin Island; *in* Generator Lake, Baffin Island, N.W.T. and Tasiujaq Cove, Ekaluqad Fiord, Baffin Island, N.W.T. 1968, *Can. Oceanog. Data Centre*, C.O.D.C. Ref. 22-68-777, No. 1, 27 p.

0006 BLISS, L.C. - 1972

Devon Island I.B.P. Project, High Arctic Ecosystem, Project Report 1970 and 1971; *Dept. Botany, Univ. Alta.*, 413 p.
Abstract under 0006

0117 BROAD, D.S. - 1968

Lower Devonian Heterostraci from the Peel Sound Formation, Prince of Wales Island, Northwest Territories; unpub. MSc. Thesis, Univ. Ottawa, 138 p. Devonian vertebrate faunas representing Osteostraci, Heterostraci, Arthrodira, Acanthodii and Crossopterygii were obtained from the conglomerate, sandstone and carbonate facies of the Peel Sound Formation of Prince of Wales Island, Arctic Canada. One locality examined in detail shows a conformable passage between the conglomerate facies and the underlying Read Bay Formation. Heterostracan faunas from the basal 450 feet of Peel Sound sandstone and conglomerate include thirteen species representing the families Cyathaspididae, Corvaspididae, Traquairaspididae and Pteraspidae. Included are the new genera *Torpedaspis* and *Pseudotraquairaspis*, and the new species *Traquairaspis rambaldi* and *Pteraspis (Simopteraspis) arctica*. A reconstruction of the cyathaspidid *Torpedaspis* gen. nov. is attempted on evidence from an entire specimen.

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Comparison with similar heterostracan faunas elsewhere in the world strongly suggests a Downtonian and Ditonian age for the conglomerate facies; hence the base of the formation at this locality approximates to the Siluro-Devonian boundary. Vertebrate faunas elsewhere suggest a probable Early and Middle Devonian age for the sandstone and carbonate facies. Heterostraci are common at sixteen stratigraphically separated sandstone horizons. Their distribution suggests that populations occupied a near-shore brackish environment which was repeatedly destroyed by periodic influx of coarse clastics due to rapid but intermittent uplift of the Boothia Arch. A progressive facies change and abrupt faunal change from the Ludlovian Read Bay Formation to the Downtonian and Ditonian Peel Sound Formation indicates change from shallow marine conditions (characterized by invertebrates) through transitional marginal brackish conditions (characterized by abundant Heterostraci) to fluvial conditions.

0118 CHRISTIE, R.L., COOK, D.G., NASSICHUK, W.W., TRETTIN, H.P., and YORATH, C.J. - 1972
The Canadian Arctic Islands and the Mackenzie Region; *Guidebook A66*, 24th Int. Geol. Cong., 146 p.
The Canadian Arctic includes one of the largest archipelagos of the world: the land and enclosed marine waters are more than 650,000 square miles in area; almost 950,000 square miles (243,200 km²) if the offshore continental margin and slope are included. This sparsely vegetated and thinly populated region extends about 1,500 miles (2400 km) from southeastern to western extremities, and 1,200 miles (1920 km) from the mainland of North America to the northern tip of the northernmost island. Although, in the past, the Canadian Arctic was one of the world's most inaccessible regions and the scene of journeys involving incredible hardships, accessibility now has increased greatly through a network of air routes and airfields. Ice-breakers and ice-strengthened ships reach, almost annually, the larger islands and the settlements along the north coast of the mainland. Systematic geological study of the archipelago by the Geological Survey of Canada began in 1947; since about 1959 there has been an increasing pace of geophysical and surface exploration and of wildcat well drilling. The major oil discovery in northern Alaska in 1968 resulted in an even greater increase in oil exploration in the Canadian Arctic, both on the mainland and in the islands.
The Mackenzie region includes some 200,000 square miles (512,000 km²) of plains, mountains, and uplands. The broad Mackenzie River, flowing northward to the Arctic Ocean, provided a natural highway for early exploration and today carries substantial heavy freight traffic. Many small communities lie along the Mackenzie River and on the large Great Slave and Great Bear Lakes. Access along the Mackenzie valley by boat and winter road, depending on the season, is routine. Air transport from several centres allows quick access to almost all parts of the region.
The northern limit of trees passes through the northern part of the region, as does the southern limit of continuous permafrost.

The economic development of the Arctic Islands and adjacent regions poses problems in an age of awareness of potential disruption to a delicate local ecological balance, and to the life style of the indigenous people. The modernization and exploitation of this 'new' area is on view to the world, so that it may be a showcase either of an enlightened, balanced development or of a new disaster area in the process of formation.

0119 COAKLEY, J.P. - 1966
History and bottom sediments of Stanwell-Fletcher Lake, Somerset Island, N.W.T.; unpub. MSc. Thesis, Univ. Ottawa, 83 p.
Stanwell-Fletcher Lake lies in a post-Cretaceous graben on the east side of the Boothia Arch, Somerset Island, Northwest Territories. The lake site was formed by glacial excavation of a down-faulted block of relatively soft Cretaceous (?) rocks, and the history of the area can be traced through three stages as post-Pleistocene uplift progressed; marine, estuarine, and the present lacustrine stage. The last stage is believed to have commenced approximately 5,000 years ago.
Since that time, the saline water formerly occupying the lake site has been completely replaced by fresh water, largely through circulation during the estuarine stage. The lack of chemical stratification and the isothermal nature of the lake indicate efficient circulation and hence oxygenation of the water in spite of the year-round ice-cover.
In general the bottom sediments of Stanwell-Fletcher Lake are unlaminated, fine-grained deposits oxidized to a reddish-brown colour at the surface. Poor sorting and positive skewness are the rule even in the seasonally ice-free, wind-agitated margins. Silt and mud predominate in the central portions of the lake, whereas the marginal areas are generally sandy. The distinctness of these two groupings of sediments is attributed to differing modes of transport and deposition, namely, bottom traction and seasonal deposition of the sand as opposed to slow, year-round settling out of the mud. Surface organic carbon averages 2.3%, and total carbonates less than 1%. The appearance downward in the cores of apparently detrital dolomite and *in situ* foraminiferal tests is accompanied by an increase in mean grain size. The higher energy estuarine phase is believed to have been operative at that time.
The cold climate retards chemical weathering and limits the duration of sediment transport by streams. The rate of sedimentation in the lake is therefore low and sorting is poor because the ice-cover minimizes winnowing by wave activity. Chemical and biological processes in the water are inhibited by the low temperatures with the result that autochthonous sediments such as organic matter and precipitated carbonates (marls) are insignificant in the deposits. As chemical breakdown of clay-producing minerals is minimal, the clay minerals present were mechanically derived from source rocks in the area.

0120 COAKLEY, J.P., and RUST, B.R. - 1968
Sedimentation in an Arctic lake; *J. Sed. Petrology*, vol. 38, No. 4, pp. 1290-1300.

Stanwell-Fletcher Lake is 400 miles north of the Arctic Circle, covers 131 square miles, and is over 100 m deep. Its size and the severe climate restrict summer melting of ice to the margins. The ice insulates the water, which remains essentially isothermal, warming slightly from 1.3 to 1.6°C during the summer. Inflowing water is nearer 4°C, and therefore sinks and mixes with the lake water, a process which maintains thermal and chemical homogeneity in the lake and oxygenates the surficial bottom sediment.

Sedimentation is very slow because of the short period of stream flow and the low organic activity in the lake. Silty sand derived from river bed loads accumulates on shallow marginal deltas and shelves. The sediment is poorly sorted because ice cover prevents wave action and removal of the fine material to deeper water. Mud, derived largely from the suspended loads of rivers, settles slowly in the central part of the lake. Faint laminae in the shelf sands may be varves, but the deep water mud is structureless. Evidently seasonal sedimentary variations do not affect the center of the lake, probably because ice cover minimizes transporting currents.

The oxidation-reduction boundary in the sediment is at 5-20 cm, deeper than in temperate lakes, because of oxidation at the lake bottom and slower reduction within the sediment.

0121 DEWIS, F.J. - 1971

Relationship between mineralogy and trace element chemistry in sediments from two fresh water deltas and one marine delta within the Mackenzie River drainage basin; unpub. MSc. thesis, Univ. Calgary, 98 p.

Sediment samples from two northern Alberta fresh water deltas (one in Lake Claire and one in Lake Athabasca) and from the marine Mackenzie River delta were analysed for mineralogical composition and abundance of the trace elements B, Cu, Zn, Ni, Li and Mn. In both the marine and fresh water deltas the total clay content of the samples correlated highly with the trace elements studied. The concentration of B and total clay in the bottom sediments from all three deltas was found to increase with distance from the mouth of each delta (the increase was less well-defined by Cu, Zn, Ni, Li and Mn). The variations in trace element concentrations in the two fresh water deltas are a result of variations in total clay content. The slopes of regression lines, computed for the boron and total clay content of the fresh water and marine delta sediments, were found to be equal which indicated that it was unlikely boron adsorption was a significant factor in controlling the boron content of sediments in the marine Mackenzie River delta. Discriminant function analysis showed that the fresh water and marine delta sediments were not statistically different based on their boron and total clay content. Mineralogical and chemical differences in the source material of the fresh water and marine deltas are believed to be responsible for the differences between the fresh water and marine delta sediments rather than any adsorption mechanism. The low temperature of the Mackenzie River delta

environment may be a factor in the lack of boron adsorption in the marine delta.

0122 DEWIS, F.J., LEVINSON, A.A., and BAYLISS, P. - 1972

Hydrogeochemistry of the surface waters of the Mackenzie River drainage basin, Canada-IV. Boron-salinity-clay mineralogy relationships in modern deltas; *Geochimica et Cosmochimica Acta*, vol. 36, pp. 1359-1375.

Bulk sediment samples from two northern Alberta fresh water deltas and from the marine Mackenzie River delta were analysed for mineralogy and the trace elements B, Cu, Zn, Ni, Li and Mn. In both the marine and fresh water deltas the total clay content of the samples correlates highly with the trace elements studied. The concentration of B and total clay in the bottom sediments from all three deltas increases with distance from the mouth of each delta (the increase is less well-defined for Cu, Zn, Ni, Li and Mn). The trace element variations in the two fresh water deltas result from variations in total clay content. If the two similar fresh water deltas were preserved in an ancient environment, they could be mistaken for a marine delta based solely on the boron content of the whole rock analyses as the boron content ranges are analogous to those reported for modern and ancient marine deltas.

The slopes of regression lines, computed between the boron and total clay content of the fresh water and marine delta sediments are equal, which indicates that boron adsorption from sea water is not a significant factor in controlling the boron content of sediments in the marine Mackenzie River delta. Although the separation of the marine and fresh water regression lines is statistically significant, discriminant function analysis shows that the mineralogical and chemical differences of the samples can be explained better by variations in the source area rather than by their occurrence in either the fresh water or marine deltas. The low water temperature of the Mackenzie River delta environment, and low silica content of the Mackenzie River, may be factors in the small boron increase in the marine delta for an alternative adsorption explanation. The boron content of shales and other fine-grained sediments may be useful to determine distance from a standard line, but its usefulness as an indicator of paleosalinity is questionable.

0123 DINELEY, D.L. - 1965

Notes on the scientific results of the University of Ottawa expedition to Somerset Island, 1964; *Arctic*, vol. 18, No. 1, pp. 55-57.

The general aim of the expedition was to study the geology and geomorphology of northern Somerset Island, with a view to extending work into other parts of the Precambrian highlands in later field seasons.

The expedition arrived at Somerset Island on 11 June 1964 and left on 14 August. A rapid examination by helicopter of the north coast between Aston Bay and Prince Leopold Island provided valuable data on local topography, surficial and solid geological formations and eskimo sites.

GEOLOGY

0124 DINELEY, D. - 1966

Geological studies in Somerset Island, University of Ottawa expedition, 1965; *Arctic*, vol. 19, No. 3, pp. 270-277.

Geological studies around Aston Bay and Limestone Island, Stanwell-Fletcher Lake, and Creswell Bay in Somerset Island include the structure of the Pre-Cambrian metamorphic basement, the stratigraphy, sedimentology, and palaeontology of the Aston and Hunting formations, the Palaeozoic rocks, and the younger strata north of Stanwell-Fletcher Lake. The Recent sedimentology of the lake and local Quaternary features are investigated.

0125 DINELEY, D.L. - 1971

Arches and basins of the southern Arctic Islands of Canada; *Proc. Geol. Assoc.*, vol. 82, Part 4, pp. 411-444.

In the southern islands of the Canadian arctic archipelago and on the adjacent mainland three types of terrain predominate - uplands of crystalline rocks, plateaux of flat-lying strata, and lowlands of younger, relatively undisturbed strata. Forming the eastern boundary of the region lie the Baffin-Ellesmere mountains adjacent to Baffin Bay and Davis Strait, and to the north-west are the arctic ocean lowlands. Each of these major areas is profoundly different from the others in its geology, and these differences reflect crustal behaviour since Pre-Cambrian time. In the southern arctic islands region, several major northerly projecting basement features, the Minto, Wellington, Boothia and Melville-Southampton Arches separate the shallow Palaeozoic accumulations of the Wollaston, Victoria Strait, Jones-Lancaster and Foxe Basins. The Minto and Wellington Arches contain Pre-Cambrian sedimentary strata with some lavas and sills which are relatively little disturbed. In contrast, the Boothia and Melville-Southampton Arches are largely composed of granitic gneisses and greenschists much folded along north-south and north-east-south-west lines respectively. Early 'post-Archean' sediments and numerous basic intrusives of uncertain age also occur. The rocks of these arches have a complex Pre-Cambrian history and the Boothia Arch was elevated dramatically in late Silurian-early Devonian and again possibly in Tertiary times.

Facies variation within the strata of the basins gives little indication of positive movement of the arches in early Palaeozoic time. The influence of the Canadian Shield to the south and the developing Franklinian Geosyncline to the north were more important in facies control. Much of the deposition within the basins was of shallow water carbonates with some fine clastics and, at least locally, evaporites. Many kinds of lime-secreting and other organisms influenced sedimentation and biogenic rocks are common. This region seems also to have been occupied by some of the earliest-known vertebrate faunas, and it may have been a centre of Silurian agnathan radiation.

In late Silurian-early Devonian time an orogeny sharply elevated the Boothia Arch and may have established the Cornwallis Fold Belt. The Siluro-Devonian Peel Sound Formation, spreading from the Boothia Arch into the Victoria Strait, ?Melville

and Jones-Lancaster Basins, exhibits lateral facies changes from alluvial fans through fluvial to marine strata.

Little is known of the geological history of the area from Devonian until Quaternary times. It is thought to have been a broadly positive area undergoing denudation and shedding sediment northward to the Sverdrup Basin. Nevertheless, Cretaceous Tertiary sediments occur in a few small outcrops far north of what has been regarded as the shoreline of those times. On Somerset Island the presence of *Lingula* in such strata may indicate a connexion with the Sverdrup Basin sea or with open water to the south. Sediment transport southward from the northern side of Barrow Strait is suggested near the axis of the Boothia Arch in southern Somerset Island. Fault activity at a later date is perhaps a rejuvenation of earlier trends of movement.

The recently suggested isostatic origin of these arches or uplifts seems to be in accord with the facts, and appears to indicate that a wide area of relative isostatic equilibrium now exists between the Franklinian Geosyncline and the (Canadian Shield) craton, but that this was not the case in Palaeozoic time.

0126 DINELEY, D.L., and RUST, B.R. - 1968

Sedimentary and paleontological features of the Tertiary-Cretaceous rocks of Somerset Island, Arctic Canada; *Can. J. Earth Sci.*, vol. 5, pp. 791-799.

A 300 m succession of non-marine clastic rocks, herein termed the Idlorak Formation, lies in a graben on the Precambrian basement of Somerset Island, Arctic Canada. The indigenous microflora is probably late Cretaceous or Tertiary in age. Abraded fish remains, reaching 65 cm in length, include arthrodires, other placoderms, and cross-opterygians, which were probably derived locally from former outcrops of Upper Devonian rocks.

Eighty percent of the Idlorak Formation is well-sorted quartz sandstone; the remainder is shale, siltstone, and minor conglomerate. Abundant large-scale cross-stratification indicates fluvial transport from the north, and the presence of *Lingula* suggests a marginal coastal environment such as a delta. The largely arenaceous Griper Bay Formation and equivalent formations, now nearly 400 km to the north, may have formerly extended southward to provide the bulk of the source material.

0127 DIXON, O.A., WILLIAMS, S.R., and

DIXON, J. - 1971

The Aston Formation (?Proterozoic) on Prince of Wales Island, Arctic Canada; *Can. J. Earth Sci.*, vol. 8, No. 7, pp. 732-742.

Substantial exposures of a thick basal sedimentary sequence, the Aston Formation of Somerset Island, occur on eastern Prince of Wales Island and incorporate at least 2600 ft (793 m) of arkose, subarkose, and orthoquartzite, with minor dolostone, chert, and mudstone. The detrital sediments, derived from contemporary uplands on the site of the present Boothia Arch, accumulated in shallow marine to lagoonal environments. A thin, extensive, and distinctive stromatolitic dolostone in the two major exposures of the formation has an environmental and possibly

a regional time-stratigraphic significance. Gabbro dikes and sills, some of them exceeding 1000 ft (305 m) in thickness, intrude the Aston Formation.

0128 DIXON, J., WILLIMAS, R., and TURNER, S. - 1972 Stratigraphical setting of the Silurian thelodonts from Prince of Wales Island, Northwest Territories; *Lethaia*, vol. 5, pp. 281-282. Additional and corrected information is given regarding the stratigraphy and palaeoecology of the thelodont-bearing sequence on Prince of Wales Island. The thelodont fauna is not older than latest Wenlockian.

0129 EMBRY, A.F. - 1970

A late Devonian reef tract on northeastern Banks Island, N.W.T.; unpub. MSc. thesis, Univ. Calgary, 121 p.

The exposed Upper Devonian succession on northeastern Banks Island, N.W.T. is 3700 feet thick and has been correlated with the Griper Bay Formation. It consists mainly of terrigenous clastic rocks which were deposited in a marine shelf to coastal complex environment. The source area was located to the west. The age of the exposed section ranges from the base of the Frasnian to the Middle Famennian. Devonian strata have been moderately deformed, and north-south trending folds and normal faults are present. Deformation occurred during the Mississippian, and the structures were reactivated in the Tertiary.

A 200 foot carbonate unit occurs in the middle of the succession. It has been herein named the Mercy Bay Member and is of Middle Frasnian age. It contains many organic buildups and represents a Devonian reef tract. The reef tract was located on the western shelf of an exogeosyncline which extended along the margin of North America between the stable craton and a western tectonic highland. The main facies changes in the Mercy Bay Member occur in an east-west direction. The organic build-ups in the eastern part of the study area, which is the seaward edge of the reef tract, are narrow, linear bioherms which trend north-south. They are encased in younger terrigenous clastic rocks. To the west, the organic buildups, which are biohermal in the lower part and biostromal in the upper part, are more numerous. The lower bioherms trend east-west, and the inter-biohermal strata, which consist of dark, fine-grained, argillaceous limestones, are penecontemporaneous. The organic buildups on the western edge of the outcrop area are larger and are biohermal. The shoreward edge of the reef tract is not exposed.

The lower portion of all the organic buildups is composed of corals and tabular stromatoporoids which built biogenetic banks in the quiet and intermediate energy zones. These energy zones are postulated to have been below 30 feet of water depth. The upper portion is composed of massive stromatoporoids which built rigid reefs in the high energy zone (above 30 feet). Successive sea level rises allowed the reefs to grow upward. The cessation of reef growth was caused by a rise in sea level and an influx of terrigenous sediment.

The Griper Bay Formation appears to be a potential producer of hydrocarbons. The main potential reservoirs are the high energy coastal complex sandstones and possibly the organic buildups of the Mercy Bay Member.

0130 EMBRY, A.F., and KLOVAN, J.E. - 1971

A late Devonian reef tract on northeastern Banks Island, N.W.T.; *Bull. Can. Pet. Geol.*, vol. 19, No. 4, pp. 730-781.

The Upper Devonian Weatherall Formation, outcropping on northeastern Banks Island, N.W.T., contains a 200-ft-thick limestone unit here termed the Mercy Bay Member. The member is Middle to Late Frasnian in age. Gyr Falcon Bluff has been chosen as the type section.

Mercy Bay Member outcrops on the extreme northeastern portion of Banks Island, and many excellent exposures permit detailed paleogeographical and paleoecological studies. The member contains numerous organic build-ups and represents a Late Devonian reef tract located in the marine-shelf environment of an exogeosyncline situated between a tectonic highland to the northwest and a stable craton to the southeast.

The main facies changes in the Mercy Bay Member occur in an east-west direction. The organic build-ups in the eastern part of the study area are narrow, linear bioherms trending north-south. They are encased in younger terrigenous clastic rocks. To the west the organic build-ups, which are biohermal in the lower part and biostromal in the upper, are more numerous. The lower bioherms trend east-west. Penecontemporaneous interbiohermal strata consist of dark, fine-grained argillaceous limestone. Organic build-ups on the western edge of the outcrop area are bioherms which trend north-south.

The lower portion in all organic build-ups consists of corals and tabular stromatoporoids. These are interpreted as biogenetic banks constructed in the quiet and intermediate-energy zones (water depths more than 30 ft). The upper portion is composed of massive stromatoporoids. This facies represents rigid reefs constructed in the high-energy zone (above 30 feet). Successive sea-level rises allowed the reefs to grow upward. Cessation of reef growth was caused by an influx of terrigenous sediment related to the seaward migration of the northern and western shorelines.

The outcropping organic build-ups of the Mercy Bay Member are tightly cemented, but frequent bitumen occurrences indicate that they were once oil-bearing. Organic build-ups of the Mercy Bay Member probably occur in the subsurface to the west.

0131 EMBRY, A.F., and KLOVAN, J.E. - 1972

Absolute water depth limits of late Devonian paleoecological zones; *Sonderdruck aus der Geologischen Rundschau*, vol. 61, No. 2, pp. 672-686.

A refined scheme of reefal limestone classification, which places more emphasis on the >2 mm components (conglomeratic fraction) and on the mode of organic binding, allows for a more detailed facies description of organic buildups. The classification has been applied to late Devonian organic buildups which

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outcrop on northeastern Banks Island, Canadian Arctic Archipelago. The distribution and sequences of facies in one organic buildup has led to the determination of absolute water depth limits of three major Late Devonian paleoecological zones. Corals were the dominant fauna below 70 feet (21 m); tabular stromatoporoids flourished between 70 feet (21 m) and 30 feet (9 m) of water depth; massive stromatoporoids were the dominant fauna between 30 feet (9 m) and sea level. The main controlling factor on the depth limits of the zones was wave energy (normal wave base, 30 feet 9 m; storm wave base, 70 feet 21 m).

0132 EVERETT, K.R. - 1968

Soil development in the Mould Bay and Isachsen areas, Queen Elizabeth Islands, Northwest Territories, Canada; *Inst. Polar Studies*, Rep. No. 24, Ohio State Univ., 75 p.

Soils developed on the fine-grained sedimentary rocks of the Western Queen Elizabeth Islands illustrate well the weakening of the soil-forming processes with increasing latitude. Most of the soils of the Mould Bay area, Prince Patrick Island, are thin with weak morphological and chemical profiles. In contrast to the Tundra soils of northern Alaska and Victoria Island, the desertic soils of Prince Patrick Island are low in organic matter. They have developed largely under the processes of salinization and calcification. Their complex, mosaic associations reflect the dominant influence of subtle drainage changes.

The soils of the Isachsen area of Ellef Ringnes Island are similar to those of Prince Patrick Island. However, profile development is even less well defined. The degree of expression of the soil-forming processes here has been reduced to almost nothing.

The soils and soil-forming factors are expressed better on Prince Patrick Island, partly because of its more southerly latitude and somewhat more coarse-grained parent materials, and partly because the soil-forming factors there have had a greater uninterrupted period over which to operate.

0133 FRENCH, H.M. - 1970

Soil temperatures in the active layer, Beaufort Plain; *Arctic*, vol. 23, No. 2, pp. 229-239. This paper describes soil temperatures measured in the active layer on slopes of varying orientations in northwest Banks Island during the summer of 1968. High soil temperatures often in excess of 60°F. at a depth of 1 inch are not uncommon in areas underlain by Beaufort Formation and reflect the high thermal conductivity and low heat capacity of these materials. The relation between the microclimates of slopes of varying orientations and the asymmetrical nature of the valleys of the region is briefly discussed.

0134 FRENCH, H.M. - 1971

Ice cored mounds and patterned ground, southern Banks Island, western Canadian Arctic; *Geografiska Ann.*, vol. 53, Ser. A, pp. 32-38. Small hydrolaccoliths are described which occur within low centred ice wedge polygons on poorly

drained meadow tundra (Kellett) soils in the Masik Valley. It is suggested that the process of ice segregation is brought about by a contraction of the water saturated layer under cryostatic pressure and that the upstanding ice wedges, which bound the polygons, form the boundaries to the closed system. There is some similarity, therefore, between these features and the closed system pingos of the Mackenzie Delta with respect to genesis.

0135 FRENCH, H.M. - 1971

Slope asymmetry of the Beaufort Plain, northwest Banks Island, N.W.T., Canada; *Can. J. Earth Sci.*, vol. 8, No. 7, pp. 717-731.

The Beaufort Plain of northwest Banks Island is currently being dissected by a series of valleys which portray a striking asymmetry of their slopes. In most valleys aligned in a direction northwest-southeast, the steeper slope faces towards the southwest. The importance of both fluvial and degradational processes is stressed in the interpretation of these valleys. The asymmetry is the result of differing microclimates existing upon differently exposed slopes, which favors the development of solifluction processes on the northeast facing slopes. Consequently, the stream moves laterally towards the slope producing the least colluvium. The southwest facing slope is then undercut and steepened in angle through the operation of fluviothermal erosion processes. The microclimatic differences on the two slopes can be related to the dominant westerly winds in this part of the arctic which (a) deposit snow preferentially on the lee sides of valleys during the winter and (b) promote evaporation from exposed slopes during the summer.

0136 FRENCH, H.M. - 1972

The proglacial drainage of northwest Banks Island; *The Musk-ox*, Pub. No. 10, pp. 26-31.

The object of this paper is to describe the major proglacial drainage features of northwest Banks Island (Figure 1). Fieldwork undertaken in 1968 involved the field mapping and aneroid surveying of landforms in the vicinity of Ballast Brook, together with a brief examination of the surficial deposits. Subsequent air photo interpretation has extended the study area to include the extreme coastal regions around Bar Harbour and Cape Prince Alfred.

0137 FYLES, J.G. - 1965

Surficial geology, western Queen Elizabeth Islands; *in Report of Activities: Field, 1964*, Geol. Surv. Can., Paper 65-1, pp. 3-5.

0138 FYLES, J.G. - 1966

Quaternary stratigraphy, Mackenzie Delta and Arctic Coastal Plain; *in Report of Activities, May to October, 1965*, Geol. Surv. Can., Paper 66-1, pp. 30-31.

0139 FYLES, J.G. - 1967

Winter Harbour moraine, Melville Island; *in Report of Activities, May to October, 1966*, Geol. Surv. Can., Paper 67-1, Part A, pp. 8-9.

0140 FYLES, J.G. - 1967

Mackenzie Delta and Arctic Coastal Plain; in Report of Activities, May to October, 1966, Geol. Surv. Can., Paper 67-1, Part A, pp. 34-35.

0141 FYLES, J.G., HEGINBOTTOM, J.A., and RAMPTON, V.N. - 1972

Quaternary geology and geomorphology, Mackenzie Delta to Hudson Bay; *24th Inter. Geol. Cong.*, Excursion A-30 guidebook, 23 p.

This field trip has two interrelated objectives involving facets of the geomorphology and Quaternary geology of the Arctic Coast and Lowland, Interior Plains, and Shield regions of northwest Canada. First, it is intended to illustrate the occurrence of permafrost and ground ice and attendant geomorphic features; second, to provide an overview of the glacial and related landforms that are striking features of the landscape and to review the glacial history of the region.

The landscape of northwestern Canada, within the Coastal Plain, Interior Plains, and Shield regions is characterized by a striking array of geomorphic features relating to permafrost, glaciation, and changes in level of lakes or the sea. These features are particularly obvious because much of the area is treeless and of low relief and because of the widespread use of air travel. The glacial features are the product of the Continental or Laurentide ice sheet and originated, in a general way, from a similar sequence of events during the same time interval as the much better known glacial features of southern Canada and northern U.S.A. The trip is intended to illustrate these landforms and their regional pattern from aircraft, and to include an aerial transect from the limit of Laurentide glaciation in the Mackenzie Delta region to the central part of the ice sheet area in the vicinity of Hudson Bay, crossing the site of the last glacier remnants west of Hudson Bay (Fig. 1).

The field trip and guidebook were planned to comprise two distinct parts: (1) a traverse by aircraft along the route outlined in Figure 1 with an accompanying guidebook dealing basically with features visible from an aircraft following this specific route, and (2) more detailed treatment of the lower Mackenzie region including specific information for sites illustrating the principal elements of the geomorphology and Quaternary geology at Inuvik and near Tuktoyaktuk.

This published guidebook deals only with the second portion of the proposed trip, in the lower Mackenzie region. Because the trip will not take place, the route log for the other part of the trip (i.e. the traverse by aircraft) has been omitted as it appears to be of little relevance other than in the context of the trip itself. This "omitted" portion of the guidebook relies heavily on those sections of *Geology and Economic Minerals of Canada* (fifth edition, 1970) dealing with Physiography (Bostock, 1970a) and Quaternary geology (Prest, 1970) and on the accompanying Physiographic Map of Canada (Bostock, 1970b) and *Glacial Map of Canada* (Prest, Grant and Rampton, 1968). Interested readers are referred to these sources of information.

0142 GIGUÈRE, J.F. - 1968

Element distribution in coexisting pyroxenes from granulite rocks of southeast Stanwell-Fletcher Lake area, Somerset Island, District of Franklin, N.W.T.; unpub. MSc. Thesis, Univ. Ottawa.

Part I: The area studied is situated on Somerset Island, District of Franklin, N.W.T.

Most of the rocks in this area are Proterozoic metamorphics of granulite facies. It is suggested that these rocks were formed as the result of relatively high temperature and water pressure, and low confining pressure for the granulite facies.

Part II: The distribution of magnesium, bivalent and trivalent iron, manganese, titanium and calcium between coexisting orthopyroxene and calcic pyroxene in the granulite rocks was studied.

From the shape of the best fit coefficient of distribution curve with respect to magnesium and bivalent iron, it is concluded that the distribution of these ions in orthopyroxene is not ideal.

The coefficient of distribution of manganese with respect to magnesium and bivalent iron was found to decrease towards unity, that is, approach ideality with increasing temperature.

It is suggested that an exchange equilibrium exists between trivalent iron and titanium, provided that titanium is assumed to be trivalent.

Calcium is not involved in an exchange equilibrium in coexisting pyroxenes.

A tentative geothermometer is proposed on the basis of the coefficient of distribution of magnesium with respect to bivalent iron, and of the coefficient of distribution of manganese with respect to magnesium and bivalent iron. From this geothermometer, a range of temperatures and pressures for published pyroxene pair analyses in granulitic rocks is established. The temperatures and pressures range approximately between 680°C with a pressure of 5200 Atm and 760°C with pressure of 3000 Atm.

With this geothermometer, the values for the rocks from the Stanwell-Fletcher Lake area are 785°C with corresponding pressure of 3,050 Atm.

0143 GIGUÈRE, J.F. - 1972

Coexisting pyroxens in some granulite-facies gneisses from Somerset Island; *Can. Mineral.*, vol. 11, pp. 548-551.

The Precambrian rocks of Somerset Island in the Canadian Arctic consist mainly of a variety of high-grade gneisses and granulites (Blackadar 1967). In 1964 and 1965, the University of Ottawa Arctic Expedition, led by D.L. Dineley, obtained information on the Precambrian geology between Stanwell-Fletcher Lake and Creswell Bay, and numerous specimens were collected. This report describes seven of the specimens and presents chemical data on the contained orthopyroxene and calcic pyroxene.

The rocks of the study-area consist of a variety of light to dark coloured gneisses, amphibolites, and migmatites, all of which consist of various combinations and proportions of quartz, plagioclase, potassium feldspar, orthopyroxene, calcic pyroxene, hornblende, biotite, and garnet. Sillimanite and kyanite are uncommon and sapphirine is rare. Rocks with hornblende and biotite are interlayered with rocks that do not contain these minerals, and all the rocks are assigned to the granulite facies.

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The mineral assemblages and proportions found in seven specimens of gneiss are listed in table 1. The composition of the contained plagioclase ranges from An 30 to An 55.

0144 HENOCH, W.E.S. - 1964

Preliminary geomorphological study of a newly discovered Dorset culture site on Melville Island, N.W.T.; *Arctic*, vol. 17, No. 2, pp. 120-125.

0145 HORN, D.R. - 1963

Marine geology, Peary Channel, District of Franklin, Polar Continental Shelf Project; *Geol. Surv. Can.*, Paper 63-11, 33 p.

0146 HORN, D.R. - 1967

Recent marine sediments and submarine topography, Sverdrup Islands, Canadian Arctic Archipelago; unpub. Ph.D. Thesis, Univ. Texas, 362 p. Submarine topographic features of the channels, sounds, fiords, and bays can best be explained as the products of extensive glacial excavation of a pre-existing drainage system. Troughs, hanging troughs, strings of deeps or basins, terminal sills, linear rises and depressions, and oversteepened deltas are considered direct or indirect evidence of glacial scour. Following glaciation, a negative movement of the Sverdrup Basin was accompanied by flooding of the northern part of the Archipelago. Only the upper portions of former interfluvial areas remained above sea level. These topographic highs are the present-day islands of the Canadian Arctic Archipelago.

Statistical analyses of beach, fluvial, deltaic, and offshore marine sediments reveal characteristics that may be unique to polar deserts and ice-covered seas. Textures of beach and fluvial sediments are a function of associated relief and parent material. The deltaic environment is defined as that portion of the sea floor extending from the mouth of a river to approximately 3,200 feet from shore. Deltaic sediments show a progressive decrease in grain size seaward. Size distribution is related to the settling velocities of particles of different diameters. Offshore sediments have uniform textural properties. They are a combination of silt and clay (settled from suspension), and a minor but significant portion of sand- to granule-sized sediment (ice-rafted). An increase in mean grain size on the crests of submarine topographic highs suggests that winnowing by currents is taking place over these features. Two large areas of the sea floor lack a cover of Recent sediment.

Organic carbon constitutes 0.84 to 2.14% of the offshore sediments. A dual source, terrigenous and phytoplanktonic, may explain the relatively high percentage of organic carbon. There is a positive correlation between percent organic carbon and amount of clay in the samples.

Results of semiquantitative clay-mineral analyses of source rock, fluvial, deltaic, and offshore marine sediments indicate that montmorillonite, kaolinite, and illite are the dominant clay minerals. In this northern region, there is no change in clay mineralogy during weathering and transport. It is suggested that this may be characteristic of

weathering under polar desert conditions. The mineralogy of parent materials on the islands controls the clay mineral distribution in offshore areas. In Louise Fiord, well-crystallized kaolinite is differentially flocculated close to shore.

A study of the roundness of quartz grains of sand, silt, and clay size reveals that the distribution of this property is bimodal. Coarse and medium sands are well rounded, fine sands through coarse silts are angular, and fine silt and clay-sized particles are well rounded. High roundness of grains in the medium to coarse sand grades is attributed to abrasion. Well rounded quartz in the silt-clay size range is considered to be a product of solution.

0147 IQBAL, J. - 1972

Sedimentology and distribution of benthonic foraminifera in M'Clure Strait (Canadian Arctic Archipelago); unpub. MSc. Thesis, Dalhousie Univ.

M'Clure Strait is one of the main interisland channels in the Canadian Arctic Archipelago. These channels owe their origin to a pre-Pleistocene fluvial drainage system which was modified by the Pleistocene glaciers and subsequently inundated as these glaciers retreated.

Recent benthonic foraminifera in the M'Clure Strait have been studied from 40 grab samples. The foraminiferal assemblage is essentially similar to those reported from the adjacent areas of the Eastern Arctic. Distinct North Atlantic (sub-arctic) affinities are also apparent. A total of 74 species belonging to 48 genera and 27 families have been identified, described and illustrated. Of these 57 species are calcareous and the remaining 17 are arenaceous. Predominant species are: *Saccammina sphaerica*, *Cribrostomoides subglabrosus*, *Trochammina nana*, *Trochammina quadriloba*, *Cibicides lobatulus*, *Islandiella teretis*, *Islandiella norcrossi*, and *Islandiella islandica*.

The rose Bengal staining technique gave very ambiguous results and it was not possible to distinguish living specimens with confidence. Consequently, the entire population has been treated as a thanatocoenose.

Sedimentary analysis of 36 samples reveals that the Recent sediments in M'Clure Strait are predominantly muds and clays with small amounts of coarse material (sand and gravel) occurring in a random distribution irrespective of depth and distance from shore. This is considered to be the result of extensive ice-rafting, which is the dominant mode of sediment transportation in the area.

The environmental parameters studied to evaluate and correlate the associated foraminiferal distribution were: bathymetry, sediment distribution, temperature and salinity. Visual analysis failed to correlate the random and patchy distribution patterns of the predominant species with these environmental parameters. Only very broad generalizations permit the grouping of the fauna into (a) Calcareous, (b) Arenaceous, and (c) Mixed. Total population appears to be the result of faunal mixing caused by extensive ice-rafting, winnowing and current activity.

The application of Factor Analysis brings out three definite faunal assemblages (or thanatopes) based

on such factors as depth, distance from shore, nature of the substrate and test composition.

Thanatotope I is exclusively arenaceous, decreases away from shore and shows some preference for fine-grained substrates. The indicator species for this assemblage are: *Cribrostomoides crassimargo*, *Saccorhiza ramosa*, *Textularia earlandi* and genus *Trochammina*. Thanatotope II is predominantly calcareous, increases away from shore and is found in silt and sandy silt substrates. The indicator species for this assemblage are: *Astrononion gallowayi*, *Cibicides lobatulus*, *Cassidella complanata*, *Eponides tener*, *Fissurina semimarginata*, *Hyperammina elongata*, genus *Islandiella*, *Lagena laevis*, *Oolina hexagona*, *Planispirinoides bucculentus*, *Quinqueloculina seminulum* and *Triloculina trihedra*. Thanatotope III is a mixture of calcareous and arenaceous species which agree in their consistent occurrence in all types of sediments, from clay to gravelly sand, and almost universal occurrence in their areal distribution. The indicator species for this assemblage are: *Buccella frigida*, *Cibicides lobatulus*, *Cribrostomoides subglobosus*, *Elphidium bartletti*, genus *Islandiella*, *Lagena meridionalis*, *Melonis zaandami*, *Nonionella auricula*, genus *Reophax*, and *Saccammina sphaerica*.

0148 JAHN, A. - 1972

Tundra polygons in the Mackenzie Delta area; in *Hans-Poser-Festschrift*, Verlag Erich Goltze, Göttingen, pp. 285-298.

Investigations carried on in the tundra of the Mackenzie Delta validate the differentiation of the four basic types of polygons (polygonal net): high and low, concave and convex. The evolution of polygons and their transformation - from low into high and from concave into convex - occur through disturbances in morphological-and-climatic equilibrium of the tundra with the concurrent change of depth of the seasonally thawed layer. Such transformations are conditioned by changes in heat (thermal) balance of the ground, local or regional, or else by changes of denudational balance on inclined surfaces.

0149 JAHN, A. - 1972

Some regularities in thermokarst development; in *Processus Périglaciaires Étudiés sur le Terrain*, Symp. Inter. Geomorphologie, Liege, vol. 67, pp. 167-176.

Thermokarst processes in permafrost areas depend on heat (thermal) balance of the ground. The layer that thaws in summer (the active layer of the permafrost) acts as insulator by protecting ground ice from thawing. The presence of the active layer counteracts thermokarst processes. On the other hand, a removal or incision of this layer by erosion and denudation (including solifluction), facilitate thermokarst action.

Morphological action may thus be detected in potential thermokarst areas by examining the ratio heat (thermal) balance (B_t) to denudation balance (B_d) in every place of the area.

0150 JOURNAUX, M.A. - 1969

Phénomènes périglaciaires dans le Nord de l'Alaska et du Yukon; *Bull. Assoc. Géog. Française*, No. 368-369, pp. 337-350.

Invited to stay in Alaska and in Yukon, the author presents many pictures of landscapes and exposes some problems of periglacial morphology: ice in soil and in particular ice wedges and pingoes; oriented lakes and their evolution; frost boils of clay or silt, a.s.o.

0151 KERFOOT, D.E., and MACKAY, J.R. - 1972

Geomorphological process studies, Garry Island, N.W.T.; in *Mackenzie Delta Area Monograph*, ed. D.E. Kerfoot, 22nd Inter. Geog. Cong., pp. 115-130.

0152 KLOVAN, J.E., and EMBRY, A.F. - 1971

Upper Devonian stratigraphy, northeastern Banks Island, N.W.T.; *Bull. Can. Pet. Geol.*, vol. 19, No. 4, pp. 705-729.

Devonian strata of northeastern Banks Island consist of 3700 feet of sandstones, siltstones, and shales, with minor but spectacular carbonate reef buildups. These strata range in age from lowermost Frasnian to mid-Famennian and are time equivalents of the Melville Island Group of Melville Island. The sequence of environments represented by these rocks may be related to the development of a northerly derived clastic wedge prograding southward through time. The area underwent Ellesmerian deformation, which produced gentle folds and normal faults which were re-activated during Tertiary deformation.

0153 KNIGHT, R.J., and CHURCH, M. - 1970

Tasiujaq Cove, Ekaluqad Fiord, Baffin Island, 1968; in *E.M.R. Can. Ocean. Data Centre 1970 Data Record Series No. 1, Sect. 2*, pp. 35-39.

0041 KUC, M., and HILLS, L.V. - 1971

Fossil mosses, Beaufort Formation (Tertiary) Northwestern Banks Island, Western Canadian Arctic; *Can. J. Bot.*, vol. 49, No. 7, pp. 1089-1094.

Abstract under 0041

0154 LAMOTHE, C., and ST.-ONGE, D. - 1961

A note on a periglacial process in the Isachsen area, N.W.T.; *Geog. Bull.*, E.M.R., No. 16, pp. 104-119.

In several regions of the Canadian Arctic, the melting of ground-ice triggers erosional processes that bring about the removal of large quantities of unconsolidated material on steep valley walls. As a result, large hollows are rapidly excavated by mud flows. Measurements made on Ellef Ringnes Island show that the back wall of such a hollow retreated by as much as 10 m in one season. These processes are considered to be among the most rapid erosional agents now active under the present periglacial morphoclimatic conditions of the High Arctic.

0155 MACKAY, J.R. - 1970

Disturbances to the tundra and forest tundra environment of the western Arctic; *Can. Geotech. J.*, vol. 7, No. 4, pp. 420-431.

The more important physical disturbances to the tundra environment are discussed with examples. Thermokarst subsidence, not thermal erosion, is shown to

be the dominant result of man-induced disturbances, such as those caused by the bulldozing of seismic lines and firebreaks. It is shown that a clear distinction between thermokarst subsidence and thermal erosion is necessary, if the causes of the disturbances are to be prevented and minimized, or the results treated. The typical surface disturbance to the tundra results in a deepening of the active layer. Therefore, foreknowledge of the effect of a disturbance on deepening the active layer, together with information on the ice content of the permafrost affected, makes it possible to predict the amount of thermokarst subsidence likely to take place. Three practical examples of three types of ground disturbance are given: a fire near Inuvik, N.W.T.; a patch of vegetation trampled and killed by a dog at Garry Island, N.W.T.; and seepage down a walking trail in an ice-wedge area at Garry Island, N.W.T. The effects of the disturbances are illustrated and discussed.

0156 MACKAY, J.R. - 1971

The origin of massive icy beds in permafrost, western Arctic coast, Canada; *Can. J. Earth Sci.*, vol. 8, No. 4, pp. 397-422.

Massive beds of ground ice are shown to exist along the arctic coastal plain east of the Alaska-Yukon boundary for a distance of at least 500 km. The massive ground ice can be seen in both undisturbed and glacially disturbed Pleistocene sediments. An examination of several thousand seismic shot hole logs, from drill holes of 15 to 35 m in depth, also corroborates the widespread occurrence of ground ice. The icy beds typically have an ice content, defined in terms of the weight of ice to dry soil, in excess of 200% for sections as much as 35 m thick. A theory is presented which suggests that: the ice is of segregation origin; the source of excess water was from the expulsion of ground water during the freezing of sands; and high pore water pressures, favorable to ice segregation, developed beneath an aggrading impermeable permafrost cover. Permafrost aggradation may have occurred either on an exposed sea floor during a period of sea level lowering which would have accompanied a glacier advance, or following a warm interval in which there had been deep thaw. Similarities in the origin of pingo ice and massive ice are discussed.

0157 MACKAY, J.R. - 1972

The world of underground ice; *Ann. Assoc. Amer. Geog.*, vol. 62, No. 1, pp. 1-22.

Underground ice is restricted to permafrost areas where its distribution is sporadic and often unpredictable. A knowledge of the distribution and abundance of underground ice is essential to northern development, because a variety of man induced disturbances can cause underground ice to thaw, often with serious consequences. The criteria for a classification of the principal types of underground ice are the source of the water prior to freezing and the processes which transfer water to the freezing plane. The origin of massive icy bodies in the western Arctic of North America is explained by a water expulsion theory. The excess water now found in the icy bodies is attributed to

water expelled from coarse textured sediments by the downward growth of permafrost. The suggested mechanism is illustrated by three pingos which have grown since 1950. The role of glaciation in the formation of relic offshore permafrost in relatively shallow Arctic coastal areas is examined. The evidence suggests that offshore permafrost is present in some shallower portions of the Beaufort Sea from north-eastern Alaska eastwards to the high Arctic islands of Canada. If offshore permafrost with underground ice is present, then thermal disturbance problems must be taken into consideration in future offshore exploration. KEY WORDS: *Aggradational ice, Epigenetic ice, Ice, Massive ice, Offshore permafrost, Pingo ice, Segregated ice, Underground ice.*

0158 MACKAY, J.R. - 1972

Offshore permafrost and ground ice, southern Beaufort Sea, Canada; *Can. J. Earth. Sci.*, vol. 9, No. 11, pp. 1550-1561.

The distribution and origin of offshore permafrost is discussed for the southern Beaufort Sea. Two types of permafrost are identified: permafrost which is in thermal equilibrium with negative sea bottom temperatures, and disequilibrium permafrost, which is not in equilibrium with either positive or negative sea bottom temperatures. The origin of permafrost is considered in terms of the Quaternary period when coastal areas were exposed to cold air temperatures and then submerged. The effect of warm river waters, primarily from the Mackenzie River, is shown to ameliorate coastal water temperatures and may be responsible for a thin active layer at some sites. Water quality and oxygen isotope ratios are given for some samples. The evidence suggests that some relic land permafrost, with ground ice, is present beneath the southern Beaufort Sea. Perforated permafrost should be present, but not extensive thermokarst depressions. By inference, permafrost probably underlies much of the Canadian Arctic waters although ground ice is likely restricted to a relatively few shallow coastal zones.

0159 MACKAY, J.R. - 1972

Permafrost and ground ice; *in Proc. Can. Northern Pipeline Res. Conf.*, Feb. 2-4, Nat. Res. Council Can. (NRCC 12498), pp. 235-248.

The permafrost terrain of northwest Canada has a great variability in its ground ice content. Extensive areas are largely ice free, and construction there can probably be handled by conventional means. Other areas contain abundant ground ice, of several types, down to the depth which is subject to thermal disturbances induced by construction or hot buried pipelines. Therefore, the distinctive permafrost problems are those involving high ice content ground, such as its distribution, both vertically and horizontally, and its engineering properties, when frozen and thawed.

All ground ice formed either during the growth of permafrost or subsequently thereafter. An attempt is made to discuss, in broad terms, some aspects relating to the growth of permafrost and the origin of ground ice in the Yukon Coastal Plain, Mackenzie Delta area, and Lower Mackenzie Valley. It is suggested that research into the origin of ground ice

could contribute towards a more economical mapping program, a fuller understanding of the properties of frozen ground and a better prediction of thermal disturbances.

0160 MACKAY, J.R. - 1973

The growth of pingos, western Arctic coast, Canada; *Can. J. Earth Sci.*, vol. 10, No. 6, pp. 979-1004. The growth rates of 11 closed system pingos have been measured, by means of precise levelling of permanent bench marks anchored well down into permafrost, for the 1969-1972 period. As pingo growth decreases from the summit to the base, growth of the ice-core decreases from the center out to the periphery. The pingos have grown up in the bottoms of lakes which have drained rapidly and thus become exposed to permafrost aggradation. The specific site of growth is usually in a small residual pond where permafrost aggradation is retarded. The size and shape of a residual pond exercises a strong control upon the size and shape of the pingo which grows within it. The ice-core thickness equals the sum of the pingo height above the lake flat and the depth of the residual pond in which the pingo grew. Pingos tend to grow higher rather than both higher and wider. Pingos are believed to grow more by means of ice segregation than by the freezing of a pool of water. The water source, and the associated positive pore water pressure, result from permafrost aggradation in sands and silts in the lake bottom under a closed system with expulsion of pore water. The fastest growth rate of an ice-core, for the Western Arctic Coast, is estimated at about 1.5 m/yr, for the first one or two years. After that, the growth rate decreases inversely as the square root of time. The largest pingos may continue to grow for more than 1000 yr. Four growth stages are suggested. At least five pingos have commenced growth since 1935. As an estimate, probably 50 or more pingos are now growing along the coast.

0161 MACKAY, J.R., RAMPTON, V.N., and FYLES, J.G. - 1972

Relic Pleistocene permafrost, western Arctic, Canada; *Science*, vol. 176, pp. 1321-1323. Icy layers and interbedded frozen sediments along the Arctic Coastal Plain of northwestern Canada have been subjected to glacial deformation. Radio-carbon dates indicate that the deformation took place more than 40,000 years ago.

0162 MARLOWE, J.I. - 1968

Sedimentology of the Prince Gustaf Adolf Sea area, District of Franklin; *Geol. Surv. Can.*, Paper 66-29, 83 p.

The Prince Gustaf Adolf Sea area is located on the continental shelf bordering the Arctic Ocean. It is underlain principally by moderately deformed siltstone, sandstone, and shale formations of Mesozoic to Tertiary age that form part of the Sverdrup Basin structural province, and by unconsolidated sand and gravel of the Arctic Coastal Plain (Beaufort Formation). The physical setting is dominated by a polar climatic regime, which maintains an ice cover over the area throughout most of the year.

Physiographic features of the area suggest that the sea bottom has been exposed previously to subaerial processes of erosion. On a broad scale, channels form a dendritic pattern, the gradient of which is generally toward the Arctic Ocean. Smaller scale features suggest that ice action has been effective in shaping the present sea bottom. An island shelf and slope occurs around all the land masses of the area and forms a nickpoint in the bottom profile that may represent a stillstand of sea level 300-400 metres deeper than the present level.

Under present conditions, sand is transported from the islands by ephemeral streams and deposited in relatively shallow depths near shore. Mud covers the greater part of the area. However, sandy layers occur in the sub-bottom at nearshore stations, indicating that hydraulic energy levels at those stations have been higher in the past than they are at present. Sediment textures coarsen with depth in cores from throughout the area and suggest that there was a general lowering of energy levels during the deposition of the sediment contained in core samples. Increasing depth of water associated with a transgressive sea is inferred from these data. Core samples show that two major stratigraphic units are present in the sediment of Prince Gustaf Adolf Sea. These are (1) an upper, yellow-brown, generally structureless unit containing foraminiferal remains and abundant oxidized, detrital pyrite; and (2) an underlying, grey unit that contains fine bedding structures, fresh, detrital pyrite, and no faunal remains. Contacts between these units are generally transitional, and commonly do not coincide with textural changes. Characteristics of the two units indicate that they were deposited in widely differing sedimentary environments. In the lower unit, the absence of faunal remains and the presence of fresh, detrital pyrite and fine depositional structures suggest a restricted, reducing environment in which there was little or no life. Very fine, cyclical laminae in this unit indicate that glaciers or ice caps may have dominated the sedimentary environment during the deposition of the unit. Beds of the upper unit, however, appear to have been deposited in a relatively well-oxygenated environment in which an abundant microfauna existed. The change from restricted to open, ventilated conditions probably was a result of an incursion of water from the Arctic Ocean over topographic sills into the Prince Gustaf Adolf Sea area. The distribution of foraminifera in the upper unit may be related to former current patterns.

0163 MARLOWE, J.I., and VILKS, G. - 1963

Marine geology, eastern part of Prince Gustaf Adolf Sea, District of Franklin; *Geol. Surv. Can.*, Paper 63-22, 23 p.

This preliminary report is based on field observation and a partial compilation of data from the marine geology program carried out during the summer of 1962 in Prince Gustaf Adolf Sea and adjacent channels. The study is part of a regional project initiated in 1960 in conjunction with the Polar Continental Shelf Project (Pelletier, 1962). The area of investigation (Figure 1) includes the east

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half of Prince Gustaf Adolf Sea, Maclean Strait, Desbarats Strait, and the sea between Ellef Ringnes and Bathurst Islands, all in the District of Franklin.

The purpose of the study was to provide data that will lead to an understanding of the sedimentary environment and to the reconstruction of the recent physiographic history of the area. To do this, sediment samples were collected from the sea bottom in the inter-island channels, from selected areas in the near-shore zone, and from the beds of streams discharging into the areas of potential interest. In the inshore phase of the program, traverses were made in a seaward direction from the shoreline (located by means of the tide crack in the ice). On large delta fronts, three radiating traverses were laid out to investigate longshore, as well as seaward variations in bottom sediment. To provide greatest sample coverage in the area of maximum expected sediment variation, samples were collected at logarithmically spaced intervals extending to a maximum distance of 2 miles from shore. Access holes were cut in the ice with a power auger and a snapper sampler was lowered and raised by means of a hand winch and tripod. A total of forty-nine samples was collected during the inshore phase of the program, covering the area from Hospital Bay to Noice Peninsula.

Coring operations in Prince Gustaf Adolf Sea and adjacent seas were carried out by a two-man party using a light coring rig and a Sikorsky S-55 helicopter. Traverses were made from Ellef Ringnes Island to the midline of Prince Gustaf Adolf Sea, and to Bathurst, Loughheed and Cameron Islands (Figure 2). Samples were taken by means of a gravity corer with a 6-foot core barrel. The maximum length of core obtained was about 3 feet, although the corer commonly penetrated the bottom with its full length. Compaction of sediment in the nose of the corer apparently prevented better recovery.

In the final stage of the program, sixteen streams that empty into the marine areas covered by the inshore and offshore phases of the program were selected for their apparent large volume of sedimentary delivery. The beds of these streams were sampled from head to mouth and samples of outcrop were collected wherever significant lithologic changes occurred. During this part of the program, transportation was provided by a Bell helicopter and positions were located with the aid of aerial photographs.

Collection of samples in the near-shore zone was carried out by Vilks, who is responsible for the identification and analysis of microfauna in this paper. Sea-bottom cores and streambed samples were collected by Marlowe, who is responsible for the physiographic and sedimentological interpretations.

0164 McCANN, S.P., and OWENS, E.H. - 1969

The size and shape of sediments in three Arctic beaches, southwest Devon Island, N.W.T., Canada; *Arctic and Alpine Res.*, vol. 1, No. 4, pp. 267-278. The general characteristics of arctic beaches are considered. Sample data on size distribution characteristics and roundness due to abrasion of modern beach material from three beaches in the Cape

Ricketts-Radstock Bay area of southwest Devon Island are presented. The area is one of limited wave action due to the inhibiting effects of sea ice. Sorting and roundness values of the beach material provide indirect measures of wave energy and allow comparisons to be made with beaches in other environments. Changes in mean size, sorting and roundness values both along and across the beaches suggest longshore transport by wave action.

0165 McDONALD, B.C., and LEWIS, C.P. - 1972

Geomorphic and sedimentologic processes of rivers and coast, Yukon coastal plain; in *Envir. Soc. Prog. Northern Pipelines of the Task Force on Northern Oil Development*, internal report.

The primary objective of the study was to obtain, for the Yukon coastal plain between the Mackenzie delta and the Alaskan border (Figure 1), reconnaissance data about modern river and coastal environments which would be of use in making decisions about future development in the area. Specific objectives can be conveniently divided into two parts: those concerned with rivers and those concerned with coasts.

0166 McDONALD, B.C., and LEWIS, C.P. - 1973

Sedimentary and geomorphic processes, Yukon coastal plain; in *Report of Activities, Part A: April to October 1972*, *Geol. Surv. Can., Paper 73-1, Part A*, pp. 233-235.

The major objective of this project is to examine the modern sedimentary environments of the coast and rivers of the Yukon Coastal Plain (Fig. 1) from the Mackenzie Delta, west for about 180 km, to the Alaska border (part of NTS 117 S.W. and 117 S.E.). The study focuses on the types, magnitudes and frequencies of erosional and depositional processes presently active in the area. This information, in turn, will be used to assess their potential impact on various human activities.

0167 MIALL, A.D. - 1969

The sedimentary history of the Peel Sound Formation, Prince of Wales Island, Northwest Territories; unpub. Ph.D. Thesis, Univ. Ottawa.

The continental and marine sediments underlying most of Prince of Wales and adjacent islands were termed the Peel Sound Formation by Blackadar and Christie (1963). They are upturned against the Boothia Uplift in the Cornwallis Fold Belt, a north-south axis along the eastern margin of the island. In this study the formation has been divided into Upper and Lower parts. The Lower Peel Sound (Lower Devonian, up to 600 feet thick) consists of limestones, sandstones and shales transitional from the underlying Read Bay Formation (Silurian), and is exposed along the Cornwallis Fold Belt. The transition is found at all localities except near the north end of the island where Peel Sound beds rest with angular unconformity on the Read Bay. The Upper Peel Sound Formation comprises five distinct facies which are in part lateral equivalents and form a series of north-south belts across the island. They are, in westward order: the Conglomerate, Conglomerate-Sandstone, Sandstone, Sandstone-Carbonate and Carbonate Facies. The conglomerates

(up to approximately 1000 feet thick) overlies the Lower Peel Sound in the Cornwallis Fold Belt, but the bases of the other facies successions are not exposed. Fossils from the Sandstone-Carbonate and the Carbonate Facies have been dated as mainly Lower-Middle Devonian.

The clastic rocks of the Peel Sound Formation were formed as a result of uplift along the Boothia axis, which began to rise in earliest Devonian times causing deposition of littoral sands in the predominantly marine carbonate Lower Peel Sound succession. The base of the Peel Sound is drawn at the first conglomerate or redbed unit. Continuing uplift formed a major landmass, and clastic sediments derived therefrom were deposited as fluvial sands and alluvial fan wedges interbedded with marine and marginal marine sediments.

Orogenic uplift reached a peak at the beginning of Upper Peel Sound (mid-Lower Devonian) times. The volume and grain size of clastic detritus increased sharply, a wide alluvial plain developed alongside the Boothia Uplift, and the coastline receded 12-28 miles (19-45km) to the west. In the east, along the mountain front, coarse conglomerates were deposited. Outlines of some of the fans have been drawn from maps of clast distribution and size variations, and the conglomerates are interpreted as debris flood deposits. Clast types are all from Paleozoic and Proterozoic rocks of the Boothia Uplift area.

Fan deposits wedge out westwards into the Conglomerate-Sandstone Facies. Debris flood conglomerates were replaced by sands and silts deposited by braided streams. Fining upward cycles were formed by channel migration and infill. Sedimentary structures suggest a low stream sinuosity.

In the Sandstone Facies streams were probably of high sinuosity, but some horizontally bedded sandstones are thought to have been formed by sheet-like floods that overrode stream channels and reached upper regime (planar bed) flow.

Red fluvial deposits are present up to approximately 28 miles (45 km) from the Boothia Uplift. In the area of the Sandstone-Carbonate Facies rivers built short-lived deltas 5-10 miles (8-16 km) into the sea. Their deposits are inter-bedded with carbonates and shales interpreted from lithologic and faunal evidence as marine and estuarine in origin. Sandstone-shale sequences were probably formed in coastal barrier complexes. These conclusions are based on comparisons with sediments of modern coastal regions, particularly the Mississippi Delta area.

The carbonate rocks are mainly dolomite, the origin of which is uncertain. The marine carbonates were probably laid down in a very quiet, shallow sea. Uplift along the Boothia axis probably slowed down or ceased during the late Peel Sound times. The post-Middle Devonian history of the area is unknown.

0168 MIAL, A.D. - 1970

Devonian alluvial fans, Prince of Wales Island, Arctic Canada; *J. Sed. Petrology*, vol. 40, No. 2, pp. 556-571.

Lower-Middle Devonian continental conglomerates, with minor sandstones, form a belt 150 miles long and up to 10 miles wide in eastern Prince of Wales

Island, bordering an uplifted area of Lower Paleozoic and Precambrian rocks (Boothia Uplift). The succession forms part of the Peel Sound Formation; it reaches 1000 feet in thickness and towards the west the coarse clastics intertongue into sandstones, which in turn grade into shales and carbonates. Conglomerate clast types and directional sedimentary structures indicate derivation from the Boothia Uplift.

The conglomerates are poorly sorted and mean grain size lies in the pebble range, comparing closely with modern alluvial fan deposits. Areal variations in clast lithologies are interpreted in terms of dispersal on eleven alluvial fans. Areal variations in grain size and clast roundness are interpreted as inter-fan in origin (gross differences between adjacent fans). Measurements of maximum clast size revealed intra-fan changes, namely decrease with distance of transport.

Clast changes in vertical section are attributed to varying rates of uplift and erosion in the source area.

Comparison of grain size and textural characteristics of the conglomerates with those of modern deposits suggests a debris flood mode of origin.

0169 MIAL, A.D. - 1970

Continental marine transition in the Devonian of Prince of Wales Island, Northwest Territories; *Can. J. Earth Sci.*, vol. 7, No. 1, pp. 125-144.

In eastern Prince of Wales Island the Peel Sound Formation is subdivided into upper and lower members on the basis of lithology. The upper member comprises five laterally equivalent north-south facies belts which are in westward order:

- 1) Conglomerate Facies: cobble and boulder conglomerates deposited on alluvial fans mainly by the action of debris floods.
- 2) Conglomerate-Sandstone Facies: interbedded conglomerate, fine to coarse red sandstone and red siltstone in a repeated fining-upward succession, deposited by low sinuosity braided streams. Cyclic sedimentation is attributed to channel migration and infill.
- 3) Sandstone Facies: the presence of laterally extensive planar cross sets suggests point bar deposition in high sinuosity streams. Tabular bedded sandstone was deposited by stream floods in upper regime flow.
- 4) Sandstone-Carbonate Facies: streams flowing westward formed small deltas, accumulating red, pink, and buff sandstones as topset deposits, interbedded with dolomites containing marine fossils, and clean washed gray sandstones, shales and dolomites with ostracods, pelecypods, gastropods, and *Lingula*, indicating an estuarine environment.
- 5) Carbonate Facies: dolomites with abundant marine fauna and limited clastic content. Sedimentary structures indicate quiet, shallow water conditions. Paleocurrent evidence indicates an easterly source, confirmed by conglomerate clasts derived from the Boothia Uplift, an area of Lower Paleozoic and Proterozoic rocks extending northwards from the Boothia Peninsula to Somerset Island.

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0170 MIALL, A.D. - 1970

A new Lower Devonian rock unit in the Canadian Arctic Islands: Discussion; *Can. J. Earth Sci.*, vol. 7, No. 3, pp. 1027-1029.

Vertebrate fossils from clastic rocks of the Peel Sound Formation on north-central Prince of Wales Island indicate that rocks as young as Emsian may be present, contrary to the statement of Ormiston (1969) that Siegenian to Emsian carbonate sediments on northwestern Prince of Wales are the youngest rocks present on the island. A revised cross-section through northern Prince of Wales shows Ormiston's carbonates as a facies variation of the Peel Sound Formation, which rests on the underlying Read Bay Formation with a generally gradational contact, not a regional unconformity.

0171 OWENS, E.H. - 1969

The Arctic beach environment, south-west Devon Island, N.W.T.; unpub. MSc Thesis, McMaster Univ., 152 p.

Investigations have been carried out in the southern Queen Elizabeth Islands, N.W.T., to determine some of the features and characteristics of the beach environment in that area of the Canadian Arctic Archipelago. Analysis of beach material from three locations, mapping, profiling, measurement of tidal cycles, and a study of ice conditions have provided some insight into the processes acting upon these beaches. The period when those wave processes which operate freely at lower latitudes are active in the study area is less than two months in the year. The role of ice in preventing wave generation and restricting wave action in the littoral zone greatly reduces the level of marine processes in this sheltered environment. Numerous ice-push ridges were recorded and mapped, but the characteristics of the beach result primarily from the action of infrequent storms. Comparisons with other arctic areas, Cape Thompson and Point Barrow, Alaska, and the Sverdrup Islands, indicate the variety of conditions which exist within the arctic region. These may be related to exposure, or fetch, and the distribution and movement of sea ice which determines the length of time for which waves processes can operate in the littoral zone.

0172 OWENS, E.H., and McCANN, S.B. - 1970

The role of ice in the Arctic beach environment with special reference to Cape Ricketts, southwest Devon Island, Northwest Territories, Canada; *Amer. J. Sci.*, vol. 268, pp. 397-414.

The effects of ice on the form of the beach zone at Cape Ricketts, southwest Devon Island, in particular in the formation of ice mounds and ice-push ridges, are described. Consideration of meteorological data for Resolute, Cornwallis Island, and of ice cover data for the Barrow Strait-Lancaster Sound sea area provides information for a broader discussion of the role of ice in the beach environment.

0173 PELLETIER, B.R. - 1961

Polar Continental Shelf Project, western Queen Elizabeth Islands, District of Franklin, 1961; *Geol. Surv. Canada*, unpub. Top. Rept. No. 47, 8 p.

The purpose of this report is to summarize the activities of that part of the submarine geology unit of the Geological Survey of Canada which is participating in the Polar Continental Shelf Project (Frontispiece). Programs and results of the past two field seasons are reviewed and references are made to earlier reports and to projected publications of the near future. Future programs for field work and laboratory studies are presented with conclusions regarding these researches and the applications attempted.

0174 PELLETIER, B.R. - 1962

Submarine geology program, Polar Continental Shelf Project, Isachsen, District of Franklin; *Geol. Surv. Can.*, Paper 61-21, 10 p.

The purpose of this report is to describe the organization and working methods of a submarine geology project that commenced in April 1960 in the inshore and offshore waters of the western Queen Elizabeth Islands, District of Franklin (Fig. 1). This project, including the field and laboratory work, was organized by officers of the Geological Survey under the direction of the co-ordinator of the Polar Continental Shelf Project, and was carried out in collaboration with scientists from other federal agencies attached to the shelf project.

0175 PELLETIER, B.R. - 1963

Contributions of the Marine Geology Unit of the Geological Survey of Canada to the Polar Continental Shelf Project, District of Franklin, 1962; *Geol. Surv. Canada*, Unpub. Top. Rept. 69, 15 p.

The purpose of this report is to summarize the activities of that part of the marine geology group of the Geological Survey of Canada which is participating in the Polar Continental Shelf Project (Frontispiece). Programs and results of previous field seasons were reviewed earlier (Topical Report 47), and are summarized here together with current projects. Future programs for field and laboratory studies are also presented. Some conclusions and applications involving the earlier research programs are given by means of illustrations. These illustrations demonstrate the direction that certain programs in the future will take. References are made to earlier reports and to projected publications of the near future.

0176 PELLETIER, B.R. - 1965

Bottom studies on the Arctic Continental Shelf (Polar Continental Shelf Project); in Report of Activities: Field, 1964, *Geol. Surv. Can.*, Paper 65-1, p. 12.

0177 PELLETIER, B.R. - 1966

Development of submarine physiography in the Canadian Arctic and its relation to crustal movements; in Continental Drift, Roy. Soc. Canada Spec. Pub. No. 9, ed. G.D. Garland, Univ. Tor. Press, pp. 77-101.

This report deals primarily with the development of submarine physiography in the Canadian Arctic (Fig. 1), and is based on the hypothesis of Fortier and Morley (1956) that the Arctic Archipelago is a

geological unity and that the network of inter-island channels is a submerged river system of Tertiary age, which previously drained a continuous land mass (Fig. 2). The new soundings, and the palaeontological and lithological evidence obtained with bottom grabbers and cores, offer additional support to the general theory of subaerial erosion of a pre-existing single land mass by streams. Certain lines of topographic evidence indicate that modification of such river valleys by valley glaciers also took place (Pelletier, 1961, 1962, 1963; Horn, 1963) and was followed by widespread submergence. This submergence was followed by an interval of post-Pleistocene emergence, according to the comprehensive study of relict strand lines and raised marine deposits carried out by Craig and Fyles (1960). This emergence may be continuing although the gravity data of Sobczak (1963) tentatively indicate that the western part of the Archipelago and adjacent continental shelf may be in isostatic equilibrium.

0178 PELLETIER, B.R. - 1966
Canadian Arctic Archipelago and Baffin Bay, Part B. Bathymetry and Geology; *in* Encyclopedia Oceanography, Encycl. Earth Sci., vol. 1, pp. 160-167.

0179 PELLETIER, B.R. - 1967
Sedimentation in Arctic waters of the western Queen Elizabeth Islands; District of Franklin, Canada; *Mar. Sed.*, vol. 3, No. 4, pp. 90-99.
This report is a preliminary statement of continuing studies of sedimentation carried out since 1960 in Canadian Arctic waters under the direction of the Polar Continental Shelf Project (Department of Energy, Mines and Resources). The program includes investigations in the following sedimentary environments: lacustrine, fluvial, inshore deltaic, inshore non-deltaic, channel, and offshore marine (i.e. Arctic continental shelf). The major area of study is in the western portion of the Queen Elizabeth Islands (Figure 1).

0180 PELLETIER, B.R. - 1970
Earth sciences studies in Arctic marine waters, 1970; *Bedford Institute Ocean Science Reviews 1969/70*, pp. 11-24.

0181 PELLETIER, B.R., and SHEARER, J.M. - 1972
Sea bottom scouring in the Beaufort Sea of the Arctic Ocean; *in* 24th Int. Geol. Cong., Sect. 8, pp. 251-261.
Marine geological investigations undertaken during the summers of 1970 and 1971 in the Beaufort Sea with echo-sounding and side-scan sonar equipment have shown the sea bottom to be composed mainly of linear scratches of varying width, depth and length. Churning and scouring by ice islands and pressure ridges as they scrape the bottom are thought to be the origin of these features. In many areas, generally in depths of water between 10 and 30 m, the bottom is marked by systems of parallel scours. This is thought to be a result of one or more pressure ridges moving as a solid unit with the Arctic pack ice.

The frequency of occurrence of scouring along the ship's track is similar and at a maximum (15 to 20 scours/km) for all depth ranges between 10 and 50 m. Below 50 m the frequency of occurrence decreases, with no scours observed at depths >75 m. The above data are difficult to reconcile with observations made from submarines of the actual depth distribution of pressure ridge keels. This disparity is thought to be due to the cumulative nature of scouring on the bottom. Depending upon the rate of sedimentation at any given point, deep scours (maximum observed relief about 10 m) which may be the result of scouring in earlier post-glacial times (lower sea level) may still possess some topographic expression. Unless these relict scours are recognized, anomalously high results would be obtained for the present amount of scouring at various depths.

0182 PISSART, A. - 1966
Etude de quelques pentes de l'île Prince Patrick; *Ann. Soc. Geol. Belgique*, vol. 89, Bull. No. 5-10, pp. B377-B402.
La description de quelques pentes de l'île Prince Patrick (76° lat. N.), c'est-à-dire d'une région périglaciaire typique ne présentant pratiquement aucune trace de morphologie glaciaire, dévoile quelques particularités de l'évolution des versants sous ce climat froid.
Un processus essentiel est l'accumulation de la neige aux endroits sous le vent. Au printemps, l'eau de fonte donne naissance à des phénomènes de ruissellement et de solifluxion qui modelent des creux de nivation, particulièrement bien développés dans les sables très fins.
La solifluxion paraît nettement plus efficace sur les pentes faibles que sur les pentes fortes car, paradoxalement, les premières ont une capacité de transport plus grande que les secondes. Au dégel, l'humidité y persiste, en effet, beaucoup plus longtemps. Il en résulte souvent l'existence d'une rupture de pente très brutale au pied des versants raides, aspect rappelant parfois la morphologie des pays arides.
Les différences lithologiques sont généralement très bien mises en valeur par les processus périglaciaires et les replats structuraux sont souvent aussi bien dégagés que dans les régions arides.
L'étude d'un versant passant latéralement d'un glacis de solifluxion à une longue pente concave, entaillée de chenaux, souligne que les divers facteurs régissant l'évolution des pentes réagissent l'évolution des pentes réagissent les uns sur les autres et ce cas simple montre combien il est difficile de comprendre le façonnement des versants.

0183 PISSART, A. - 1966
Le rôle géomorphologique du vent dans la région de Mould Bay (île Prince Patrick - N.W.T. - Canada); *Ann. de Géomorphologie*, vol. 10, No. 3, pp. 222-236.
J. Tricart et A. Cailleux (1961, p. 214) ont souligné l'importance du vent dans de nombreuses régions périglaciaires arctiques. Cette action est d'après eux considérable dans ces régions étant donné:
1. l'absence de végétation,
2. la fréquence des vents violents,

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3. la faiblesse des précipitations,
4. la concentration de l'eau par le gel qui a pour effet de dessécher la surface du sol,
5. la fourniture d'une grande quantité de débris fins par la gélivation.

0184 PISSART, A. - 1967

Les modalités de l'écoulement de l'eau sur l'île Prince Patrick; *Biul. Peryglacjalny*, No. 16, pp. 217-214.

The author discusses some characteristics of stream flow under an Arctic climate, that of Prince Patrick Island, in the extreme north of Canada. The more important of these are, the melting of the snow while the air temperature remains below 0°C, the flow of water below snow patches which washes the surface of the soil underneath, the commencement of stream flow, in spring in beds that are still choked with snow, and the prevention of all stream erosion for a considerable time during maximum discharge by ice which covers the stream bed.

From source to mouth, valleys often show: (1) an open cross-section, found in the zone where the volume of debris brought down the valley sides by mass movement is too great for the transporting capacity of the stream; (2) a V-profile which begins when stream flow is sufficient to carry away the debris brought down the slopes; (3) a wide bed, which after the floods of the general thaw have subsided, is characterized by braided flow.

0185 PISSART, A. - 1967

Quelques résultats de l'étude des versants de l'île Prince Patrick; *in Symp. Intern. de Géomorphologie*, Liège-Louvain, June 8-16, 1966, pp. 215-227.

The study of some slopes on Prince Patrick Island shows some characteristics of the slopes evolutions under an arctic climate.

An important action is the accumulation of snow in snowpatches below which appear nivation hollows; these are very large in fine-grained sands.

Flowing of water below snow patches washes the surface of the frozen ground underneath and, because the temperature of this water is 0° centigrade, there is no thawing and no development of solifluction. After the melting of the snow, the ground often remains covered with fine, washed debris. In a few places, the flowing of water following desiccation cracks gives features similar to "lapiès".

The evolution of steep slopes where water does not remain, is slower than that of gentle slopes where solifluction is very active. For this reason, a sharp knick point, like in arid countries, often appears at the lower part of abrupts.

Lithological differences clearly appear and structural surfaces have a very large extent. Slopes are most often concave or convex. Plane facets do not seem to be more frequent than in Belgium; their inclinations gather around two main values: 30 to 32 degrees which is the equilibrium slope of gravity talus, and 5 to 7 degrees which seems the lower limit of solifluction "en loupes" (solifluction lobes); below this value, solifluction still works, but more slowly and in continuous sheets.

0186 PISSART, A. - 1967

Les pingos de l'île Prince-Patrick (76°N-120°W); *Geog. Bull.*, vol. 9, No. 3, pp. 189-217.

More than 150 pingos have been observed on Prince Patrick Island. The majority of these domes of injected ice may be divided into two distinct groups: The first group is made up of more than 100 pingos located on the surface of the island's summit at an altitude of about 100 metres. They are aligned in two parallel rows of domes, circular in ground plan, whose height and diameter do not exceed 13 metres and 250 metres respectively. Presenting no positive trace of present day evolution and showing no relationship with the topography, these forms exist in the valleys as well as on the summits. They are possibly related to some deep geological structure. The second group of pingos is made up of domes at an altitude close to sea level and situated at the head of two bays more than 90 km distant from each other. In this group particularly are elongated pingos resembling eskers as well as those with the characteristic circular shape. Observed cuts have shown the arrangement of layers in the sides of the pingos as well as the core of injected ice. They appear to have developed following a definite change of sea level which drowned the bay and resulted in the melting of the upper permafrost. The later re-establishment of the permafrost may have begun with the appearance of this injected ice. Other pingos of a different type have also been recognized on the island.

0187 PISSART, A. - 1968

Les polygones de tundra de l'île Prince Patrick; *in Mélanges de Géographie*, vol. 1; pp. 151-163.

L'auteur montre la variété d'aspect des polygones de fentes de gel d'une île de l'archipel Reine Elisabeth. A côté de "low center polygons" et de "high center polygons" généralement localisés sur la surface plane de terrasses fluviales, existent d'autres polygones peu apparents qui couvrent toute la surface occupée par les sables et graviers de la formation de Beaufort. Ces structures s'étendent aussi bien sur les versants que sur les sommets et les fonds de vallées. Elles apparaissent comme un réseau polygonal dessiné par une simple dépression de quelque cm. de profondeur qui correspond tantôt à des coins de glace et de sables, tantôt à des coins de sables et de graviers. Il s'agit alors de "ground veins" ou "sand wedge polygons" semblables à ceux qui ont été décrits plusieurs fois au cours des dernières années. La distinction entre les deux types de formes uniquement d'après la morphologie ne paraît pas possible.

Les coins de glace des polygones de tundra s'élargissent parfois considérablement en provoquant de grands glissements de terrain qui affectent le permafrost lui-même.

0188 PISSART, A. - 1968

Les polygones de fente de gel de l'île Prince Patrick; *Biul. Peryglacjalny*, No. 17, pp. 171-180.

The author describes the variety of form and structure of frost fissure polygons on an island in the Queen Elizabeth Archipelago. Polygons formed by wedges of ice, by wedges of mineral soil and by

wedges of sand and ice have developed together under the present-day climate. Sections through several of these structures are described. The conditions determining which type of polygons has developed, appear to be primarily the granulometry of the soil and its humidity during the summer.

0189 RAMPTON, V.N. - 1971

Ground ice conditions: Yukon coastal plain and adjacent areas; *in* Report of Activities, Part B: November 1970 to March 1971, Geol. Surv. Can., Paper 71-1B, pp. 128-130.

0190 RAMPTON, V.N. - 1972

An outline of the Quaternary geology of the lower Mackenzie region; *in* Mackenzie Delta Area Monograph, 22nd Inter. Geograph. Cong., pp. 7-14.

0191 RAMPTON, V.N. - 1972

Surficial deposits of portions of the Mackenzie Delta (107C), Stanton (107D), Cape Dalhousie (107E), and Malloch Hill (97F) map-sheets; *in* Mackenzie Delta Area Monograph, 22nd Inter. Geograph. Cong., pp. 15-27.

Investigation of the surficial deposits of the Mackenzie Delta, Stanton, Cape Dalhousie, and Malloch Hill map-sheets between 1965 and 1966 by Fyles (1966, 1967) and myself (Rampton 1970, 1971), has resulted in the production of geology maps at a scale of 1:125,000 (Rampton 1972a). The objective of this paper is to reduce the data presented on these maps to a scale where one can obtain an overall picture of the distribution of surficial materials and geomorphic features. For the Quaternary history of the area, the reader is referred to Mackay (1963) and Rampton (this volume pp. 7-14).

0043 RITCHIE, J.C. - 1972

Pollen analysis of Late-Quaternary sediments from the Arctic treeline of the Mackenzie River delta region, Northwest Territories, Canada; *in* Climatic changes in Arctic areas during the last ten-thousand years, Acta. Univ. Ordanka, vol. 3, Geol. 1, pp. 253-271.

Abstract under 0043

0192 ROOTS, E.F. - 1963

Progress report - Investigations related to the general field of interest of the International Upper Mantle Project; *Polar Cont. Shelf Proj.*, internal report, 2 p.

0193 ROOTS, E.F. - 1963

Report of investigations by the Polar Continental Shelf Project related to upper mantle problems; *Polar Cont. Shelf Proj.*, internal report, 6 p.

0194 ROOTS, E.F. - 1969

Geology of Western Queen Maud Land; *Amer. Geog. Soc.*, Plate VI, Folio 12-Geology, Antarctic Map Folio Series.
Western Queen Maud Land forms the western part of the Atlantic sector of the continental mass of East Antarctica. It is bounded on the north by the Antarctic basin of the South Atlantic Ocean and on the west by the Weddell Sea to Ross Sea depression.

The region inland from Princess Martha Coast (longitudes 2°E to 6°W) was investigated by the field parties of the Norwegian-British-Swedish Antarctic Expedition of 1949-1952 (Roots, 1952, 1953).

0195 ROOTS, E.F. - 1970

Arctic Canada, Greenland, and the northernmost Atlantic Ocean; *in* Polar Research, A Survey, Nat. Acad. Sci., Washington, pp. 17-48.

0196 ROY, S.K., and HILLS, L.V. - 1972

Fossil woods from the Beaufort Formation (Tertiary), northwestern Banks Island, Canada; *Can. J. Bot.*, vol. 50, No. 12, pp. 2637-2648.

Fossil woods belonging to the Pinaceae (*Pinoxylon albicauloides* Greguss, 1954; *Picea beaufortense* sp. nov.; *Laricioxylon occidentale* sp. nov.; *Abietoxylon koreanoides* sp. nov.; *A. traumatiductus* sp. nov.) and a single representative of the Eleagnaceae (*Eleagnaceoxylon shepherdoides* gen. et sp. nov.) are described and illustrated. Two main conclusions are derived from this investigation. They are (1) the fossil woods of the Beaufort Formation are very similar to the woods of some extant arborescent species of northern North America and northeastern Asia and (2) the fossil flora indicates a temperate climate similar to that of the present-day boreal forest.

0197 RUST, B.R. - 1968

Deformed cross-bedding in Tertiary-Cretaceous sandstone, Arctic Canada; *J. Sed. Petrol.*, vol. 38, No. 1, pp. 87-91.

Cross-beds in sandstone near Stanwell-Fletcher Lake, Somerset Island, Arctic Canada are deformed into regular structures which resemble recumbent folds. The majority of deformation axes are orientated perpendicular to the dip of undeformed cross-beds, and overturning is always in the downcurrent direction. In some cases there is a gradual transition from deformed to undeformed cross-beds in both the upcurrent and downcurrent directions. These features are considered as most satisfactorily explained by deformation due to the overriding drag of a mass of sediment moved by the current.

0198 RUST, B.R., and COAKLEY, J.P. - 1970

Physico-chemical characteristics and postglacial desalination of Stanwell-Fletcher Lake, Arctic Canada; *Can. J. Earth Sci.*, vol. 7, No. 3, pp. 900-911.

Stanwell-Fletcher Lake is a cold monomictic Arctic Lake, essentially isothermal at about 1.5°C, with almost complete ice cover throughout the year. The annual heat input is about 13,000 cal cm⁻², much less than that of dimictic Arctic lakes. The lake is isochemical, with very low ionic concentrations. The lake basin was formed during the Pleistocene by glacial scouring of soft sediments from a graben. As the ice retreated the basin filled with sea water, and became a fjord. Subsequent isostatic uplift raised the marine shorelines to 150 m above present sea level; the uplift curve indicates emergence of the fjord sill and termination of estuarine conditions about 3500 years ago. Tidal influx persisted for about 1100 years before the lacustrine phase started.

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Comparisons with modern fjords and coastal meromictic lakes suggest that most of the salt left the lake during its lacustrine phase. The mechanism was probably entrainment of salt water into a deep freshwater current flowing over the chemocline due to convective circulation in summer.

0199 ST-ONGE, D.A. - 1959

Polar Continental Shelf Project Geographical Branch participation; *Polar Cont. Shelf Proj.*, internal report, 12 p.

0200 ST-ONGE, D.A. - 1959

Note sur l'érosion du gypse en climat périglaciaire; *Rev. Can. de Géog.*, vol. 13, Nos. 3-4, pp. 155-162. Five gypsum diapirs pierce the Mesozoic sedimentary rocks of Ellef Ringnes Island. One of these, the Isachsen dome, was visited by the Author in May 1959. Under either temperate or warm and humid climates gypsum is generally associated with low-relief karst features. On Ellef Ringnes Island, however, the gypsum domes rise to 125 metres above the low plain. It seems that under the present periglacial morphoclimatic conditions now prevailing on the island, the permafrost, the low rainfall, the absence of chemical erosion and the low frost-shattering index of gypsum combine to make gypsum a very resistant rock.

0201 ST-ONGE, D.A. - 1960

Polar Continental Shelf Project Geomorphological research; *Polar Cont. Shelf Proj.*, internal report, 21 p.

0202 ST-ONGE, D.A. - 1961

The ground ice in the Deer Bay Area, Ellef Ringnes Island, Northwest Territories; in *Geology of the Arctic*, Univ. Toronto Press, vol. II, p. 1092. Extensive ground ice mantled by 0.3 to 0.6 m of silts occurs in the Deer Bay area on Ellef Ringnes Island in the Canadian Arctic Archipelago. Profiles from construction pits and observations made on river-bank exposures and mudflows suggest that this ground ice is continuous in areas below 75 m above sea-level. The possibility of its origin owing to burial of sea ice is discussed.

0203 ST-ONGE, D.A. - 1962

La cartographie géomorphologique de la région d'Isachsen, Ile Ellef Ringnes, T.N.-O.; unpub. extract D.Sc Thesis, Univ. Catholique de Louvain, Belgique, 15 p.

0204 ST-ONGE, D.A. - 1964

Les formes de nivation de l'île Ellef Ringnes, Territoires du Nord-Ouest; in *Acta Geographica Lovaniensia*, vol. 3, pp. 287-304. Cet article résulte d'observations faites au cours de trois étés passés sur l'île Ellef Ringnes T.N.-O., comme membre du Programme d'étude de la Plateforme Continentale Arctique. L'île Ellef Ringnes fait partie de l'archipel de la Reine Elizabeth du Nord canadien. L'île est formée de roches relativement tendres (schistes et grès) du Mésozoïque, localement injectées de dykes et de sills de gabbro. Lors de l'orogénèse alpine ces

terrains furent faiblement plissés, mais localement, l'ascension de noyaux diapiriques de gypse permien provoqua des déformations plus importantes.

Dans le nord de l'île et à de rares endroits dans le centre de celle-ci, les formations plissées sont recouvertes d'un épandage alluvial, qui date probablement de la fin du Tertiaire.

L'île Ellef Ringnes fait partie des Basses Terres de l'Arctique canadien. Les parties les plus élevées du relief ne dépassent que rarement 300 mètres d'altitude absolue. Le relief, découpé par les nombreux cours d'eau exploitant une structure différenciée, ne porte aucune trace de glaciation. Il semble que le relief a évolué durant la majeure partie du Pléistocène sous un régime morphoclimatique périglaciaire.

Malgré les faibles précipitations, moins de 100 mm par année, les formes de nivation sont nombreuses et variées.

0205 ST-ONGE, D.A. - 1964

Three Canadian geomorphological maps; abstract, 20th Inter. Geog. Cong., London, p. 35.

Two of these maps show the Island of Ellef Ringnes. One shows the whole island at the scale of 1:250,000 and demonstrates the overwhelming importance of fluvial erosion in sculpturing the present relief.

Although indisputable glacial forms are absent, the raised beaches suggest an isostatic uplift of about 30 m. during the last 8,000 years. The second map of the island at a scale of 1:30,000 shows the area around Isachsen, with the importance of structural control of relief clearly visible. The widespread periglacial forms are also shown. The final map (by S.H. Richard) is of the Nyngard Area, Saskatchewan, scale 1:250,000. The map shows the surface materials and land forms of this heavily glaciated area, and the meltwater channels and lake plains provide evidence of the pattern of deglaciation.

0206 ST-ONGE, D.A. - 1964

Problems of geomorphological map legends and their value to optimum land utilization; *Geog. Bull.*, No. 22, pp. 1-10.

Geomorphological mapping has many scientific and economic applications. However, it is presently hindered by the fact that no adequate legend has yet been devised. This paper discusses legends now in use in various countries, and evaluates their usefulness to optimum land utilization.

0207 ST-ONGE, D.A. - 1965

Notes on the geomorphological maps of Ellef Ringnes Island; in *Proc. Inst. Panamericano de Geog. e Hist.*, Ottawa, pp. 97-112.

Since Lozinski (1909) defined the "periglacial facie" a vast literature has developed describing landforms both active and fossil, associated with cold climates. In most cases, only selected landforms were studied: various types of patterned ground, conglifluction, nivation and so on. Few authors, however, have both described and mapped all the landforms in a given high Arctic area. This approach, nevertheless, is essential if the relative importance of each process active in cold climate areas is to be assessed (Robitaille, 1960). The influence of

lithology on a given agent of erosion, for example, can best be brought out by detailed geomorphological mapping of a suitable region.

During the summers of 1959-61 the writer carried out detailed mapping and studies of process on Ellef Ringnes Island. This island, with an area of 5,139 sq. mi., is located in the north central part of the Queen Elizabeth Islands. In addition to the Arctic Ocean which washes its northern shore, the island is surrounded, in a clockwise direction by the following water bodies: Peary Channel, Hassel Sound, Danish Strait and Prince Gustaf Adolf Sea.

0208 ST-ONGE, D.A. - 1965

La géomorphologie de l'île Ellef Ringnes, Territoires du Nord-Ouest, Canada; *Geog. Br. M & T.S. Can.*, Paper 38, 58 p.

0209 ST-ONGE, D.A. - 1968

Geomorphic maps; *Encycl. Geomorphology*, R.W. Fairbridge, Reinhold, pp. 388-403.

0210 ST-ONGE, D.A. - 1969

Nivation landforms; *Geol. Surv. Can.*, Paper 69-30, 12 p.

The numerous rock types on Ellef Ringnes Island in the Queen Elizabeth Islands, N.W.T. makes it possible to study the influence of lithology on landforms resulting from the activity of a given process. Nivation, a combination of frost shattering, gelifluction and sheet wash, carves a series of landforms which vary according to the type of rock in which they occur. Lithology, in determining debris size, controls the agents of removal and consequently the nature of the nivation landform.

0211 SHEARER, J.M., MACNAB, R.F., PELLETIER, B.R., and SMITH, T.B. - 1971

Submarine pingos in the Beaufort Sea; *Science*, vol. 174, pp. 816-818.

Numerous underwater mounds found on the continental shelf of the Beaufort Sea are thought to be pingos (hills that have a central core of ice) which have formed in the marine environment subsequent to oceanic transgression.

0212 TEDROW, J.C.F. - 1966

Polar desert soils; *Soil Sci. Soc. Amer. Proc.*, vol. 30, No. 3, pp. 381-387.

The northern extremities of ice-free land are mantled primarily with Polar Desert soils. Polar Desert soils are sparsely colonized by vascular plants and in many instances the organic component scarcely enters the soil system. Low temperature, relatively dry soil conditions, a desert pavement, mildly acid to alkaline reaction, and salt efflorescences commonly characterize the Polar Desert soils.

0213 TEDROW, J.C.F. - 1968

Pedogenic gradients of the polar regions; *J. Soil Sci.*, vol. 19, No. 1, pp. 197-204.

Soils of the polar regions are divided into three zones - Arctic Brown, Polar Desert, and Cold Desert. The Arctic Brown soil coincides approximately with the arctic tundra belt, the Polar Desert zone is penecontiguous with the high arctic, and the Cold

Desert zone is represented by the ice-free sectors of Antarctica. The zones are broad and diffuse. Well-drained soils of the southern sectors of the Arctic Brown soil zone have embryonic podzolic affinities whereas soils of the northern portions of this same zone exhibit a low temperature calcification process akin to a cold steppe condition. Vascular plants form a continuous mat in the Arctic Brown soil zone but within the Polar Desert soil zone they are patchy or at times completely lacking. In the Polar Desert soils algae and diatoms appear to be the main contributors of soil organic matter. The Cold Desert soils of Antarctica are virtually void of organic matter. The above three soil zones, in effect, are sectors of a pedogenic gradient. Progressing from the northern fringes of the forested land, to colder climates, precipitation decreases, organic matter content of the soil decreases, and soil pH values tend to increase. In the Polar Desert soils, alkaline reactions are common whereas the Cold Desert soils of Antarctica are usually saline. Polar Desert soils and Cold Desert soils have many morphologic affinities. Tundra and Bog soils dominate areally in the main tundra belt but are confined to the local swales and depressions in the high arctic. Both Tundra and Bog soils tend to have higher pH values as one progresses to colder, drier climates. Neither Tundra nor Bog soils have, as yet, been recorded in Antarctica.

0214 TEDROW, J.C.F. - 1972

Soil morphology as an indicator of climatic changes in the Arctic areas; *Acta Univ. Ouluensis*, vol. 3, Geol. 1, pp. 61-74.

The possibilities of using pedologic information to reconstruct past climates of the arctic region are considered. The arctic region is divided into three soil zones: (1) Polar Desert, (2) Subpolar Desert and (3) Tundra, with zonal boundaries corresponding approximately to high arctic, mid-arctic and low arctic, respectively. Within each zone, four genetic varieties of soil are listed. The old landscapes of the far north of North America including Greenland, have certain soil properties which suggest a past warmer climate. The time under consideration in these sectors, however, is Early Pleistocene or possibly Late Tertiary. Within the Tundra and Polar Desert soil Zones, buried organic matter was studied with respect to age and pollen composition. Ages of the buried organic matter ranged from 1,200 to 10,600 yr. B.P. Pollen from the buried organic layers is similar to that of the present with some buried samples indicating possibly warmer conditions. The buried organic matter which is as much as 4 feet deep probably reached its present position during a warmer episode at which time there was deeper seasonal thaw in the soil, which in turn would suggest warmer summer temperatures. Several cases of buried soil profiles are considered along with paleoclimate implications. In Alaska, one soil buried beneath Early Wisconsin (Würm) drift and one buried beneath dune sand (3,840 yr. B.P.) showed soil features similar to those soils presently in the area. One buried soil from northern Sweden indicated past climate that was warmer and more moist.

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0215 TEDROW, J.C.F., BRUGGEMANN, P.F., and WALTON, G.F. - 1968

Soils of Prince Patrick Island; *Arctic Inst. N. Amer.*, Res. Paper No. 44, 82 p.

Prince Patrick Island, one of the more northerly islands of the Canadian Arctic Archipelago, centers approximately on 76°45'N., 119°30'W. The island is referred to botanically as a rock desert or fell field, geographically as high arctic, and pedologically as a region of Polar Desert soils. Unlike the main tundra belt to the south, the landscape has a pronounced desert-like appearance with closed vegetation confined to the lower, wet positions. Genetic soils in decreasing abundance are Polar Desert, Tundra (Upland and Meadow) and Bog. A few isolated examples of Arctic Brown soil are present. Polar Desert soils are characterized by a desert pavement and a poorly defined A-B-C horizon sequence. Usually Polar Desert soils have high pH values, high levels of soluble constituents and at times free salts are present. Organic matter in Polar Desert soils is apparently contributed largely by algae. Tundra soils, confined mainly to the lower positions, are comparatively shallow-developed, attesting to the rigorous regional climate.

Clay minerals consist of an illite-vermiculite-montmorillonite mixed-layer mineral, vermiculite, illite, kaolinite, and clay-size quartz with vermiculite concentrated at the surface.

Buried organic matter from two Tundra soils yielded C-14 dates of 5600 and 8460 years B.P. and contained *Salix*, *Cyperaceae*, *Gramineae*, *Picea*, *Alnus* and other pollen. Local soils maps for 3 sectors and a reconnaissance soil map based on field studies and aerial photography are given for the entire island.

0216 TEDROW, J.C.F., and THOMPSON, C.C. - 1969

Chemical composition of polar soils; *Biuletyn Peryglacjalny*, No. 18, pp. 169-181.

For pedologic purposes the polar regions are divided as follows: (1) Arctic Brown soil zone, which occupies that terrain between the tree line and the high arctic, (2) Polar Desert soil zone, which is contiguous with the high arctic, and (3) Cold Desert soil zone of Antarctica. In going from the Arctic Brown soil zone to the colder, drier, polar deserts of the high arctic and finally to the cold deserts of Antarctica, one encounters certain pedogenic changes. Soils of the northern fringes of the forest zone tend to have weak podzolic affinities, but in progressing to cooler, drier conditions, the soils could be described as being a variety of cold steppe. Soils of the high arctic and of the antarctic continent have many features in common with those of the temperate deserts. Representative deep, well-drained (zonal) soils from each of the regions were analyzed for organic matter, pH values, Si, Al, Fe, Ca, Mg, Na, K, Cl, Cu, Co, B, Ga, Pb, Zr, Ni, Sn, Zn, Mo, Mn, V, Cr, Sr, and Ti. Zonal soil processes of the polar regions are briefly discussed.

0217 THOMAS, J.F.J. - 1960

Chemical quality of surface waters of Ellef Ringnes Island, N.W.T. collected during the summer of 1960; *M. & T.S. Min. Proc. Test Rep. MPT 60-123*, internal report, 11 p.

This report covers the chemical analyses of ten surface waters collected by Mr. St. Onge and associates, Polar Continental Shelf Project, Department of Mines and Technical Surveys during the summer of 1960.

Also included are the analytical results obtained on five composite samples of one stream water and a few test results on melted samples of glacial ice. All waters were collected from streams or glaciers on Ellef Ringnes Island, N.W.T.

The waters were chemically analysed by standard methods of water examination and the usual relatively-complete analysis was done on the samples, whenever sufficient water was available. Separate samples were not received for the determination of iron and manganese.

0218 THOMAS, J.F.J. - 1960

The total concentration of sediments in stream samples from Ellef Ringnes Island, N.W.T., collected June and July, 1960; *M. & T.S. Min. Proc. Test Rep. MPT 60-107*, internal report, 8 p.

0219 TRETTIN, H. - 1969

A Paleozoic-Tertiary fold belt in northernmost Ellesmere Island aligned with the Lomonosov Ridge; *Geol. Soc. Amer. Bull.*, vol. 80, pp. 143-148.

A south-trending belt of sialic Paleozoic rocks on the northern coast of Ellesmere Island lines up with the Lomonosov Ridge. It was deformed (1) in Middle Ordovician or earlier time, (2) between the Late Silurian and the Middle Pennsylvanian, and (3) in the Tertiary. The Paleozoic movements elevated terrane continuous with the Lomonosov Ridge relative to terrane on the east, but the Tertiary movements did not cause such relative uplift. About 40 km inland, the south-trending orogen terminates against east-trending structures, that conform with the predominant structural grain of northern Ellesmere Island. The zone of structural intersection, marked by Early Devonian (or older) ultrabasic intrusions and a Tertiary graben, was repeatedly a site of crustal extension.

0220 TUKE, M.F., DINELEY, D.L., and

RIJST, B.R. - 1966

The basal sedimentary rocks in Somerset Island, N.W.T.; *Can. J. Earth Sci.*, vol. 3, pp. 697-711.

In northwest Somerset Island quartz sandstones of the Aston formation and dolostones of the overlying Hunting formation rest unconformably on metamorphic basement rocks. Except for stromatolites and trace fossils the formations are unfossiliferous, and their age has been interpreted as Proterozoic by previous authors.

The Aston sandstones pass conformably upward into the Hunting dolostones, which are conformably overlain by Ordovician strata. A similar succession with Middle Cambrian trilobites at the base occurs on Boothia Peninsula. It is therefore suggested that the Aston and Hunting formations comprise a Palaeozoic succession continuous with the fossiliferous Ordovician rocks. This hypothesis does not appear to be incompatible with regional interpretations of Proterozoic-Palaeozoic relationships. The sedimentary structures and petrology of the Aston sandstones suggest that they were derived from

the basement rocks and deposited in a shallow marine environment. Sedimentary structures and stromatolites in the Hunting dolostones show that they were laid down in coastal lagoons and tidal flats.

0221 TURNER, S., and DIXON, J. - 1971
Lower Silurian *Thelodonts* from Prince of Wales Island, Northwest Territories; *Lethaia*, vol. 4, pp. 385-392.

Thelodont scales, determined as *Thelodus laevis* (Pander), *Logania martinsoni* Gross, and *Phlebolepida* gen. et sp. indet., and other agnathan remains have been found in the dolomite-limestone sequence of the Transition Beds between the Allen Bay and Read Bay Formations. This *thelodont* association is typical of the Middle and Lower Upper Silurian of Osel and Gotland, and its presence therefore provides evidence for the upper age limit of the transition beds.

0222 VILKS, G. - 1964
Foraminiferal study of East Bay, Mackenzie King Island, District of Franklin; *Geol. Surv. Can.*, Paper 64-53, 26 p.

The area of this study was chosen to provide information on the Foraminifera of an Arctic inshore environment. Results show that the population is dominated by arenaceous agglutinated forms and that the number of species decreases toward the shore although the number of individuals increases. Each of three bathymetric zones is apparently dominated by a particular species and the whole population is indicative of a cold environment with lengthy annual ice cover.

0223 VILKS, G. - 1969
Recent foraminifera in the Canadian Arctic; *Micropaleontology*, vol. 15, No. 1, pp. 35-60.
The Recent foraminifera in the ice-covered seas of the Canadian Arctic were found to be distributed in two bathymetric zones with their common boundary at about the 200-metre isobath. The information was used to support a theory of a regional lowering of sea level during the Holocene. The rate of sedimentation during the past 8000 years is indicated to be 4.4 cm. per 1000 years.

0224 VILKS, G., ANTHONY, E.H., and WILLIAMS, W.T. - 1970
Application of association-analysis to distribution studies of Recent Foraminifera; *Can. J. Earth Sci.*, vol. 7, No. 6, pp. 1462-1469.
Counts of species of foraminifera from 75 samples of sediment from East Bay, Mackenzie King Island, in the Canadian Arctic were converted to a matrix of presence-absence data (56 species X 75 stations). These were submitted to both normal and inverse association-analysis as a preliminary test of the application of that multivariate method to problems in marine ecology. The results are compared with observations made at the time the survey was carried out. Although the pattern of sampling was not the most suitable for association-analysis, the results indicate that the method may prove quite informative.

0225 WAGNER, F.J.E. - 1962
Faunal report, submarine geology program, Polar Continental Shelf Project, Isachsen, District of Franklin; *Geol. Surv. Can.*, Paper 61-27, 10 p.

0226 WAGNER, F.J.E. - 1964
Faunal report - II, marine geology program, Polar Continental Shelf Project, Isachsen, District of Franklin; *Bed. Inst. Ocean.*, Report B.I.O. 64-1, 15 p., unpub. ms.
This report is the second on material collected by Geological Survey of Canada personnel in conjunction with the Polar Continental Shelf Project. The area of study covers a section of the floor of the Arctic Ocean off the western edge of the Queen Elizabeth Islands. The lines of traverse extend seaward about 115 miles northwest from Ellef Ringnes Island and about 95 miles northwest from the tip of Borden Island. Because this area overlaps part of that sampled in 1960, nine of the 1960 stations are repeated, along with the twenty new stations located in 1962. Eight of the stations are located on drowned headlands, three in the intervening channels, sixteen on the continental shelf and two on the continental slope (see Fig. 1). Depths of water at these stations are between 180 metres and 1239 metres, with the majority being in the 350- to 600-metre range.

0227 WAGNER, F.J.E. - 1972
Molluscan fauna as indicators of Late Pleistocene history, southeastern Beaufort Sea; *24th Int. Geol. Cong.*, Sect. 8, pp. 142-153.
One hundred and forty-nine grab samples were examined from the Beaufort Sea area bounded by latitudes 68°45'10"N and 71°34'18"N and longitudes 128°19'W and 140°37'W. Of these, 97 were collected from CSS Hudson between August 26 and September 20, 1970; the remaining 52 samples were obtained on a helicopter operation during April 1971. Molluscs were obtained from 95 of these 149 samples. Fossil molluscs were picked from 8 of the 52 Hudson cores, and were also collected from four localities on Herschel Island and one locality at Kay Point, Yukon Territory. Molluscs from a depth of 10 to 30 cm in one core have been radiocarbon-dated at 700±180 years B.P., and from the 400- to 406-cm interval in another core gave an age of 3530±240 years B.P. A comparison of fossil molluscs from the cores with the recent fauna suggests that 3500 years ago sea level was approximately 270 m lower than at present, and 700 years ago it was approximately 15 m lower than now.

0228 YARRANTON, G.A., and RITCHIE, J.C., - 1972
Sequential correlations as an aid in placing pollen zone boundaries; *Pollen and Spores*, vol. 14, No. 2, pp. 213-223.
On propose d'établir les limites d'une zone pollinique en se basant sur la présence de dépressions dans un graphique de coefficients de corrélation continue d'une colonne stratigraphique. Les véritables limites de zone peuvent être distinguées des simples oscillations par l'examen de la corrélation entre les échantillons de chaque côté de la variation. La méthode a été appliquée aux données palynologiques d'une coupe du Pléistocène supérieur provenant du nord-ouest de l'Arctique canadien. Une

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comparaison des zones, établies par corrélation, avec les zones originales, déterminées subjectivement, a montré qu'en moyenne les premières sont à la fois plus uniformes intérieurement et plus discontinues que les dernières.

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0229 ANDRIEUX, P. - 1966
Resistivity studies in glaciers and ice caps; *Ice*, No. 20, p. 9.

0230 BERKHOUT, A.W.J. - 1970
The gravity anomaly field of Prince of Wales, Somerset and northern Baffin Islands, District of Franklin, Northwest Territories; *Publ. Dom. Observ.*, vol. 39, No. 7, pp. 179-209.
The area of study covers approximately 360,000 km², comprising Somerset, Prince of Wales, and northern Baffin Islands. A total of 2700 gravity observations at intervals of 10 to 15 km are included. Major negative anomalies occur on Borden and Brodeur peninsulas, in the area east of Agu Bay, on north-eastern Somerset Island, and on northwestern Prince of Wales Island. These lows are explained by the presence of Upper Proterozoic metasedimentary rocks which underlie some of the lows, but are covered by Lower Paleozoic rocks elsewhere. An important conclusion is that during Upper Proterozoic time vast basins existed which were the sites of accumulation of clastic sediments. The observed gravity field outlines these basins and suggests that they may be interconnected.
A northerly trending gravity high is associated with the Boothia Uplift and two parallel highs occur to the west of it, all three being separated by gravity lows. The density contrast between crystalline rocks of the uplift and the adjacent Paleozoic rocks is not sufficient to explain the change of gravity over the Boothia Uplift. It is suggested that three northerly trending basement uplifts exist, separated by graben in which Upper Proterozoic quartzitic rocks occur. The Boothia Uplift became active again in Paleozoic time and overthrusts the quartzitic rocks in the west; this is reflected by observed negative anomalies along its western flank. The gravity high over Prince Regent Inlet may reflect a basement fault block beneath the Paleozoic rocks, whereas adjacent gravity lows represent the depressed areas occupied by thick deposits of Upper Proterozoic quartzitic rocks.
The northerly and northeasterly trends of the two systems of basement fault blocks cut across the generally easterly (Archean) trend of basement structures, as on Baffin Island. Similar observations have been made in the Canadian Shield. These unusual trends may possibly originate along ancient orogenic zones with northerly and northeasterly trends.
Several smaller, local anomalies occur. Two gravity highs on Prince of Wales Island are probably caused by mafic intrusions and a gravity low on Bylot Island is explained by light Mesozoic sedimentary rocks.

0231 BERKHOUT, A.W.J., and SOBCHAK, L.W. - 1967
A preliminary investigation of gravity observations in the Somerset and Prince of Wales Islands Arctic Canada with map; Gravity map series No. 81, *Dom. Observ.*, 10 p.
During the spring and summer of 1965 some 750 gravity observations were made in the Prince of Wales and Somerset Islands area. The Bouguer anomaly map prepared from these data displays a series of north-trending highs and lows in the central and southern part of the area. These anomalies are attributed to density variations within the crystalline basement rocks. Two local gravity highs over western Prince of Wales Island are interpreted as indicating relatively near-surface basic intrusions.

0232 BERRY, M.J., and BARR, K.G. - 1971
A seismic refraction profile across the polar continental shelf of the Queen Elizabeth Islands; *Can. J. Earth Sci.*, vol. 8, No. 3, pp. 347-360.
During the spring of 1967, a seismic refraction experiment was conducted from the SW tip of Prince Patrick Island in the Queen Elizabeth Islands of Arctic Canada to a point mid-way down the continental slope, some 220 km from the coast. It was found that seismic recording on sea ice was plagued by unusually high background noise levels which could be attributed to low frequency (below 1 Hz) oscillations of the ice pans and to the broadband noise generated by frequent ice cracking. It was discovered, and is shown theoretically, that seismic wave propagating through a water layer (the ocean) and incident on the ice layer from below provide an exact $\pi/2$ phase shift between the horizontal and vertical components of surface motion. This fact can be used to advantage in digital processing. The interpretation shows a crustal model with depths to the M discontinuity of 28 ± 4 km at the coast, thinning to 15 ± 9 km at the end of the profile. The velocity of the mantle is measured as 8.05 ± 0.17 km/s. Mid-way down the continental slope there are 5.0 ± 1.63 km of sediments overlying material with a velocity of 5.36 ± 0.15 km/s. Material of a similar velocity, 5.72 ± 0.18 km/s, lies 2.7 ± 1.9 km beneath the surface material at the coast, where the surface layer has a velocity of 4.76 ± 0.4 km/s. It is concluded that the data support the hypothesis that the Canada Basin has an oceanic rather than a continental crust.

0123 DINELEY, D.L. - 1965
Notes on the scientific results of the University of Ottawa expedition to Somerset Island, 1964; *Arctic*, vol. 18, No. 1, pp. 55-57.
Abstract under 0123

0124 DINELEY, D. - 1966
Geological studies in Somerset Island, University of Ottawa expedition, 1965; *Arctic*, vol. 19, No. 3, pp. 270-277.
Abstract under 0124

0233 FRASER, D. - 1963
Geomagnetic activity at high latitudes; in Axel Heiberg Island, Preliminary Report 1961-1962, ed. F. Muller et al., McGill Univ.

A variation station which continuously recorded the relative variations of three orthogonal components of the earth's magnetic field was maintained in operation at the Expedition Base Camp from 28 July, 1961, until 4 August, 1961. The records obtained will be used in an investigation of high latitude geomagnetic activity being carried on by the Dominion Observatory under the direction of Dr. K. Whitham.

0234 GEOLOGICAL SURVEY OF CANADA - 1969
Index to map sheets, aeromagnetic series, Sheet No. 16, 181 sheets. *Geol. Surv. Can.*

0235 GOH, R. - 1972
A marine magnetic survey in the Mackenzie Bay/Beaufort Sea area Arctic Canada; unpub. MSc. Thesis, Univ. Br. Col.

This thesis presents an investigation of the variations in the magnetic field obtained in the Mackenzie Bay/Beaufort Sea area of the Canadian Arctic.

It was found that the variations obtained at sea were strikingly correlated with those recorded at Point Atkinson, a fixed station on land, 150 miles from the survey area. In addition, it was found that the higher frequencies present in the marine records were severely attenuated with respect to the corresponding frequencies in the Point Atkinson recordings. It was concluded that the Mackenzie Bay/Beaufort Sea area is geomagnetically anomalous and that this situation is probably caused by higher electrical conductivity material underlying the Mackenzie Bay/Beaufort Sea area, abutting lower conductivity material of the North American craton underlying Point Atkinson. This conclusion has important implications relating to the tectonic history of the Canadian Arctic.

0236 HAMILTON, A.C. - 1963
Gravity measurements in Canada, January 1, 1960 to December 31, 1962; *Publ. Dom. Observ.*, vol. 28, No. 3, 34 p.
This triennial report has been prepared for the Thirteenth General Assembly of the International Union of Geodesy and Geophysics (I.U.G.G.) on behalf of the Associate Committee on Geodesy and Geophysics which is the National Committee representing Canada in the International Union. It is an attempt to summarize the measurements of gravity and to review the research on gravity for the period from Jan. 1, 1960 to Dec. 31, 1962. Annual reports have been published in the Canadian Geophysical Bulletin (Garland, Editor) and similar triennial reports (Hamilton, 1960; Innes, 1957) have been prepared for previous General Assemblies.

0237 HATTERSLEY-SMITH, G. - 1960
Geophysical and other studies of the Polar Continental Shelf Project; *in* Can. Geophys. Bull., No. 13, pp. 89-90.

0038 HATTERSLEY-SMITH, G. - 1961
North-western Queen Elizabeth Islands (Polar Continental Shelf Project and Geographical Branch, Department of Mines and Technical Surveys); *in* Can. Geophys. Bull., No. 14, pp. 96-98.

0238 HATTERSLEY-SMITH, G. - 1965
Resistivity studies in glaciers and ice caps (National Research Council, in collaboration with Observatories Branch, Polar Continental Shelf Project and McGill University; P. Andrieux, University of Paris); *in* Can. Geophys. Bull., No. 18, p. 143.

0239 HOBSON, G.D. - 1962
Seismic exploration in the Canadian Arctic Islands; *Geophysics*, vol. 27, No. 2, pp. 253-273.

The Polar Continental Shelf Project, a broad program of research in the Canadian Arctic, was started in 1959. Seismic studies were undertaken by the Geological Survey of Canada. Refraction and reflection techniques were employed in the first stages of a reconnaissance program during May, June, July, and August 1960.

Certain new techniques were developed during this seismic program in the high Arctic. The crew operated from motor toboggans in 1960 but helicopters will be used more extensively in the future for a more efficient operation. Adverse weather conditions such as blizzards, low temperatures, white-outs, wind, and rain are a hindrance to operations at various times of the year.

The sea ice appears to present no great noise problem to standard recording techniques. Several air shots were recorded in direct comparison with surface shots but the gain in energy level is not enough to justify using the method. The records from various locations within the Sverdrup Basin indicate that both reflection and refraction techniques are satisfactory. A cross-section illustrates the results of the 1960 program.

0240 HOBSON, G.D., and OVERTON, A. - 1967
A seismic section of the Sverdrup Basin, Canadian Arctic Islands; *in* Seismic Refraction Prospecting, Soc. Expl. Geoph., Tulsa, ed. A.W. Musgrave, pp. 550-562.

Seven seismic refraction profiles were completed in 1961 in the Canadian Arctic Islands under the Polar Continental Shelf Project of the Department of Mines and Technical Surveys. These seven profiles were shot along a line extending from a location 30 miles north of Ellef Ringnes Island, along the west coast of this same island to a point 30 miles south of the island into Belcher Channel.

The program was carried out using an S-55 helicopter with the supply support and major moves by Otter fixed-wing aircraft. Dynamite charges were successfully detonated in depths of water to 1,285 ft without the use of "boosters." A Decca Survey Chain provided regional navigation but this system is not sufficiently accurate for long-range seismic refraction surveying. These seven profiles are presented in a cross section across the Sverdrup Basin, correlated by seismic velocities, indicating a thickness of approximately 40,000 ft of sediment in the center of the Basin to a formation with a horizontal velocity of 20,000 ft/sec "Basement" or the base of the unmetamorphosed sediments may be 64,000 ft deep at this location.

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0241 HORNAL, R. - 1961

Detailed gravity surveys on Ellef Ringnes and Meighen Islands, Queen Elizabeth Islands, Northwest Territories, 1960; unpub. B Sc. Thesis, Queen's Univ., 28 p.

Four detailed gravity surveys were conducted in the summer of 1960 in the vicinity of Isachsen, Northwest Territories; the thickness of the Meighen Island Ice-Cap was determined; the intrusive rocks of the Isachsen area were found to be 1500 feet thick where they appeared as ridges and 700 feet thick where they were buried under the valleys; the presence of an intrusive body beneath Deer Bay was verified; the approximate thickness of the Isachsen and Dumbbell domes was found to be 4000 feet. The lack of proper maps reduced the accuracy of the dome survey but it was not a problem in the other surveys.

0242 HORNAL, R.W., SOB CZAK, L.W., BURKE, W.E.F., and STEPHENS, L.E. - 1970

Preliminary results of gravity surveys over the Mackenzie Basin and Beaufort Sea; *Dept. Energy, Mines and Res., Gravity Map series of Earth Phys. Br.*, 12 p. and 3 maps.

Three Bouguer anomaly maps at a scale of 1:1,000,000 and contoured at 5 mgal intervals have been prepared from 6,100 gravity observations made in the Interior Plains and on the Beaufort Sea from latitude 60°N to 72°N.

The major features of the gravity field are: a gravity low over the Mackenzie Mountains which is attributed to a thickened sedimentary sequence and a deeper crust-mantle boundary; a relatively positive anomaly of 50 mgal striking north from Trout Lake to Great Bear Lake which reflects a ridge or trough of mafic rock within the Precambrian basement; a negative anomaly over the Mackenzie River delta of 55 mgal which results from the deposition of more than 21,000 feet of Cretaceous and Tertiary sediments; and a circular positive anomaly of 130 mgal situated south of Darnley Bay which is explained by a cone-shaped basic intrusion. Smaller variations in the gravity field in the Interior Plains may be attributed to changes in the depth to the Precambrian basement and density variations within the sedimentary column.

0243 HUNTER, J.A. - 1972

A model study of reflected seismic waves from the bottom of the permafrost layer; *in Report of Activities, November 1971 to April 1972, Geol. Surv. Can., Paper 72-1, Part B, pp. 44-46.*

0244 HUNTER, J.A. - 1973

Shallow marine refraction surveying in the Mackenzie Delta and Beaufort Sea; *in Report of Activities, Part B: November 1972 to March 1973, Geol. Surv. Can., Paper 73-1, Part B, pp. 59-66.*

0245 HUNTER, J.A., BURNS, R.A., GOOD, R., and BAZELEY, P. - 1972

Shallow seismic refraction survey Mackenzie River valley; *in Report of Activities, May to October 1972, Geol. Surv. Can., Paper 72-1, Part A, pp. 86-87.*

0246 HUNTER, J.A., and GAGNE, R.M. - 1973

Shallow seismic surveys, Mackenzie Valley, Northwest Territories and Ste-Scholastique, Quebec; *in Report of Activities May to October 1973, Geol. Surv. Can., Paper 73-1, Part A, pp. 51-52.*

0247 HUNTER, J.A.M., and GOOD, R. - 1971

A hammer seismic investigation of the permafrost layer, Mackenzie Delta; *in Report of Activities, November 1970 to April 1971, Geol. Surv. Can., Paper 71-1, Part B, pp. 49-50.*

0248 HUNTER, J.A., and ROSNUK, L. - 1972

Shallow seismic surveys, Yukon coast; *in Report of Activities, May to October 1972, Geol. Surv. Can., Paper 72-1, Part A, p. 86.*

0249 JESSOP, A.M. - 1970

How to beat permafrost problems; *Oilweek*, Jan. 12, 1970, pp. 22, 24 and 25.

Permafrost means problems in drilling and production. Knowing where the permafrost is will not solve all the problems, but good data will help in coming to grips with them. Pure science may be able to provide some of the data.

0250 JOHANNESSEN, O.M., POUNDER, E.R., SERSON, H., SMITH, S.D., FINLAYSON, D., KEYS, J., WEBER, J.R., and LANGLEBEN, M.P. - 1970

Cruise report from the ice drift study in the Gulf of St. Lawrence 1970; *McGill Univ. Marine Sc. Centre, Report No. 15, 53 p.*

M/V "STEPHENVILLE" was escorted on March 3 into the ice pack between the Magdalen Islands and the Baie de Chaleurs in the Gulf of St. Lawrence by an ice-breaker. Four buoys with radar reflectors, anemometers, and suspended current meters were placed on nearby floes. The "STEPHENVILLE" was allowed to freeze into a large floe and the vessel and buoys drifted for 27 days in a generally southerly direction towards Prince Edward Island.

Routine observations were made throughout the period of the position of the ship and buoys (by Decca navigator and radar), of wind velocity at different heights and locations, and of currents at 6 levels. A total of 450 hydrocasts were made using an STD (salinity, temperature, depth) recorder developed by the National Research Council, together with a few Nansen casts for calibration of the STD instrument. Boundary layer studies were made using sonic anemometers in the air and a current profiler and current meters in the water. Ocean tilt was investigated using a hydrostatic levelling technique and the heat budget was studied using two profile stations.

0251 JOHNSON, G.W., and LILLESTRAND, R.L. - 1972

Deviation of solar culmination from meridian transit in polar regions; *The Can. Surveyor*, vol. 26, No. 4, pp. 357-368.

Solar culmination does not occur precisely at meridian passage except at the time of summer or winter solstice. The extent of the deviation between culmination and meridian passage is analyzed with particular emphasis on the polar regions, where the deviation reaches its maximum. As the Pole is approached,

a zone is reached within which no culmination whatsoever occurs. Graphs are given that show the zenith angle difference, the local hour angle and the azimuth angle at the time of culmination as a function of the observer's latitude and the time of the year.

0252 JUDGE, A. - 1973

The prediction of permafrost thickness; *Can. Geotech. J.*, vol. 10, No. 1, pp. 1-11.

With a knowledge of the mean annual ground temperatures, the general lithology at a given location and a regional distribution of the geothermal flux from the earth's interior, it is possible to make reasonable estimates of the presence or absence of permafrost and its thickness. The prediction is complicated by changes of the local surface temperature in the past due to a variety of factors ranging from changes of climate to forest fires.

0253 KLINKENBERG, H. - 1971

Geodetic operations in Canada; report submitted to I.U.G.G., Moscow, 30 p.

This report on geodetic operations in Canada deals mainly with the activities of the Geodetic Survey of Canada, however, the National Research Council, the Gravity Division of the Earth Physics Branch, the Tides and Water Levels Section of the Marine Sciences Branch, the Mapping and Charting Establishment of the Canadian Armed Forces, and the Universities of New Brunswick, Laval and British Columbia are also engaged in geodetic operations or modest research and development activities.

Since October, 1968, the Geodetic Survey of Canada has been responsible not only for first-order horizontal and vertical control surveys, but also for secondary control surveys. Before October, 1968, secondary control surveys were performed by the field section of the Topographical Survey, but as a result of a reorganization of the Surveys and Mapping Branch of the Department of Energy, Mines and Resources this field section has become part of the Geodetic Survey of Canada.

0254 LAROCHELLE, A., and BLACK, R.F. - 1963

An application of palaeomagnetism in estimating the age of rocks; *Nature*, vol. 198, No. 4887, pp. 1260-1262.

0255 LAW, L.K., DELAURIER, J., ANDERSEN, F., and WHITHAM, K. - 1963

Investigations during 1962 of the Alert anomaly in geomagnetic variations; *Can. J. Phys.*, vol. 41, pp. 1868-1882.

Magnetic variations measured at three stations across the strike of the anomaly in electrical conductivity of the earth's mantle suggested by Whitham and Andersen (1962) near Alert, Ellesmere Island, have been analyzed by simple potential theory. The anomalous internal contributions to the magnetic variation vector show striking confinement consistent with an underground current in a northeast-southwest direction at a depth between 50 and 70 km, a few kilometers southeast of Alert. If the anomalous conductor is approximated by a uniform infinite cylinder, the horizontal field response as a function of frequency can then be explained with a

conductivity of $\approx 3 \times 10^{-11}$ e.m.u. and a cylindrical radius of about 50 km. The vertical field response is, however, an unsatisfactory fit to this model. A possible asymmetry is noted based on the hourly range data: this could be explained by the dipping of the real conductor under Ellesmere Island. Preliminary earth potential measurements show that, as expected, the electric field variations are abnormally low at Alert.

The gravitational consequences of the cylindrical model are discussed and compared with two profiles from the same region. A Bouguer anomaly is found in the predicted region if certain regional gradients are assumed, but its magnitude is smaller than that predicted from the cylindrical model in hydrostatic equilibrium. It is clear that approximate agreement can be obtained with crustal thinning of some 20 km. The significance of the thermal anomaly thought to be responsible for the electrical conductivity anomaly is discussed briefly.

0256 LAW, L.K., DELAURIER, J., and NIBLETT, E.R. - 1973

Geomagnetic variation anomalies; in *Tectonic Styles in Canada*, G.A.C. Spec. vol. 11, pp. 157-159.

0257 LAW, L.K., PATERSON, W.S.B., and WHITHAM, K. - 1965

Heat flow determinations in the Canadian Arctic Archipelago; *Can. J. Earth Sci.*, vol. 2, No. 1, pp. 59-71.

Three heat flow determinations were made in M'Clure Strait between Prince Patrick and Banks Islands in the northwestern part of the Arctic Archipelago of Canada. The three stations lie within 55 km of a point some 130 km SSW. of Mould Bay, Prince Patrick Island, and yield a weighted mean heat flow of $0.84 \pm 0.09 \mu\text{cal cm}^{-2} \text{ s}^{-1}$, or 57% only of the worldwide continental average. The measurements were made from sea ice in water depths of some 430 m using a thermal probe and portable equipment carried in a fixed-wing aircraft.

Instrumental limitations and errors are discussed, together with environmental factors. The uncertainties interpreting this result as a truly subnormal equilibrium heat flow are outlined but it is concluded that the calculated systematic errors are unlikely to exceed 25%. Consequently in the absence of any known major perturbing effect, it must be concluded that the structure responsible for the suppression of vertical magnetic field variations at Mould Bay observatory does not extend 130 km to the south, is not produced by an anomalously high near-surface temperature, or is of late-Quaternary origin.

0258 LILLESTRAND, R.L. - 1970

General constant of refraction when using a Roelofs prism; *Control Data Corp.*, internal report CDC TM 95243-6, 17 p.

Astronomical atmospheric refraction can be represented by an equation of the form

$$\psi = R_0 \frac{p}{p_s} \frac{T_s}{T} \tan z - 0.067 \tan z \sec^2 z + \text{higher order terms}$$

where z is the measured zenith angle of the celestial target and R_0 is the general constant of refraction.

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p is the measured atmospheric pressure and p_s is standard pressure, in this case taken as 760 mm Hg. Similarly, T is the measured temperature and T_s is the standard temperature, in this case taken as 273.°2 Kelvin.

R_0 is dependent on water vapor content to some extent and it is shown in the present memo that

$$R_0 = 60."46 \quad (4 \text{ mm water vapor})$$

$$R_0 = 60."51 \quad (0 \text{ mm water vapor})$$

Under the conditions encountered during the Canadian North Pole Research Program of 1969 it is recommended that a value of 60."50 be used.

The first two terms in the above equation for atmospheric refraction will yield an accuracy of 1."0 or better out to a zenith angle of 80°.

The above given values for R_0 apply when using a Roelofs prism to view the sun. Included in the calculation of these values are (1) the effects of the spectral band pass of the green filter in the Roelofs prism, (2) the daylight relative visibility factor of the eye, and (3) the spectral energy distribution of the sun as seen from the earth.

The coefficient R_0 depends on the zenith angle of the sun. This dependence is very weak and may be ignored out to a zenith angle of about 80°. Beyond this the variation increases sharply and depends increasingly on atmospheric haze and cloud conditions. Because of the spectral bound established by the band pass characteristic of the filter, even at 90° the effect of the assumption that R_0 is constant is to create a maximum error of only 6 seconds of arc.

0259 LILLESTRAND, R.L., and WEBER, J.R. - 1972

Plumb line deflection at North Pole; *Abstract*, presented Amer. Geophys. Union, San Francisco.

The deflection of the gravity vertical in the neighborhood of the Lomonosov Ridge near the North Pole is estimated to be 9 arc seconds (280 m) in a direction of 34°E longitude. The deflection is derived from a comparison of sea ice drift paths, one of which is based on astronomical observations and the other on transit satellite measurements. In addition, acoustic ranging measurements were made from acoustic transponders on the ocean floor. The scatter of individual deflection determinations yields a circular error probability (CEP) of about 4 arc seconds. The complexity of the sea ice drift, the nature of the measurement geometry and the irregular time intervals between measurements limits the accuracy of this estimate with the existing data. Direction and magnitude of this deflection implies a mass deficiency in the region of the Lomonosov Ridge reflecting a lower density material imbedded in a denser oceanic crust. This supports the hypothesis that the Lomonosov Ridge is a rafted fragment of continental crust.

0260 MACKAY, D.K. - 1969

Electrical resistivity measurements in frozen ground, Mackenzie Delta area, Northwest Territories; *Assoc. Inter. Hydro Sci.*, Bucarest, pp. 363-375.

The use of resistivity as an aid in the identification of frozen rock/soil types and in mapping the

upper permafrost surface is discussed with reference to the Mackenzie Delta region, Northwest Territories. Apparent resistivity ranges of some identifiable frozen materials are tabled. Of materials sounded, sands and gravels have the highest resistivities, silts the lowest, with peats falling into an intermediate category.

Variations in topography, drainage, and vegetative cover may be useful indicators of relative differences in apparent resistivity. Ground temperature is an important factor affecting apparent resistivity; for example, resistivity doubles for a drop of 1.5°C to 2°C in the top three meters of frozen gravels.

Resistivity techniques are of use in mapping the upper permafrost surface, particularly in deltas where numerous heat sources such as channels and lakes influence its configuration. Resistivity data complements seismic, drillhole and ground temperature data in permafrost investigations.

0261 MILNE, A.R. - 1963

A 90-km sound-transmission test in the Arctic; *J. Acoust. Soc. Amer.*, vol. 35, No. 9, pp. 1459-1461.

A 90-km sound-transmission test on the continental slope of the Arctic Ocean north of the Canadian Archipelago is described. Spectrum levels of sounds from 1-lb explosive charges vs distance are presented for frequencies in the range 12 cps to 16 kcps. Results confirm the low-pass filtering effect of the ice canopy and assist in the determination of transmission losses.

0262 MILNE, A.R. - 1966

Statistical description of noise under shore-fast sea ice in winter; *J. Acoust. Soc. Amer.*, vol. 39, No. 6, pp. 1174-1182.

Ambient noise under short-fast sea ice in midwinter is generated at the surface of the ice by wind action as well as by mechanical cracking caused by declining air temperatures. An attempt has been made to relate field measurements of underwater noise to the sources of the noise by means of a geometrical model of the environment. The statistical properties and the spectra of the under-ice noise can be related to the surface density and the waveform of the source pressure pulses by means of the model.

0263 MILNE, A.R. - 1972

Thermal tension cracking in sea ice: a source of underice noise; *J. Geoph. Res.*, vol. 77, No. 12, pp. 2177-2192.

A summary is given of the important observations that relate the rheological properties of sea ice to the occurrence of surface tension cracks and explain how the noises produced by myriad surface cracks are observed under the ice. Ice-cracking noise is expected where the surface of the sea ice is cold and has a sufficiently low salinity to approximate a brittle solid. This condition is more likely to occur in seas covered by a high percentage of multi-year ice and where wind-mixing in leads was absent when the seas congealed. The acoustic water waves observed from crack-excited plate waves are described and two examples of single-frequency Crary wave arrivals are shown. A mechanism is postulated to explain the

tendency for regularity in the spacing of pressure ridging in the Arctic Ocean. Thermal pre-stressing at the ice surface, added to flexural stresses caused by wind-induced flexural-gravity standing waves, can produce significant tensile stress maxima at antinode spacings. For 3 meters of ice, the predicted antinode spacings are 132 meters where a high probability of through-the-ice fractures can occur. Flexural-gravity waves that propagate in the presence of thermal pre-stressing should produce a correlation of wind speed with ice-cracking noise.

0264 MILNE, A.R., and CLARK, S.R. - 1964
Resonances in seismic noise under Arctic sea-ice; *Bull. Seis. Soc. Amer.*, vol. 54, No. 6, pp. 1797-1809.

Spectrograms of underwater seismic noise between 0.2 and 2.0 cps from the bottom of relatively shallow ice-covered seas show a line structure which indicates that vertical resonances occur within layers bounded at depth by the Mohorovicic discontinuity. The line structure appears with most clarity when recognizable transients are excluded. Under these quasi-stationary noise conditions, measurements of pressure spectra indicate that the seismic noise of the observed level can be generated by a vertical bobbing of the ice field as a whole.

0265 MILNE, A.R., and GANTON, J.H. - 1964
Ambient noise under Arctic-Sea ice; *J. Acoust. Soc. Amer.*, vol. 36, No. 5, pp. 855-863.

Underwater ambient-noise spectra and amplitude distributions are described for data acquired during field experiments made in the spring, late summer, and winter within the Canadian Arctic Archipelago. Measurements in each case were made using a bottom-mounted hydrophone. The ice cover was fast to the shore during the spring and winter experiments. In the summer experiment, the ice cover, although 10/10, was free to move. The ambient noise was generally impulsive and at times highly non-Gaussian. The significant noise was the result of mechanical activity associated with the ice cover. For shore-fast spring and winter ice, surface cracks as a result of thermal stresses were important; for late summer ice, relative motion of the floes was important.

0266 MILNE, A.R., GANTON, J.H., and McMILLIN, D.J. - 1967
Ambient noise under sea ice and further measurements of wind and temperature dependence; *J. Acoust. Soc. Amer.*, vol. 41, No. 2, pp. 525-528.

Measurements of underwater-pressure spectral density from M'Clure Strait (2-5 May 1966), the Beaufort Sea (31 July and 16 August 1965), and the Canada Deep (14 April 1965) are presented. The M'Clure Strait measurements, made under shore-fast sea ice, exhibited a variability related to air-temperature and wind-speed changes of a similar nature to those reported previously for midwinter under-ice noise. The great differences in the magnitude and variation with frequency of the ambient noise observed under sea ice is again illustrated with three sets of measurements obtained during 1965-1966. The noise observed under the shore-fast ice of M'Clure Strait

in the springtime appeared to be governed by air-temperature and wind-speed changes in a similar manner to noise observed previously in the midwinter. J.H. Ganton and A.R. Milne, *J. Acoust. Soc. Am.* 38, 406-411 (1965). On the other hand, measurements made under the moving ice cover of the Canada Deep in the springtime and of the Beaufort Sea in the summer appeared to be less amenable to description in terms of easily observable physical variables.

0267 MORRISON, H.F. - 1961
Seismic investigations in the Sverdrup Basin, Queen Elizabeth Islands; unpub. MSc Thesis, McGill Univ., 76 p.

This thesis presents the results of a reconnaissance seismic program carried out by the Geophysics Division of the Geological Survey of Canada during the months April to August, 1960, in the Queen Elizabeth Islands, N.W.T. The seismic investigations were a part of a continuing, comprehensive, Arctic research program directed by the Polar Continental Shelf Project (P.C.S.P.). The P.C.S.P. was created by a Federal Cabinet directive in 1959 and is a division of the Department of Mines and Technical Surveys. The seismic operations in the summer of 1960 were of a preliminary and reconnaissance nature designed to measure the thickness of the sedimentary section in as many localities as possible and to lay the foundations for detailed investigations in following years.

0268 NIBLETT, E.R., and WHITHAM, K. - 1970
Multi-disciplinary studies of geomagnetic variation anomalies in the Canadian Arctic; *J. Geomag. & Geoelect.*, vol. 22, No. 1-2, pp. 99-111.
Recent work on prominent magnetic variation anomalies in Canada is reviewed. The first of these is on Ellesmere Island in the Arctic Archipelago, and results from magnetic and magnetotelluric data collected in 1967 are presented. Anomalous effects - i.e., an abnormally high level of magnetic activity coupled with a persistent tendency for the horizontal variation vector to be restricted to a single direction - appear to be confined to a narrow zone nearly 500 km long stretching between Alert on the north coast and Eureka on the west. Recent data indicate that the strength of the anomaly is not uniform along its strike, but is somewhat diminished in the central and southern portions. The main features of the anomaly have been explained by postulating the presence of a long narrow conducting body located in the lower part of the crust. The existence of such a conductor would provide a natural channel for currents induced over a much broader area. It may also imply an abrupt upheaval of isotherms underneath Ellesmere Island. Available surface wave dispersion and heat flow information in the Ellesmere Island area will be discussed: the evidence supporting a thermal explanation for the geomagnetic anomaly is unconvincing, but still ambiguous.

The Mould Bay anomaly is located in the eastern part of the Arctic Archipelago and is known to extend over large portions of Prince Patrick and Melville Islands. Over this area shorter period fluctuations

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in the vertical component are very strongly attenuated. The presence of a massive conducting layer deep in the crust is postulated to explain the effect. Seismic, heat flow and gravity data are available in this area, but no clear relation to the geomagnetic anomaly has been found.

0269 NIBLETT, E.R., and WHITHAM, K. - 1973
Geomagnetic variation anomalies, heat flow, seismicity; *in* Tectonic Styles in Canada, Geol. Assoc. Can. Spec. Paper 11, pp. 157-159.

0270 NIBLETT, E.R., WHITHAM, K., and CANER, B. - 1969
Electrical conductivity anomalies in the mantle and crust in Canada; *in* The Application of Modern Physics to the Earth and Planetary Interiors, ed. S.K. Runcorn, vol. 8, No. 3, pp. 155-172.
Three prominent magnetic variation anomalies have been found in Canada and subjected to detailed study. Two of these are located in the Arctic Archipelago and the third lies in the Cordillera in southern British Columbia.
The first anomaly, at Alert on the northern end of Ellesmere Island, was discovered by Whitham, Loomer, and Niblett from the records of a temporary magnetometer station established there for the IGY. Higher-quality data became available after a permanent magnetic observatory was set up late in 1961. The standard magnetograms at Alert (recording speed 2 cm/hour) display an abnormally high level of irregular magnetic activity and also a persistent tendency for the horizontal variation vector to be confined to a single direction. The main features of the anomaly have been explained by postulating the presence of a massive highly conducting body in the lower part of the crust. Field experiments in the vicinity have indicated that the structure may be several hundred kilometres long with a cross-section scale length of roughly 100 km.
The second Arctic anomaly is at Mould Bay on Prince Patrick Island and was discovered after the establishment of a permanent magnetic observatory there in 1961. Here the outstanding feature of the magnetograms is the absence of shorter-period fluctuations in the vertical component. The existence of a large subterranean conductor - a horizontal slab perhaps a few hundred kilometres in extent - is again suggested in order to explain the effect. At this location supporting evidence for an anomalous structure deep in the crust or in the upper mantle is available from seismic observations.
In southern British Columbia a series of field observations by the University of British Columbia and the Dominion Observatory have shown that along east-west profiles across the Cordillera from the coast to the Alberta plains, the vertical force variations are consistently smaller west of longitude 118° (approximately) than they are to the east of this meridian. Similar effects have been observed on east-west profiles farther to the south in the United States and it has been found that the western Cordillera region may be generally characterized by small vertical force variations and low seismic P_n velocities, while the eastern Cordillera and plains area is characterized by higher values of these

parameters. These observations suggest that the physical properties of the deep crust or upper mantle under the eastern and western Cordillera are not the same, and that two broad structural regimes may be separated by a narrow transition zone.

0271 OVERTON, A. - 1965
Seismic refraction surveys, western Queen Elizabeth Islands and polar continental margin; *in* Report of Activities, November 1965 to April 1966, Geol. Surv. Can., Paper 66-2, pp. 20-24.

0272 OVERTON, A. - 1970
Seismic refraction surveys, western Queen Elizabeth Islands and polar continental margin; *Can. J. Earth Sci.*, vol. 7, No. 2, pp. 346-365.
The Arctic seismic program of 1964 and 1965 comprised two refraction profiles between Prince Patrick Island and Melville Island, and one refraction profile extending 192 km onto the ocean northwest of Brock Island. Numerous intermediate layer (P_1) and upper mantle (P_n) events were also recorded on paths not confined to the profiles, thus allowing a "time-term" analysis for these events.
High-velocity layers within the sedimentary section cause a velocity inversion problem, whereby the lower velocity and depth of the underlying basement complex is not revealed by the seismic refraction method. The bottom of the basement complex is marked by the intermediate layer having a compressional wave velocity of about 6.25 km/s and depths near 10 km.
Velocity of P_n events is 8.18 km/s and these were recorded near the critical distance at one station, providing an estimate of the time-term to depth conversion factor of 9.56 km/s. P_n events traversing Eglinton Island and the west coast of Melville Island show excess times of 0.6 s to 3 s. This region of apparently low mantle velocity may be related to the geomagnetic variation anomaly reported near by.
The average time-term of 3.67 s represents an average crustal thickness of 35 km. Some variation in crustal time-terms is caused by differing thicknesses of low velocity sediments rather than undulations on the crust-mantle interface. The time-term of 3.07 s for the most distant shot on the ocean profile does not, by itself, suggest a thinner crust than similar values among the islands; this is shown to be a possible interpretation problem.
A negative correlation between crustal time-terms and Bouguer gravity values is noted to be partly due to the effect of varying proportions of low-velocity - low-density rocks and high-velocity - high-density rocks within a few km of depth.

0273 PATERSON, W.S.B., and LAW, L.K. - 1966
Additional heat flow determinations in the area of Mould Bay, Arctic Canada; *Can. J. Earth Sci.*, vol. 3, No. 2, pp. 237-246.
Seven determinations of geothermal heat flow were made in the general area of southern Prince Patrick Island in the Canadian Arctic Archipelago. Measurements were made from sea ice in water depths of between 200 and 600 m. The mean heat flow for the two stations on the continental shelf in the Arctic Ocean was $0.46 \pm 0.08 \mu\text{cal cm}^{-2} \text{ s}^{-1}$. The mean heat

flow for the five stations in the channels to the east of Mould Bay was $1.46 \pm 0.16 \mu\text{cal cm}^{-2} \text{ s}^{-1}$. The instrument and field methods are described. Errors due to the instrument and to the environment are discussed.

0181 PELLETIER, B.R., and SHEARER, J.M. - 1972
Sea bottom scouring in the Beaufort Sea of the Arctic Ocean; *in* 24th Int. Geol. Cong., Sect. 8, pp. 251-261.
Abstract under 0181

0274 PICKLYK, D.D. - 1969
A regional gravity survey of Devon and southern Ellesmere Islands; *Dom. Observ.*, E.M.R., Grav. Map Series No. 87, 10 p.
During the summer of 1967, a Dominion Observatory field party in co-operation with the Polar Continental Shelf Project made a regional gravity survey of Devon Island east of longitude 89°W and southern Ellesmere Island east of longitude 88°W (Figure 1). Baumann Fiord in the west and Makinson Inlet in the east mark the northern limits of the survey of Ellesmere Island. Stations were also established on Coburg Island and Philpotts Island. Some 463 stations were occupied during the survey which was part of the Observatory's continuing program to map the Arctic Islands. The results of the survey are presented as a Bouguer anomaly map (in pocket) at a scale of 1:500,000. Some earlier results obtained by the Observatory in 1961 and 1962 (Sobczak, *et al.*, 1963) are incorporated in the map.

0275 POULIN, A.O. - 1972
On the thermal nature and sensing of snow-covered Arctic terrain; unpub. Ph.D. Thesis, McGill Univ., 235 p.
Aerial imagery in the 8-14 micrometer spectral band was obtained of selected areas of the North American Arctic above the 75th parallel during three periods: early winter, mid-winter and early spring, 1963-1964. Questions arising from analysis of the imagery led to a winter experiment in which study was concentrated on the temperature differences that develop at shorelines, but a number of secondary studies were also conducted. Aerial radiometric data and photographs were correlated with ground data which included subsurface temperatures in the soil, ice and snow on both sides of a shoreline. A classification system for thermal features exhibited by arctic terrain and preliminary criteria for seasonal maps were developed. It was found that: (1) a thermal condition, named the "cold fringe effect", develops late in winter that allows the identification of areas where sea and lake ice is frozen to the bottom, (2) it may be possible to map snow depths from surface temperature on undisturbed ice, and (3) useful infrared data can be obtained under very hazy and moderately windy conditions. Secondary studies included solar heating effects and infrared transmission through haze. Numerous examples of thermal imagery are included, and recommendations for future research are given. Six appendices present basic principles; thermal and radiation properties of snow, ice and soil; data; and description of equipment.

0276 PRAUS, O., DELAURIER, J.M., and LAW, L.K. - 1971

The extension of the Alert geomagnetic anomaly through northern Ellesmere Island, Canada; *Can. J. Earth Sci.*, vol. 8, No. 1, pp. 50-64.
Earlier studies have shown that the anomaly in geomagnetic variations in the vicinity of Alert at the north end of Ellesmere Island is compatible with a narrow band of induced electric currents flowing in a northeast-southwest direction in the earth's crust or upper mantle. The present analysis of magnetic recordings obtained at 11 sites in Ellesmere Island during 1967 indicates that the Alert anomaly extends to the southwest as far as Eureka, a distance of 475 km. The anomaly has its greatest effect at Alert, and its "strength" diminishes by a factor of 2 or 3,225 km to the southwest. Its half-width up to this point is about 50 km. The anomalous zone curves to the west near Greely Fjord 300 km southwest of Alert and appears to broaden near Eureka. The path of the anomaly closely follows the structural trends of the near vertical, tightly-folded strata of the Franklinian geosyncline underlying the whole Lake Hazen Plateau region of northern Ellesmere Island. Evidence for the extension of the anomaly through Ellesmere Island includes the near reversal of Wiese vectors on opposite sides of the zone, the confinement of the horizontal magnetic variation and its polarization transverse to the direction of strike, and the large contrast between apparent resistivities observed inside and outside the zone.

0192 ROOTS, E.F. - 1963
Progress report - Investigations related to the general field of interest of the International Upper Mantle Project; *Polar Cont. Shelf Proj.*, internal report, 2 p.

0193 ROOTS, E.F. - 1963
Report of investigations by the Polar Continental Shelf Project related to upper mantle problems; *Polar Cont. Shelf Proj.*, internal report, 6 p.

0195 ROOTS, E.F. - 1970
Arctic Canada, Greenland, and the northernmost Atlantic Ocean; *in* Polar Research, A Survey, Nat. Acad. Sci., Washington, pp. 17-48.

0277 ROSS, D.B. - 1969
Characteristics of the ground wave attenuation function for highly inductive surfaces; *in* Proc. Conf. on Environmental effects on antenna performance, Boulder, Col., July, pp. 85-88.
The numerical distance p between two dipoles over a plane surface depends on wave frequency, path geometry and surface impedance. The parallel polarized surface fields of the ground wave are proportional to the attenuation function $F(p)$, which exhibits oscillations and rapid phase changes with range over a highly inductive surface, due to the existence of a trapped surface wave. Twenty-four values of p (of an infinite number) which make F equal to zero are given.

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0278 SANDER, G.W., and OVERTON, A. - 1965
Deep seismic refraction investigation in the Canadian Arctic Archipelago; *Geophysics*, vol. 30, No. 1, pp. 87-96.

During 1962 and 1963, the Dominion Observatory conducted refraction seismic surveys in the islands north of the Canadian mainland. These surveys are part of a project of the Government of Canada to explore the Polar Continental Shelf. The operation consisted of three stationary recording units and a shooting party which traversed the frozen sea in a tractor train. Three refraction-seismic profiles form a continuous section from the Canadian Shield through the Franklinian Geosyncline and the Sverdrup Basin to the Arctic Ocean. Post Devonian sediments in the Sverdrup Basin were found to be 10 km thick. The lower, basic portion of the crust is indicated by a velocity of 7.3 km/sec at a depth of 24 km and the base of the crust at 38 km.

0279 SANDER, G.W., OVERTON, A., and BATAILLE, R.D. - 1964

Seismic and magnetic investigation of the Deep Bay crater; *R.A.S.C. Jour.*, vol. 58, No. 1, pp. 16-30. Topographic, geological and geophysical evidence suggest that the structure of Deep Bay in Saskatchewan is the result of the explosion of a meteorite.

The underground structure of the buried crater was studied by a refraction seismic survey and was found to be 2,000 ft. deep and six miles in diameter. The crater appears to be filled with relatively soft sediments, possibly Mesozoic shales. Seismic velocities of 15,000 ft./sec. were measured within the Precambrian rocks under the crater and in its vicinity, against a velocity of 20,000 ft./sec. at greater distances from the structure.

The low velocity of propagation of seismic waves within these rocks must be due to fractures resulting from the explosion of the meteorite. The zone in which the Precambrian rocks are fractured was found to extend for three miles beyond the crater and to great depth under the structure.

A ground magnetometer survey permitted an independent estimate of the depth of the Precambrian rocks under the central portion of Deep Bay and correlates well with the seismic results. Both geophysical methods reveal a structure which conforms closely to the shape of a meteorite crater.

0280 SHEARER, J.M. - 1971

Preliminary interpretation of shallow seismic reflection profiles from the west side of Mackenzie Bay, Beaufort Sea; in Report of Activities, Part B: November 1970 to March 1971, Geol. Surv. Can., Paper 71-1, Part B, pp. 131-138.

0211 SHEARER, J.M., MACNAB, R.F., PELLETIER, B.R., and SMITH, T.B. - 1971

Submarine pingos in the Beaufort Sea; *Science*, vol. 174, pp. 816-818.
Abstract under 0211

0281 SOBCZAK, L.W. - 1963

Regional gravity survey of the Sverdrup Islands and vicinity with map; *Grav. Map Series Dom. Observ.*, No. 11, 19 p.

The results of gravity surveys carried out in 1959 and 1960 are presented in the form of an anomaly map from which five profiles are drawn to analyze the major features of the Bouguer anomaly field. The observations are correlated with magnetic and geological information and the interpretation of the gravity data is based on measured densities and densities computed from seismic velocities. On the basis of a density contrast of 0.14 gm/cc and an anomaly change of 63 mgals over a distance of 120 miles, the calculations indicate depths to basement varying from 6,800 feet near Isachsen to possibly 42,000 feet near the axis of the Sverdrup Basin. A broad positive Bouguer anomaly over Peary Channel is partly attributed to a corresponding broad lens of basic rocks extending from an outcrop on the Fay Islands. A sharp negative anomaly over Peary Channel north of the Dumbbell gypsum dome suggests a similar but larger submerged dome.

0282 SOBCZAK, L.W. - 1965

Completed gravity program, P.C.S.P., 1965; *Polar Cont. Shelf Proj.*, internal report, 16 p.

The purpose of the gravity survey this year was to establish and extend a homogeneous network of gravity stations over the sea ice of the Arctic Ocean and Ballantyne Strait and over the land area of Somerset Island and Prince of Wales Island as proposed by Sobczak (1964). A total of 1250 gravity stations were occupied in these areas. Nearly 500 gravity observations were taken over the sea ice including a traverse 230 miles in length with station intervals of 20 miles at a bearing of 335 degrees from Cape Andreasen. Over Somerset Island and Prince of Wales Island 750 gravity observations were completed at intervals of 6 to 8 miles. The participating members, dates, instruments and number of stations in the various areas of the survey are summarized in Table I and the areas completed from 1960 to 1965 on the P.C.S.P. are outlined in Figure 1. A control station network consisting of 10 primary stations was established over Somerset Island and Prince of Wales Island as indicated by Figure 2. This is an extension of the earlier control network completed in 1963.

Two new procedures, a turbine engine helicopter, the Bell 204B, and a depth recorder, the Dual channel Oscillo-riter, were employed to extend the gravity survey efficiently and to record the deeper water depths quickly over the sea ice of the Arctic Ocean.

0283 SOBCZAK, L.W., STEPHENS, L.E., WINTER, P.J., and HEARTY, D.B. - 1973

Gravity measurements over the Beaufort Sea, Banks Island and Mackenzie Delta with Map No. 151 - Mackenzie Delta - Banks Island; *Grav. Map Series Earth Phys. Br.*, E.M.R. Canada, 16 p.

The Earth Physics Branch has made about 7,700 gravity measurements over the Beaufort Sea, Banks Island and Mackenzie Delta between 1969 and 1972. Measurements were made both on land and on the sea ice of the Beaufort Sea. The major feature of the free air gravity anomaly map is an arcuate high of about 100 mgal which is one of many elliptical anomalies along the continental margin. These anomalies are explained by a thinning of the crust at the continental break.

The Bouguer anomaly field over Banks Island is highly variable with anomalies varying from +30 to -40 mgal along northerly trends. These anomalies may be related to Precambrian basement structure of the Prince Patrick Uplift. Bouguer anomalies east of the Mackenzie Delta reveal a spectacular circular positive anomaly of 115 mgal located south of Darnley Bay. The source of this anomaly has been attributed to a buried intrusion. Generally, however, extensive gravity lows in the Kugmallit Bay and Mackenzie Bay areas are underlain by thick clastic sedimentary sequences.

The land and ocean regions of the map area are near isostatic equilibrium as shown by the mean free air anomaly of 5.5 mgal. This suggests that major extensive sedimentary basins may be compensated while local basins 50 km wide or less maintain a distinct gravity expression.

0284 SOBCZAK, L.W., and TAYLOR, G.J. - 1970
Results of a differential Omega test in the Mackenzie River delta; *Geophysics*, vol. 35, No. 3, pp. 514-520.

0285 SOBCZAK, L.W., and WEBER, J.R. - 1970
Gravity measurements over the Queen Elizabeth Islands and polar continental margins; *Grav. Map Ser. Earth Phys. Br.*, Nos. 115-116, 14 p.
The Dominion Observatory has made about 8,800 gravity measurements over the Queen Elizabeth Islands and Arctic Ocean between 1960-1968. Measurements were made both on land and on the sea-ice of the ocean and inter-island areas.

The Bouguer anomaly field shows that negative anomalies occur over sedimentary basins and mountainous areas, positive anomalies occur along moderately folded regions and large positive anomalies occur over the ocean. With the exception of the anomalies over the ocean and mountainous regions, the anomalies correlate well with (1) changes in lithologies of Paleozoic and Precambrian rocks, (2) evaporite and basic rocks, and (3) changes in thicknesses of clastic and carbonate sediments.

The Archipelago region west of 90°W longitude has a mean elevation of 15 m and an average Bouguer anomaly of 6 mgal and appears to be in isostatic equilibrium. This suggests that the large thickness (10 km) of clastic sediments is compensated.

0286 SOBCZAK, L.W., and WEBER, J.R. - 1973
Deep structure and geophysical characteristics, Gravity field, Isostatic conditions, Total magnetic field, Deep structure; in *Tectonic Styles in Canada*, ed. H. Trettin, Geol. Assoc. Can., pp. 149-157.

0287 SOBCZAK, L.W., WEBER, J.R., GOODACRE, A.K., and BISSON, J-L. - 1963
Preliminary results of gravity surveys in the Queen Elizabeth Islands with maps, No. 12-Sverdrup Islands, No. 13-Prince Patrick Island, No. 14-Melville Island, No. 15-Devon Island; *Grav. Map Series Dom. Obs.*, 2 p. with maps.

During the field seasons of 1960, 1961, and 1962 officers of the Dominion Observatory, joined with those of the Polar Continental Shelf Project, in extensive gravity surveys in the Queen Elizabeth Islands. The current interest of the petroleum

exploration industry in these regions make it desirable that the geophysical information obtained on these surveys be released to the public as soon as possible. Therefore, the gravity data for some 3250 stations have been compiled in the form of Bouguer anomalies and four preliminary contour maps, Nos. 12, 13, 14, and 15, prepared for immediate release. The gravity stations on land and water were established at approximately 10-km intervals; their positions are indicated on the maps by single and double circles. The former represent detail stations, and the latter control stations. The locations and numbers of the control stations are illustrated separately in Figure 1. Principle Facts of all stations and description of control stations are available upon request from the Dominion Observatory.

0288 SOBCZAK, L.W., WEBER, J.R., and ROOTS, E.F. - 1970

Rock densities in the Queen Elizabeth Islands, Northwest Territories; *Geol. Assoc. Can. Proc.*, vol. 21, pp. 5-14.

Results of 1900 density measurements of crystalline, carbonate, and clastic rocks from the Queen Elizabeth Islands are presented graphically and in tables. The data were compiled directly from sampling of surface rocks and rock material from drill-holes, and indirectly by relating densities to seismic velocities and from detailed gravity profiles across topographic features.

The weighted mean densities of the Precambrian crystalline rocks, and of the Paleozoic carbonate rocks of the Franklinian miogeosyncline and Arctic Lowlands are each 2.76 g/cm³. The Paleozoic evaporite rocks, sampled mainly in the Bathurst Island area but common throughout the Franklinian miogeosyncline, have a weighted mean density of 2.56 g/cm³. The Franklinian clastic rocks exhibit a range of density, in part apparently related to age and/or depth of burial; the Silurian clastics have a weighted mean density of 2.62 g/cm³ and the Devonian clastic rocks 2.51 g/cm³. In contrast, the Mesozoic clastic rocks of the Sverdrup basin have a weighted mean density of 2.32 g/cm³.

0289 SPECTOR, A. - 1966

A gravity survey of the Melville Island ice caps; *J. Glaciology*, vol. 6, No. 45, pp. 393-400.
A gravity survey was made in June of 1963 of four ice caps on western Melville Island, Canadian Arctic Archipelago. Ice thicknesses were interpreted from Bouguer anomalies at 138 stations. The regional gravity field of the area has a simple form and is associated with a uniform bedrock geology. Because of this, the interpretation of the gravity data was greatly simplified in comparison with the more usual glaciological problem. It was found that greatest ice thicknesses ranged from 30 to 50 m., filling hidden valleys or depressions under the main ice-cap body. Ice-cap volumes ranged from 0.2 to 1.0 km³.

0290 SPECTOR, A., and HORNAL, R.W. - 1970

Gravity studies over three evaporite piercement domes in the Canadian Arctic; *Geophysics*, vol. 35, No. 1, pp. 57-65.

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Reconnaissance gravity surveys over three evaporite piercement domes in the Canadian Arctic Islands have been interpreted. Each dome was considered as a right-vertical cylinder divided into two homogeneous regions, a high density anhydrite zone (2.9 gm/cm^3) overlying a low density gypsum and/or rock salt zone (2.3 gm/cm^3). The cylinder is surrounded by a sedimentary sequence which has a uniform density of 2.4 gm/cm^3 . Interpretation involved a least-sum-of-squares approach to estimate the thickness of the anhydrite and gypsum-rock salt zones. The three sets of estimates gave a range of 200 to 550 m for the anhydrite thickness and a range of 700 to 5500 m for the vertical extent of domes. In each case the depths were less than expected on the basis of estimates from seismic and geological data. Possible explanations for this are: (a) the cross-sectional area of each dome decreases with depth; (b) the existence of a transition zone where a gradation occurs between the high and low density zones; and (c) the effective density contrast of the low density zone is less than 0.1 gm/cm^3 .

0291 STEPHENS, L.E., SOB CZAK, L.W., and WAINWRIGHT, E.S. - 1972

Gravity measurements on Banks Island, N.W.T. with map No. 150 - Banks Island; *Grav. Map Series Earth Phys. Br.*, 4 p.

The regional gravity survey of Banks Island was completed in 1971 in response to requests from the oil industry. The survey of Banks Island is an important link between previous gravity surveys to the north and south, the results of which have already been published in the Gravity Map Series of the Earth Physics Branch by Sobczak and Weber (1970) and Hornal, Sobczak, Burke and Stephens (1970) respectively. On Banks Island, stations were located at intervals varying from 6 to 8 miles as in previous surveys designed to complete the national gravity mapping program. A gravity control network was established on the island to provide an accurate gravity datum for the survey and for more detailed surveys carried out by the oil industry.

0292 TANNER, J.G. - 1967

Gravity measurements in Canada, January 1, 1963 to December 31, 1966; *Publ. Dom. Observ.*, vol. 36, No. 2, pp. 143-159.

0293 TANNER, J.G., and GIBB, R.A. - 1971

Gravity measurements in Canada, January 1, 1967 to December 31, 1970; *Publ. Earth Phys. Br.*, E.M.R., vol. 42, No. 2, pp. 25-46.

0294 WEBER, J.R. - 1963

Discussion of Dr. Ostenso's paper; in Proc. Arctic Basin Symposium, October, 1962, Hershey, Pa., Arctic Inst. N. Amer. and Off. Naval Res. U.S. Navy, pp. 41-45.

0295 WEBER, J.R. - 1963

Gravity anomalies over the Polar Continental Shelf; *Contrib. Dom. Observ.*, vol. 5, No. 17, pp. 3-10. As part of the Polar Continental Shelf Project a gravity survey was carried out over the continental shelf north of the Sverdrup Islands. Using decca

navigation 350 stations were observed, the outermost stations being located over the continental slope some 250 km from shore. A free air anomaly map and a bathymetric chart are presented. A very large positive anomaly feature of 120 mgals. running parallel to the continental slope was discovered. The anomaly is discussed and interpreted as the effect of the transition of the crust from continental to oceanic domain.

0296 WEBER, J.R. - 1970

The measurement of ocean-tilt by hydrostatic levelling in the Gulf of St. Lawrence, preliminary results; *Polar Cont. Shelf Proj.*, internal report, 10 p.

During the month of March the author and his assistant, Mr. Lynn Colby from the Polar Continental Shelf Project were invited to participate in the project "Ice Drift Studies in the Gulf of St. Lawrence - 1970". This project was jointly sponsored by the Marine Sciences Center of McGill University, the Bedford Institute, and the Geophysics Section of the Defence Research Establishment Ottawa. The purpose of the project was to try and determine the wind stress, the water stress, the internal ice stress, the pressure gradient force and the Coriolis force on an ice floe, that is those five quantities which make up the equation of motion, and to compare the calculated drift path with the actual drift path of the ice floe as determined from Decca. The fourth quantity in the equation of motion, the pressure gradient force, is the result of the tilt of the ocean surface which in turn may be caused by the Coriolis force, by atmospheric pressure gradients, or by changes in salinity and temperature in the ocean water. The ocean tilt is believed to be of the order of up to about 5×10^{-5} radians. We developed a hydrostatic levelling system which for the first time allows to measure ocean tilt directly. Our contribution towards the project was to determine the tilt of the ocean surface along the drift path.

0297 WEBER, J.R., and LILLESTRAND, R.L. - 1971

Measurement of tilt of a frozen sea; *Nature*, vol. 229, No. 5286, pp. 550-551.

0298 WHITHAM, K. - 1963

An anomaly in geomagnetic variations at Mould Bay in the Arctic Archipelago of Canada; *Geophys. J. Roy. Astro. Soc.*, vol. 8, pp. 26-43. Standard-run magnetograms obtained from Mould Bay, Prince Patrick Island, demonstrate a striking absence of vertical magnetic field variations corresponding to an anomalous steepening of the vertical field power spectrum. Assuming the presence of a sheet conductor at depth, it is estimated from the frequency dependence of the spectrum that a 20 km thick layer with a conductivity about 10^{-11} e.m.u. is required near the bottom of the crust. There appears to be no evidence for such a highly conducting crust. Anomalous temperatures difficult to reconcile with a stable region are required to explain the anomaly by semiconduction processes. The extent of the Mould Bay anomaly is as yet unexplored.

Russian results (Zhigalov 1960), and a search of Arctic magnetograms available here, show that severe attenuation of the vertical field fluctuations occurs over the deep ocean basins. It is concluded that the magnitude of the attenuation found on drifting stations can be explained by the presence of the conducting ocean, with reasonable estimates of the wavelength of the inducing field. However, it appears unlikely that the Mould Bay results can be so explained.

0299 WHITHAM, K. - 1964

Anomalies in geomagnetic variation in the Arctic Archipelago of Canada; *J. Geomag. and Geoelect.*, vol. 15, pp. 227-240.

Two unusual features of geomagnetic variations have now been discovered in the Arctic Archipelago of Canada. The first anomaly at Alert on Ellesmere Island is characterized by abnormally high levels of irregular magnetic activity and a persistent directional characteristic of the vector horizontal disturbance. An adequate ionospheric explanation has not been found. Recent papers have given an explanation of the gross characteristics of the Alert magnetograms in terms of induction in a large anomalous conductor in the upper mantle striking parallel to the channel separating north Ellesmere Island from Greenland. Field experiments followed by simple potential and spectral response analyses confirm the existence of a gross conductor. In this paper the uncertainties in and shortcomings of the first-order explanation and minor modifications are stressed, and an alternative solution involving induction in the conducting mantle and a highly conducting circuit examined. The alternative solution appears to be even more inadequate.

The second anomaly at Mould Bay, Prince Patrick Island, is characterized by the striking absence of shorter-period vertical field magnetic variations. Assuming the presence of a sheet conductor at depth it has been estimated earlier from the frequency dependence of the power spectrum that a 10-20 km thick layer with a conductivity near 10^{-11} emu is required near the bottom of the crust or in the upper mantle. The assumptions in deriving this explanation are outlined, and theoretical curves shown which demonstrate that the neglect of reasonable conductivity above and below the anomalous layer appears justified. Results are shown applying the same technique to plane earth induction in a non-anomalous area, and to one magneto-telluric situation of current interest.

0300 WHITHAM, K. - 1965

Geomagnetic variation anomalies in Canada; *J. Geomag. and Geoelect.*, vol. 17, No. 3-4, pp. 481-498.

Anomalies in geomagnetic variations in the Arctic Archipelago are first discussed. The gross characteristics of the Alert (Ellesmere Island) anomaly can be explained by a number of models involving a 100 km upheaval of the 1400-1500°C isotherm to within 25-30 km of the surface. The solution is not unique and may be in error by as much as 60%. However the response parameters most useful have been clearly defined. Magnetotelluric investigations lead to unusually high conductivities and a large

anisotropy as expected. However a detailed synthesis of the magnetic variation results with the magnetotelluric analysis has not proved possible. At the present time, no self consistent explanation is known, but recent aeromagnetic and other data do not support any compositional explanation.

The suppression of the vertical field fluctuations at Mould Bay, Prince Patrick Island has been investigated further and the finite areal extent of the anomaly to the east has been demonstrated. Negative heat flow experiments and seismic investigations are described and their consequences outlined. A summary of the experimental variation and magnetotelluric data, now being examined, is given. The latter again qualitatively confirms the existence of a gross conductor, but at the present time it is not known if this is thermal or compositional in origin. Experiments by the University of Toronto and the Dominion Observatory in southeastern Canada are described, which show that, within a confidence level of 20%, there are no gross anomalies in the region of Southern Ontario from London to Ottawa, or across the Logan fault in Western Quebec. However, work by the University of British Columbia indicates appreciable conductivity anomalies of a varied nature from Crescent Valley, in southern British Columbia to Lethbridge, in southwestern Alberta. Current investigations of a coast effect off Vancouver Island are also outlined.

It appears clear that considerable theoretical advances are necessary to clarify which, if any, of the unusual features found are related to abnormal temperatures in the upper mantle. Where an integrated geophysical approach has been attempted in Canada, no self consistent explanation has yet been found.

0301 WHITHAM, K., and ANDERSEN, E. - 1962

The anomaly in geomagnetic variations at Alert in the Arctic Archipelago of Canada; *Quart. J. Roy. Astro. Soc.*, vol. 7, pp. 220-243.

The anomaly, first noted during the I.G.Y., in the level of irregular magnetic activity at Alert on Ellesmere Island, Canada, has been investigated further. Analysis of the characteristics of three-component records and extensive field work in the Arctic Archipelago have shown no evidence that Alert is part of an inner zone of enhanced magnetic activity. A superposed epoch analysis of irregular magnetic activity has indicated it is unlikely that the Alert result is related to the mechanism producing polar cap absorption. An anomalous induced contribution to the observed magnetic fluctuations must therefore be considered. Despite the complexity of magnetic disturbance inside the polar cap, and the paucity of available data, it is shown that the magnitude, directional characteristics and approximate frequency dependence of the variations are consistent with the hypothesis of a large anomalous body striking parallel to the channel separating north Ellesmere Island from Greenland. Appreciable thinning of the crust, and a large heat flow anomaly would be expected. No other geophysical data are available in this logistically difficult region to support or refute this hypothesis. Until sufficient data are available for a satisfactory potential analysis the

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model must be regarded as quite speculative in view of the tectonic stability of the region.

0302 WHITHAM, K., and ANDERSEN, F. - 1966
Magneto-telluric experiments in northern Ellesmere Island; *Geophys. J. Roy. Astro. Soc.*, vol. 10, No. 4, pp. 317-345.

During the 1963 field season, a magneto-telluric experiment was successfully undertaken at and near Alert, in northern Ellesmere Island. Analysis of the results shows that the electric field is very strongly confined to a direction nearly N-S, that a strongly inhomogeneous or anisotropic situation exists with the electric field in phase ($\pm 5^\circ$) with the horizontal magnetic field for periods between 240 and 6000 s, and that the electric to magnetic field ratio is constant and very small ($0.12(6) \text{ mV km}^{-1} \gamma^{-1}$) in the same period range. At Lake Hazen, 150 km to the SW approximately, the experimental data is of poorer quality, but the inhomogeneity or anisotropy is weaker, the mean direction of the electric field between 20 and 30°E of N, the phase advance of the electric over the magnetic field nearly 45° and the electric to magnetic field ratio is frequency dependent. The magnetic variations measured at Lake Hazen suggest an extension along strike of the Alert anomaly.

The Alert results are not consistent in inhomogeneity, phase and frequency dependence with earlier models used to explain the magnetic variation anomaly observed in northern Ellesmere Island. Equally an interpretation of the magneto-telluric results in terms of a near surface plane conductor with a very large height-integrated conductivity $=6(3) \times 10^{-6} \text{ emu}$ is not consistent with the earlier magnetic variation results, fails to explain the inhomogeneity or anisotropy, and makes no geological or common sense. The inductive situation is very complex and it appears that boundary arguments must be very important and need theoretical elucidation. At the present time no self-consistent hypothesis can be derived: some of the problems in deducing one are demonstrated in the text using illustrative calculations.

0303 WYDER, J., HUNTER, J., and RAMPTON, V. - 1973
Geophysical investigations of surficial deposits at Tuktoyaktuk, N.W.T.; *Geol. Surv. Can.*, open file no. 128, 10 p.

In April of 1971, the Geological Survey of Canada started a program to investigate the potential usefulness of surface resistivity, selected borehole geophysical tools, and seismic refraction and reflection in the Mackenzie Valley transportation corridor. The results of the borehole geophysics and seismic refraction surveys undertaken at Tuktoyaktuk, NWT are presented here. A drilling and coring program was undertaken at sites where geophysical investigations were conducted.

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0304 ANDREWS, J.T., and BARNETT, D.M. - 1972
Analysis of strandline tilt directions in relation to ice centers and postglacial crustal deformation, Laurentide ice sheet; *Geografiska Annaler*, vol. 54, Ser. A, pp. 1-11.

Tilt directions on former water planes (marine and glacial lake) for 36 sites within the area of the former Laurentide Ice Sheet are projected toward the geometrical center of the ice sheet. Six zones are indicated on the basis of tilt intersections; of these, at least five have been considered as glacial dispersal centers at one time or another. The six zones are: Central Hudson Bay, southeastern Hudson Bay/James Bay, central Labrador-Ungava, northwest Hudson Bay, east of Great Slave Lake, and between the St. Lawrence and James Bay. All have geographical proximity to lows on the Free Air gravity anomaly map, but only two are indicated on current maps of postglacial uplift and rates of recovery. Late-glacial movement of ice centers might cause the migration of the loci of postglacial uplift; there is some evidence for such events but more information is required. The areas of tilt intersections form a broad U around Hudson Bay with one in the center. The U follows the present height of land and could reflect the Laurentide ice divide at its maximum stage. In this interpretation the maximum and late-glacial ice divides are not geographically displaced.

0305 ANDRIEUX, PIERRE - 1965

Les méthodes électriques de prospection appliquées à l'étude de la glace et des glaciers, résultats obtenus de 1962 à 1965; unpub. Dip. d'Eng. Géophysicien, Univ. de Strasbourg, 83 p.
Le 10 Juin 1956, un groupe de chercheurs du Laboratoire de Géophysique Appliquée de la Faculté des Sciences de Paris, s'installait au refuge de Konkordia Platz, sur le glacier d'Aletsch, en Suisse. Pour la première fois sur un glacier alpin, des mesures électriques et des enregistrements telluriques étaient réalisés. Cette expérience devait être dans l'esprit de ses promoteurs, et de L. Cagniard en particulier, le point de départ d'une nouvelle méthode d'investigation de la glace, des glaciers et des régions polaires. Depuis, en Antarctique, au Canada, au Groenland, en U.R.S.S., en Suisse, des Dizaines de sondages électriques ont été tentés sur la glace. La plupart de ces nouveaux prospecteurs électriques ont réussi à déterminer des épaisseurs; parfois ils ont échoué. Finalement, tous ou presque, en sont arrivés à s'intéresser à la résistivité de la glace et de la neige, plutôt qu'aux résultats de l'application du procédé géophysique lui-même.

En 1962, sur l'initiative de A. Bauer et sous la responsabilité du Laboratoire de Géophysique Appliquée de la Faculté des Sciences de Paris, j'ai repris les mesures de 1957. Ce rapport présente les résultats de sondages électriques en des régions de latitudes très différentes, de profils de potentiel, d'un carottage électrique dans un puits de 120 m de profondeur, d'enregistrements telluriques sur une ligne de 3 Km et d'enregistrements journaliers de la résistivité; parallèlement, des résultats obtenus en laboratoire sur des échantillons de glace artificielle et publiés par ailleurs sont ici rassemblés; une corrélation entre ces deux séries de travaux est amorcée. De nouvelles expériences sont proposées; elles concernent les Physiciens du Solide, les Glaciologues et les Géophysiciens.

0306 ANDRIEUX, PIERRE - 1970

Les methodes electriques de prospection appliquees a l'etude de la glace et des glaciers, resultats obtenus de 1962 à 1965; *Comite National Francais des Recherches Antarctiques*, No. 24, 62 p. Abstract under 0305

0307 ARNOLD, K.C. - 1959

Chronological summary of work done on Meighen Island by the Polar Continental Shelf Project - 1959; *Polar Cont. Shelf Proj.*, internal report, 25 p.

0308 ARNOLD, K.C. - 1964

Hvem oppdaget Meighen - oya ?; Soertrykk av Polarboken, pp. 126-128.

0309 ARNOLD, K.C. - 1964

Report on glaciological mapping, with special reference to the mapping of the Meighen Island ice cap; *Polar Cont. Shelf Proj.*, internal report, 32 p.

0310 ARNOLD, K.C. - 1965

Aspects of the glaciology of Meighen Island, Northwest Territories, Canada; *Jour. Glaciology*, vol. 5, No. 40, pp. 399-410. Meighen Island lies in the centre of the north coast of the Queen Elizabeth Islands and fronts on the Arctic Ocean. An ice cap of about 76 km.² covers about one-tenth of the island. Its greatest thickness of 150 m. occurs under the summit, near the south end, which was 268 m. above sea-level in 1960. The northern half of the ice cap is less than 30 m. thick; and the total volume is of the order of 2,000 X 10⁶m.³. Precipitation is low in the northern Queen Elizabeth Islands, and Meighen Island lies in an area where summer temperatures are lowest. In the winters of 1959-60, 1960-61 and 1961-62, the snow accumulation was 12.6, 18.2 and 14.1 cm. of water equivalent. Some snowfall remained on the higher part of the ice cap in the cold summer of 1961; but the ice cap diminished in volume in each year; by 36 X 10⁶, 72 X 10⁶, 22 X 10⁶ and 91 X 10⁶m.³ in the 1959, 1960, 1961 and 1962 ablation seasons. If the conditions of these four seasons were maintained the ice cap would disappear in about 100 yr. However, a radio-carbon dating of a saxifrage exposed by the retreat of the ice from a small nunatak near the northern edge gave a date of less than 100 yr., and it appears that the existence of the ice cap might be sensitively related to recent climatic change.

Careful surveys were made in 1959, 1960 and 1961 in an attempt to detect movement in the ice cap. Unequivocal evidence is not available from these surveys; but the stake network has been maintained and another survey has recently been completed.

0311 ARNOLD, K.C. - 1966

The glaciological maps of Meighen Island, N.W.T.; *Can. J. Earth Sci.*, vol. 3, No. 6, pp. 903-908. The small ice cap on Meighen Island has been studied since 1959 by scientists working with the Polar Continental Shelf Project, Department of Mines and Technical Surveys, Ottawa. The Surveys and Mapping Branch of the same Department has produced a glaciological map of the ice cap, at the scale of 1:25,000,

from special photography taken from a height of 2,280 m in 1960, and a 1:50,000 map of the whole island, showing features of glaciological interest, from standard mapping photography taken from a height of 9,150 m in 1959. The control, photography, and compilation methods used in producing these maps are discussed, and an account is given of the special features shown on them.

0312 ARNOLD, K.C., and MACKAY, D.K. - 1964

Different methods of calculating mean daily temperatures, their effects on degree-day totals in the high arctic and their significance to glaciology; *Geographical Bull.*, Canada, No. 21, pp. 123-129. When the range of temperatures is close to the freezing point, different methods of determining mean daily temperatures can cause disparities in melting and freezing degree-day totals. On the basis of data collected under such conditions, the disparities are examined and their relevancy to glaciological studies is considered.

0004 BARR, W., BARRETT, P.E., HUSSELL, D.J.T., KING, R.H., and KOERNER, R.M. - 1968

Devon Island programs, 1967; *Arctic*, vol. 21, No. 1, pp. 44-50.

0005 BARRETT, P.E., HUSSELL, D.J.T., and WHILLANS, I.M. - 1969

Devon Island Programs, 1968; *Arctic*, vol. 22, No. 2, pp. 158-160.

0313 DORT, W., ROOTS, E.F., and DERBYSHIRE, E. - 1969

Firn-ice relationships, Sandy Glacier, Southern Victoria Land Antarctica; *Geografiska Annaler*, vol. 51, Ser. A, pp. 104-111. Sandy Glacier, occupying the head of a 3 km by 1 km cirque valley, is composed of a unique alternation of ice layers and sand layers. The sand was apparently brought by occasional very strong winds from Onyx River outwash 5 km away and 1,200 m lower. Pits dug in the accumulation zone revealed 115-210 cm of firn and sand layers directly overlying glacier ice that also contains sand layers. It is believed that not long ago there was no cover of firn on any part of this glacier. Accumulation appears to have recommenced perhaps 2-3 decades before the present.

0314 ENGLAND, J.H., and ANDREWS, J.T. - 1973

Broughton Island - a reference area for Wisconsin and Holocene chronology and sea level changes on eastern Baffin Island; *Boreas*, vol. 2, No. 1, pp. 17-32. Broughton Island is 50 km from the eastern margin of the 6,000 km² Penny Ice Cap. During the early Wisconsin (>54,000 BP) Broughton Island was only partly glaciated; sea level at that time was ca. +72 m. A younger glacial readvance is delimited by lateral moraines and glacio-marine deposits ¹⁴C dated at 24,100±850 BP; sea level was +18 m. During the last Wisconsin the glaciers terminated some distance inland from Broughton Island and sea level at 9,850±250 BP was +5 m on Broughton Island. The head of Maktak Fiord, which presently contains a major outlet glacier from the Penny Ice Cap, was deglaciated about 6,000 BP.

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- 0315 HATTERSLEY-SMITH, G. - 1960
Glaciological studies by Geographical Branch, Department of Mines and Technical Surveys on the Polar Continental Shelf Project; *in* Can. Geophys. Bull., No. 13, pp. 88-89.
- 0038 HATTERSLEY-SMITH, G. - 1961
North-western Queen Elizabeth Islands (Polar Continental Shelf Project and Geographical Branch, Department of Mines and Technical Surveys); *in* Can. Geophys. Bull., No. 14, pp. 96-98.
- 0316 HATTERSLEY-SMITH, G. - 1962
Western Queen Elizabeth Islands (Polar Continental Shelf Project and Geographical Branch, Department of Mines and Technical Surveys); *in* Can. Geophys. Bull., No. 15, pp. 100-101.
- 0317 HATTERSLEY-SMITH, G. - 1963
Western Queen Elizabeth Islands (Polar Continental Shelf Project, Department of Mines and Technical Surveys); *in* Can. Geophys. Bull., No. 16, p. 120.
- 0318 HATTERSLEY-SMITH, G. - 1964
Western Queen Elizabeth Islands (Polar Continental Shelf Project, Department of Mines and Technical Surveys); *in* Can. Geophys. Bull., No. 17, pp. 130-131.
- 0319 HATTERSLEY-SMITH, G. - 1965
Devon Island (Arctic Institute of North America); *in* Can. Geophys. Bull., No. 18, pp. 138-139.
- 0320 HATTERSLEY-SMITH, G. - 1965
Melville Island (Polar Continental Shelf Project: W.S.B. Paterson and F.P. Hunt); *in* Can. Geophys. Bull., No. 18, p. 139.
- 0321 HATTERSLEY-SMITH, G. - 1965
Meighen Island (Polar Continental Shelf Project: W.S.B. Paterson); *in* Can. Geophys. Bull., No. 18, p. 139.
- 0322 HATTERSLEY-SMITH, G. - 1965
Ice Islands (Polar Continental Shelf Project and Geographical Branch, Department of Mines and Technical Surveys: D. Lindsay); *in* Can. Geophys. Bull., No. 18, pp. 142-143.
- 0323 HENOCK, W.E.S. - 1964
Postglacial marine submergence and emergence of Melville Island, N.W.T.; *Geog. Bull.*, No. 22, pp. 105-126.
This paper presents some of the results of a detailed investigation of emerged features on Melville Island that was carried out during the summer of 1962. Extensive coverage of the area was made possible by aircraft support.
The writer sums up previous observations on the evidence of glaciation and, on these and his own observations, postulates a multiple glaciation. He describes postglacial emerged features and the difficulties encountered in correlating them. He discusses the significance of seven radiocarbon dates of samples collected on the island and uses them to construct a preliminary uplift curve. This curve indicates that over the last 2,000 years uplift has been negligible and that Melville Island is near isostatic equilibrium. This comparatively early regression of postglacial sea from its coast is also corroborated by recent permafrost research at Winter Harbour.
- 0324 IKEN, A. - 1972
Measurements of water pressure in moulins as part of a movement study of the White Glacier, Axel Heiberg Island, Northwest Territories, Canada; *J. Glaciology*, vol. 11, No. 61, pp. 53-58.
In 1970 water pressure was measured in several moulins on the White Glacier. Pressure variations in some moulin channels extended over the full measuring range of the instruments (0-1 and 0-2 bar above atmospheric pressure), even at depths of less than 50 m below the surface. Measurements at different depths showed that total pressure variations were sometimes greater than this. The pressure data are compared with variations in the surface velocity of the glacier.
- 0325 IVES, J. - 1963
Canada, glaciological research in 1962: (b) Meighen Island, (c) Sea ice studies; *Ice*, No. 11, p. 8.
- 0326 KAHN, M. - 1966
Compte rendu préliminaire des observations effectuées par la méthode des tests chimiques dans l'Arctique Canadien; *Polar Cont. Shelf Proj.*, internal report, 32 p.
"Compte rendu préliminaire des observations effectuées par la méthode des tests chimiques dans l'arctique canadien à la surface et dans les glaciers de l'île Baffin, l'île Meighen, l'île Axel Heiberg avec les résultats numériques".
- 0327 KOERNER, R.M. - 1966
Accumulation on the Devon Island ice cap, Northwest Territories, Canada; *J. Glaciology*, vol. 6, No. 45, pp. 383-392.
The pattern of accumulation on the Devon Island ice cap is described. There is an area of minimum accumulation encircling the highest part of the ice cap and 100-200 m. below it. Below this zone, accumulation gradually increases to a maximum near the ice-cap edge. The overall pattern is related to snow transport by katabatic winds. There is a regional accumulation pattern of high accumulation (ca. 40.0 cm. water equivalent) in the south-east part of the ice cap and an area of low accumulation (ca. 11.0 cm. water equivalent) in the north-west. This east-south-east to west-north-west accumulation gradient is related to cyclonic activity to the east in Baffin Bay, and it is probably intensified by the presence of open water in the same area.
- 0328 KOERNER, R.M. - 1966
Devon Island; *Ice*, No. 20, p. 6.
- 0329 KOERNER, R.M. - 1967
Devon Island; *Ice*, No. 23, p. 6.

0330 KOERNER, R.M. - 1968

Fabric analysis of a core from the Meighen ice cap, Northwest Territories, Canada; *J. Glaciology*, vol. 7, No. 51, pp. 421-430.

Ice samples from a 121 m core, representing the total thickness of the Meighen Ice Cap near its highest point, were studied for ice fabric, firn- and dirt-layer distribution. The absence of a strongly preferred fabric between the surface and the base of the ice cap at the core site suggests an absence of past or present ice movement at this point. From the variations of ice texture, firn- and dirt-layer distribution with depth it is concluded that the ice cap post-dates the climatic optimum and has never been much thicker than it is at present. There is a possible relic ablation surface at a depth of 50 m which is estimated to be at least 500-600 years old.

0331 KOERNER, R.M. - 1970

The mass balance of the Devon Island ice cap, Northwest Territories, Canada, 1961-66; *J. Glaciology*, vol. 9, No. 57, pp. 325-336.

Methods used in measuring the mass balance of the Devon Island ice cap are described. The use of dyes and melt trays is recommended in the superimposed-ice and firn zones of sub-polar glaciers. The north-west part of the ice cap was studied in most detail and has had a slightly negative net balance for the period 1961-66. An inverse relationship between mean net balance (\bar{B}_n) and elevation of the equilibrium line in the north-west part of the ice cap indicates that the mean net balance there would be zero with an equilibrium line at 920 m (± 80 m) elevation. Accumulation on the ice cap is greatest in the south-east but the measurements suggest that the mean net balance there is similar to the mean net balance on the rest of the ice cap. It is concluded that the present accumulation pattern must have existed for several hundreds, and possibly thousands of years. A study of firn stratigraphy and of variations in the elevation of the firn and equilibrium lines indicates that between 1961 and 1966 only 1962 had a more negative mean net balance than the average value for the period 1934-60. During the same 26 year period the net balance at 1787 m elevation has varied, but summer conditions do not appear to have changed significantly.

0332 KOERNER, R.M. - 1970

Some observations on superimposition of ice on the Devon Island ice cap, N.W.T. Canada; *Geografiska Annaler*, vol. 52A, No. 1, pp. 57-67.

The zone of superimposed ice formation is defined and divided into two sub-zones, one of continuous and the other of discontinuous superimposed ice formation. Layering in superimposed ice is discussed and it is evident that an annual increment may consist of a series of layers which can occur in various orders according to the melt and freezing conditions obtaining. A laboratory analysis of superimposed ice did not reveal any valid method for division into annual layers. A crystal analysis indicates there is an increase in the mean crystal size and the standard deviation from this mean with decreasing altitude between the firn edge and the

equilibrium line. Below the latter the pattern is reversed. This phenomenon is used to determine a long period equilibrium line.

0333 KOERNER, R.M. - 1972

Specific electrolytic conductivity of snow and deep core samples from the Canadian Arctic Archipelago; in *Inter. Symp. on Role of Snow and Ice in Hydrology*, Banff, 13 p.

The Specific Electrolytic Conductivity of several snow and deep core samples from the Canadian Arctic Archipelago has been measured. The results show maximum conductivity values from autumn and mid-late winter snow. Percolation of melt-water in warm summers greatly reduces the magnitude of these variations. The high conductivity values in winter are believed to be caused by a decrease of the snow to soluble material ratio due to a lower snow accumulation rate and a smaller snow grain in winter. Rimming contributes to high conductivity values in autumn. There are significant variations of conductivity in the cores from the Devon Island ice cap and the Meighen Ice Cap. The cause of the Devon variations is unknown but those in the Meighen core are attributed to soluble material being blown on to the ice cap from surrounding ice-free terrain. No significant regional variations of electrolytic conductivity of snow in the Canadian Archipelago have been found.

0334 MULLER, F. - 1966

Axel Heiberg Island; *Ice*, No. 20, pp. 7-8.

0335 MULLER, F. - 1967

Axel Heiberg Island; *Ice*, No. 23, pp. 7-8.

0336 MULLER, F. - 1973

Axel Heiberg Island, N.W.T., McGill University; *Ice*, No. 41, p. 5.

0337 PATERSON, W.S.B. - 1963

Movement in Melville ice caps; *Polar Cont. Shelf Proj.*, internal report.

Positions of all markers were determined in 1963. Positions of certain ones (those where surface slope and/or ice thickness were greatest) were redetermined in 1966. Each marker was observed from two survey stations, all three angles of the triangle being measured. Table 1 gives differences (1963-1966) in seconds of the angles at the two survey stations, the lower numbered station being listed first. A reasonable figure to take for experimental inaccuracy is 10 seconds. This corresponds to a distance of 0.75 foot at 3 miles, which is about the maximum distance between marker and survey station. Three differences exceed 10 seconds, namely W6 from 182, S11 from 195, and S32 from 207. The first is unlikely to represent a genuine effect as it would imply movement parallel to a contour. The others imply movement of 0.7 and 0.5 feet respectively in the down-slope direction. However the stake at S11 was broken and replaced in 1965 and the displacement could have occurred then. The displacement of S32 may well be genuine as the difference in angle (37 seconds) is much greater than the difference at any other marker. But such small displacements could be

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due to bending of the stake by snow creep or by accumulation of rime, or warping, rather than to ice flow.

The conclusion is that at no point on the ice caps did the movement exceed 1 foot or, in other words, the velocity does not exceed 10cm yr^{-1} .

0338 PATERSON, W.S.B. - 1963
Project "Bold Survey"; ground observations; *Polar Cont. Shelf Proj.*, internal report.

0339 PATERSON, W.S.B. - 1964
Variations in velocity of Athabasca Glacier with time; *J. Glaciology*, vol. 5, No. 39, pp. 277-285. The physical setting of the Athabasca Glacier is described. Ablation of ice from the glacier contributes roughly 40 per cent of the annual outflow from the lake at the terminus. Variations of ice velocity, measured over periods ranging from a week to four months, are discussed. Few if any of these variations can be explained by changes of ice thickness. Variations in the amount of water at the glacier bed provide a plausible explanation however, and the data lend some support to Weertman's ideas on this subject. Variations in annual velocity of the glacier are not correlated with stream flow, but passage of a kinematic wave provides an explanation of these variations. The wave is attributed to a climatic change which began about 1938.

0340 PATERSON, W.S.B. - 1966
Test of contour accuracy on a photogrammetric map of Athabasca Glacier; *Can. J. Earth Sci.*, vol. 3, No. 6, pp. 909-915.
An independent survey of the positions and elevations of 59 surface markers set in the lower part of Athabasca Glacier permits assessment of the accuracy of contours on a large-scale map of the glacier. The root mean square difference between the elevation at each marker as determined from the survey and from the map was 49 cm. This is an upper limit to the standard error of the contours. It is less than three times the theoretical error and about 15% of the contour interval.

0341 PATERSON, W.S.B. - 1966
Mass balance studies on glaciers in western Canada by G. Østrem, Comments; *Geog. Bull.*, vol. 8, No. 4, pp. 383-385.

0342 PATERSON, W.S.B. - 1966
Meighen Island; *Ice*, No. 20, pp. 6-7.

0343 PATERSON, W.S.B. - 1967
A temperature profile through the Meighen ice cap, Arctic Canada; in Commission of Snow and Ice, Bern, Sept.-Oct., pp. 440-449.
Temperatures were measured in a 121 m borehole through the small (85 km²) ice cap on Meighen Island, Arctic Canada. The ice cap is virtually stagnant: thus advection of ice is not a factor in determining the temperature distribution. Temperatures below 10 m depth were in the range -16 to -18°C. Below 100 m, temperature varied linearly with depth at a rate which corresponds to a geothermal heat flux of

$0.8 \times 10^{-6} \text{ cal cm}^{-2} \text{ sec}^{-1}$. The shape of the temperature-depth curve over the range 20 to 100 m can be explained if one assumes that (1) the mean annual temperature at the surface has decreased by some 1.5°C since the year 1940 and (2) the mean annual surface temperature was increasing during the period 1880-1940, the total increase being about 3.5°C.

0344 PATERSON, W.S.B. - 1968
Glacier surges; *Can. Alpine J.*, pp. 220-223.
The Centennial Expedition enabled mountaineers to visit some of the most spectacular mountains in North America. It also incidentally enabled them to see, in Steele and Walsh Glaciers, examples of a rare and spectacular form of glacier behaviour, a surge. Many must have wondered why some glaciers behave in this way. This article will not provide any answers: the causes of glacier surges are still unknown. But perhaps a brief summary of what we do know may be of interest.

0345 PATERSON, W.S.B. - 1969
The Meighen ice cap, Arctic Canada: accumulation, ablation and flow; *J. Glaciology*, vol. 8, No. 54, pp. 341-352.
Accumulation on the Meighen Ice Cap appears to be about normal for the region, but ablation seems abnormally low. Statistical analyses of several years' data reveal the following trends: accumulation increases towards the north; ablation decreases with increase of elevation, decreases towards the north and west, and is greater on south-facing slopes than elsewhere. Because ice movement is very small, these trends explain the surface topography of the ice cap quite well. Other topics discussed are the significance of changes in the margins of a stagnant ice cap, and the rate at which net mass balance changes with elevation.

0346 PATERSON, W.S.B. - 1970
The application of ice physics to glacier studies; in Proc. Workshop Seminar, Can. Nat. Comm. Int. Hydro. Decade, pp. 43-46.

0347 PATERSON, W.S.B. - 1970
The sliding velocity of Athabasca Glacier, Canada; *J. Glaciology*, vol. 9, No. 55, pp. 55-63.
A method of estimating sliding velocity is presented. It rests on few assumptions, one of which is that longitudinal strain-rate varies linearly with depth. The flow law of ice is not used. To apply it, the sliding velocity at one point must be known. The method is used to calculate the sliding velocity at twelve points on Athabasca Glacier. These values are not related to calculated basal shear stresses. Thus one or more of the following statements must be true: (1) basal shear stress cannot be calculated by the conventional formula, (2) the roughness of the glacier bed varies from place to place, (3) sliding velocity does not obey Weertman's formula. Analysis of seven published measurements of sliding velocity leads to the same conclusion.

0348 PATERSON, W.S.B. - 1971
Temperature measurements in Athabasca Glacier, Alberta, Canada; *J. Glaciology*, vol. 10, No. 60, pp. 339-349.

The temperature in the ablation area of Athabasca Glacier is about -0.5°C at a depth of 10 m. Below 17 m the temperature is slightly below the calculated pressure melting point (average difference 0.01°deg) in some places. Heat produced by ice deformation is calculated as a function of depth in two bore holes. Only in about the lower half of the glacier thickness is this heat sufficient to maintain the ice at the observed temperature as the hydrostatic pressure is reduced by ablation. Freezing of water within the ice must provide heat for this purpose elsewhere in the glacier; it must also provide heat to maintain the deeper ice close to the melting point even though the 10 m temperature is negative. The minimum water content needed is estimated to be between 0.5 and 1%. It is argued that most of this water must be water trapped between grains when the ice formed from firn. The small difference from the pressure melting temperature measured below 17 m probably arises either from impurities or because, as a result of heat supplied for pressure-melting of ice around air bubbles, the ice is at the melting point corresponding to the bubble pressure rather than to the hydrostatic pressure.

0349 PATERSON, W.S.B. - 1972

Laurentide ice sheet: estimated volumes during Late Wisconsin; *Rev. Geophys. and Space Phys.*, vol. 10, No. 4, pp. 885-917.

Estimates are made of the volumes of the Laurentide ice sheet and the Innuitian ice sheet (covering the Canadian Arctic Islands north of latitude 74°N) from 18,000 to 6000 B.P. Relevant parts of the existing theory of flow in an ice sheet are first reviewed. Two limiting models are considered: a steady-state ice sheet, the dimensions of which do not change with time, and a stagnant ice sheet that thins at the same rate everywhere. Formulas relating ice thickness to radius and volume to area are given. The relation between area and volume of six existing ice sheets is examined to guide the choice of numerical parameters. The history of the Laurentide and Innuitian ice sheets is reviewed to help decide which model (or whether a combination of the two) is more appropriate at different times. Their volumes and thicknesses are then calculated from areas measured on a recent map of 'speculative' positions of the ice margins. Volume estimates for the Laurentide ice sheet are $26.5 \times 10^6 \text{ km}^3$ at maximum, $17.5 \times 10^6 \text{ km}^3$ at 11,800 B.P., and $6 \times 10^6 \text{ km}^3$ at 8500 B.P. The sea entered Hudson Bay shortly before 8000 B.P. and Foxe Basin a few hundred years thereafter. This divided the ice sheet into separate Keewatin, Labrador, and Foxe-Baffin ice sheets, which had an estimated total volume of 10^6 km^3 at 7500 B.P. The Keewatin and Labrador sectors had disappeared by about 6000 B.P. The volume of the Innuitian ice sheet at maximum is estimated at 10^6 km^3 . It had decreased to its present-day value of $5 \times 10^4 \text{ km}^3$ by about 8000 B.P. Maximum errors in these figures are estimated at between $\pm 16\%$ and $\pm 20\%$ at different times, plus an unknown amount for inaccuracies in the map of the ice margins. From maximum until about 12,000 B.P. the volume of the Laurentide ice sheet decreased much more rapidly than its thickness. If, at the ice sheet maximum, bedrock below its center

in Hudson Bay was in isostatic equilibrium, between 150 and 390 meters of uplift must have occurred between 9000 and 8000 B.P. Melting of ice in the Laurentide and Innuitian ice sheets between 15,000 and 6000 B.P. can account for a rise in sea level of between 56 and 76 meters.

0350 PATERSON, W.S.B. - 1972

Temperature distribution in the upper layers of the ablation area of Athabasca Glacier, Alberta, Canada; *J. Glaciology*, vol. 11, No. 61, pp. 31-41. Ten-meter temperature measurements show that Athabasca Glacier is temperate in the accumulation area but not in the ablation area. An important factor in determining whether all the ice will reach a temperature of 0°C by the end of summer is how much of the layer of ice, cooled during the previous winter, is removed by ablation. However, calculations show that, even when allowance is made for ablation, not enough heat is conducted into the ice to bring it all to the melting point. As recent work suggests that ice at 0°C is permeable to water, latent heat released by refreezing of percolating melt water is considered; it appears likely that this process is an insignificant heat source in the ablation area. Available data show that the penetration of solar radiation can probably also be neglected. The question of how widespread temperate glaciers are is discussed; it is predicted that in most, if not all, glaciers there is a region below the equilibrium line where, because ablation is low, the glacier is not strictly temperate.

0351 PATERSON, W.S.B. - 1972

Glacier Ice; book review by Paterson; *Amer. Met. Soc.*, vol. 53, No. 3, pp. 270-271.

0352 PATERSON, W.S.B. - 1972

Athabasca and Saskatchewan Glaciers; *Guidebook*, Int. Symp. Role of Snow and Ice in Hydrology, Banff, pp. 88-91.

0353 PATERSON, W.S.B., and HUNT, F.P. - 1966

Melville Island; *Ice*, No. 20, p. 6.

0354 PATERSON, W.S.B., and HUNT, F.P. - 1967

Melville Island; *Ice*, No. 23, pp. 6-7.

0355 PATERSON, W.S.B., and KOERNER, R. - 1967

Meighen Island; *Ice*, No. 23, p. 7.

0356 PATERSON, W.S.B., and KOERNER, R.M. - 1972

Devon Island; *Ice*, No. 38, p. 5.

0357 PATERSON, W.S.B., and KOERNER, R.M. - 1973

Devon Island ice cap; *Ice*, No. 41, pp. 4-5.

0358 PATERSON, W.S.B., and LUNDGAARD, L. - 1972

Melville Island; *Ice*, No. 38, p. 5.

0359 PATERSON, W.S.B., and SAVAGE, J.C. - 1970

Excess pressure observed in a water-filled cavity in Athabasca Glacier, Canada; *J. Glaciology*, vol. 9, No. 55, pp. 103-107.

During drilling in the Athabasca Glacier in April 1968, a cavity containing water was punctured at a

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depth of 9.2 m below the ice surface. Upon removing the drill, water gushed from the bore hole for about 55 s indicating an excess pressure of at least 0.25 bar within the cavity. The surrounding ice was slightly below the pressure melting point, and the excess pressure was apparently generated by the reduction in volume of the cavity caused by freezing of some of the water within it.

0360 ROOTS, E.F. - 1961

Glaciological activities; *Polar Cont. Shelf Proj.*, internal report, 3 p.

0361 ROOTS, E.F. - 1962

North-Western Queen Elizabeth Islands; *Ice*, No. 9, p. 2

0362 ROOTS, E.F. - 1964

Western Queen Elizabeth Islands; *Ice*, No. 14, p. 7.

0363 ROOTS, E.F. - 1965

Western Queen Elizabeth Islands; *Ice*, No. 17, p. 5.

0364 ROOTS, E.F. - 1965

Eastern Queen Elizabeth Islands; *Ice*, No. 17, p. 5.

0365 WEBER, J.R., and ANDRIEUX, P. - 1970

Radar soundings on the Penny ice cap, Baffin Island; *J. Glaciology*, vol. 9, No. 55, pp. 49-54.

The first successful radar echo soundings through glacier ice in Canada were carried out by the Dominion Observatory in 1965 on an outlet glacier of the Penny Ice Cap in Baffin Island. An unmodified 440 MHz SCR-718 radar altimeter was used, of the type that is readily and inexpensively available on the surplus market. The radar soundings were generally in agreement, within the range of the reading accuracy of the oscilloscope (± 15 m), with depths obtained seismically, gravimetrically, and by the electrical resistivity method. The minimum and maximum recorded depths were 45 m and 550 m, respectively. The pip positions on the standard oscilloscope were recorded visually. This recording method was not satisfactory, but for future use the instrument could easily be modified to incorporate a larger oscilloscope with continuous photographic recording. Use of the relatively high carrier frequency of 440 MHz (compared with the more customary frequency of about 35 MHz) allows the use of smaller antennas and results in better resolution of the bedrock surface.

HISTORY

0366 ENGLAND, J. - 1973

The first expeditions to Lady Franklin Bay, north-east Ellesmere Island, N.W.T., Canada; *Arctic and Alpine Res.*, vol. 5, No. 2, pp. 133-144.

Notes dating from the British Arctic Expedition of 1875 and the U.S. Army's Lady Franklin Bay Expedition of 1881 to 1884 were found by the author on Ellesmere Island. The first note, typed on board H.M.S. Discovery by Captain Stephenson on March 10, 1876, was found in 1971 in a cylinder near the cairn on the summit of Mt. Campbell, Bellot Island. Two other notes were found together in one cylinder at

Record Point on Archer Fiord in 1972. The first of these is dated August 15, 1882, and was deposited by Lt. J.B. Lockwood, U.S.A., of the Lady Franklin Bay Expedition, who removed an earlier note left by Lt. Archer, RN, from H.M.S. Discovery in the spring of 1876. Lockwood returned to Record Point the following spring and on April 29, 1883, deposited an extensive handwritten note prepared at Fort Conger on March 26, 1883, by Lt. A.W. Greely. The Greely/Lockwood note describes the excellent condition of the expedition personnel and their accomplishments at that time. It also includes meteorological observations from August 1881 to July 1882. Facsimiles of the notes appear in the paper. The history of the two expeditions is briefly recounted and the tragic end of the Lady Franklin Bay Expedition described. Only seven out of Greely's party of 25 survived the winter of 1883-84 after the failure of a supply ship to reach them in 1883.

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0367 ANDERSON, N.M. - 1966

Observations and tests with Hifix over sea ice; *Polar Cont. Shelf Proj.*, internal report, 27 p.

This report describes the observations and tests of a Hifix survey on the Lincoln Sea and Robeson Channel located between northern Ellesmere Island and Greenland. The Hifix chain was initially established to provide positioning control over the Lincoln Sea, later, the Hifix stations were relocated in Robeson Channel where further tests were carried out along with some reconnaissance hydrography.

The aims of the tests were to investigate the radio transmissions of the Hifix system over the sea ice in this area. The necessity of these tests resulted when it was found that the system did not provide sufficient range for the survey. A range of 60 miles was anticipated; a maximum range of 20 miles was attained.

0368 ANDERSON, N.M. - 1967

Hovercraft towed depth sounding system trials; *in* Trials of an SK-5 hovercraft for the Canadian Coast Guard, by R.E.F. Lewis, J.W. Storr and F.C. Brewer, Def. Res. Bd. DRML Report No. 667.

A helicopter towed depth sounding system developed by the Polar Continental Shelf Project was used for the hovercraft towing trials. The system was developed for hydrographic surveys in the Canadian Arctic. A hovercraft promised advantages over the helicopter for towing this system, e.g., the hovercraft could tow downwind, would have decidedly better weight carrying and space characteristics, and would be safer.

0369 BOLTON, M. - 1971

Hydrographic operations in the Beaufort Sea; *Can. Surveyor*, vol. 25, No. 2, pp. 115-123.

During 1970, the Marine Sciences Branch mounted a major charting program in the Canadian Western Arctic, concentrated in the Beaufort Sea. The intensive activity of the oil industry provided much of the impetus for this increased scientific effort. This paper briefly describes prior charting activities in the area, discusses the 1970 operations in some detail, and speculates on future requirements.

Detailed hydrographic surveys were carried out from CSS Baffin and CSS Parizeau; the Polar Continental Shelf Project conducted a shorebased hovercraft operation.

0370 DOUGLAS, G.R. - 1966

Test Report; weight depressor underwater body; *Polar Cont. Shelf Proj.*, internal report, 18 p. Since 1963 the hydrographic section of the Polar Continental Shelf Project has used a depressor-wing type of underwater body for echo sounding purposes. This type of body is limited in practice to 15 knots after which it becomes unstable. Tow tension at this speed was approximately 350 pounds.

0371 EATON, R.M. - 1960

Steering committee, hydrographic surveys of Polar Shelf Project; *Polar Cont. Shelf Proj.*, internal report, 1 p.

0372 EATON, R.M. - 1961

Hydrographic report, 1961; *Polar Cont. Shelf Proj.*, internal report, 4 p.

0373 EATON, R.M. - 1963

Airborne hydrographic surveys in the Canadian Arctic; *Int. Hydrographic Rev.*, vol. 40, No. 2, pp. 45-51. "None of us had ever seen waters so absolutely impossible to navigate as this Sound". This was how the Norwegian explorer SVERDRUP described Hell Gate, in the Canadian Arctic Archipelago, when he discovered it in 1899. That he later sailed through it in a ship's boat illustrates the way in which the Arctic becomes less forbidding on acquaintance. In 1960 the hydrographic section of the Polar Continental Shelf Project began to survey the predominantly ice covered waters of the Archipelago north of Parry Channel (parallel of 75°N), and in three years covered 190,000 sq. km of sea with soundings spaced 2-10 km apart. This was reconnaissance work, but techniques were evolved which will lead to the attempt, in 1963, to survey Hell Gate to normal standards of accuracy and thoroughness solely by airborne methods; the survey should be finished before the arrival of an icebreaker on her annual passage to re-supply the weather reporting station at Eureka, 350 km further north. This article describes the environment; echo sounding through ice; profile sounding by towing from a helicopter in open water; and position fixing in helicopters.

0374 EATON, R.M. - 1963

Techniques in Arctic hydrographic survey; *Polar Cont. Shelf Proj.*, internal report, 7 p.

0375 EATON, R.M. - 1964

Hydrographic section report 1963; *Polar Cont. Shelf Proj.*, internal report, 3 p. Continuing the development of techniques of hydrographic chart-making in ice-encumbered waters, a standard survey was made for the first time by purely airborne methods. Hell Gate, a channel 15 miles long by 4 miles wide between Ellesmere and Devon Is., in Lat. 77°N. Long. 90°W., was surveyed on a scale of 1:50,000. About 800 Km. of continuous profile

sounding lines were run, spaced at 500 metre intervals throughout the channel, by towing echo sounding fish behind the helicopters; in addition horizontal and vertical control was established for photogrammetric mapping of the coastline and topography; limited observations were made of the vertical and horizontal tidal movement; accuracy calibration was carried out on the Hi-Fix Decca to determine the order of error in position of a fix, and long range trials were run to determine the maximum coverage; all beaches which might be used for landing from the sea were described; and notes were taken for Sailing Direction.

0376 EATON, R.M., and ANDERSON, N.M. - 1963

Hydrographic report 1962, Part I - Introduction, Part II - Lambda party, Part III - Hi-Fix party; *Polar Cont. Shelf Proj.*, internal report, 12 p.

0069 JOLLYMORE, P.G. - 1969

A portable digital sounding system for Arctic use; *Atl. Ocean. Lab., Bed. Inst.*, report BI 1969-11, 35 p. Abstract under 0069

0377 O'SHEA, J. - 1971

Polar Continental Shelf Project Hydrographic Section final field report February-April 1970; *Polar Cont. Shelf Proj.*, internal report, 16 p. The 1970 Winter Survey on the Beaufort Sea was a continuation of the hydrographic program undertaken in 1969. Through-the-ice spot soundings were taken on a 4 mile grid, using Decca Lambda for position fixing and 2 Bell turbo-jet helicopters for transportation. As in previous years, Dominion Observatory participated, concentrating their major effort from the ocean camp. An additional gravity observer, supported by a Bell G4 helicopter, collected data in those areas of the Beaufort Sea where Baffin and Parizeau planned to operate during the summer months.

0073 PULKKINEN, H.W. - 1973

Hydrographic surveying with air cushion vehicles, trials report: evaluation of modified retractable fixed strut echo sounder; *Polar Cont. Shelf Proj.*, internal report, 46 p. Abstract under 0073

0378 ROOTS, E.F. - 1970

Bathymetric requirements in the Arctic Ocean; in Ninth Annual Hydrographic Conference, 27-29 January, Ottawa, pp. 273-286. The Arctic Ocean has several characteristics that make it unique among world oceans. The distinctive climate on its surface; its predominantly ice-covered state; its comparative isolation, surrounded by major land masses and with relatively restricted connections to other oceans, are well known facts of geography. Among the unique characteristics of the Arctic Ocean are the uses to which man has put it, and the effects that it has had on human activities. Not least of these effects have been those in the field of hydrography. The type of hydrographic work done in the Arctic Ocean, the means by which it is done, and the uses to which the hydrographic

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information is put, have in the main been different from those of other oceans. It may be of interest to look briefly at the part hydrography has played in man's knowledge and use of the Arctic Ocean and adjacent waters and the present and future responsibilities of hydrographers in that region.

0379 WADE, G.E. - 1971
Polar Continental Shelf Project Hydrographic Section Final Field Report 1971; *Can. Hydro. Serv.*, internal report, 35 p.
The 1971 field operation consisted of three separate assignments. The first was a continuation of the 1970 Hydrographic program in the Beaufort Sea - the completion of through-the-ice sounding using helicopters as a means of transportation and Decca Lambda as a positioning system. Second assignment consisted of obtaining through-the-ice soundings in Robeson Channel in the vicinity of Wrangel Bay. This was a continuation of the P.C.S.P. Hydrographic operation of 1967. Third, was a request for soundings around Hans Island in Kennedy Channel.

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0380 KOERNER, R.M. - 1970
Weather and ice observations of the British Trans-Arctic Expedition 1968-9; *Weather*, vol. 25, No. 5, pp. 218-228.
Between 21 February 1968 and 29 May 1969 four men under the leadership of W.W. Herbert traversed the Arctic Ocean between Barrow, Alaska and a small island off the coast of Spitzbergen (Fig. 1). The expedition used four sledges and dog teams and was supplied by air-drops by the U.S. Naval Arctic Research Laboratories in the early part of the journey and then by the Canadian Armed Forces. The author was glaciologist on the expedition. This article is an account of the weather conditions and scientific observations recorded on the journey. The results shown are based on a preliminary analysis of some of the data.

0381 MACKAY, D.K., and ARNOLD, K.C. - 1965
Access to Meighen Island, N.W.T.; *Arctic*, vol. 18, No. 3, pp. 194-198.

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0382 APOLLONIO, S. - 1973
Glaciers and nutrients in Arctic seas; *Science*, vol. 180, May 4, pp. 491-493.
Significantly higher concentrations of nitrate and silicate were found in glaciated South Cape Fiord than in unglaciated Grise Fiord, in the Canadian Arctic, or in adjacent Jones Sound. No significant differences in phosphate concentrations were found. Glacial activity apparently enriches the concentrations of those nutrients most critically limiting for arctic phytoplankton requirements.

0383 AVIS, R.A., and COACHMAN, L.K. - 1971
Current measurements in Smith Sound-Northern Baffin Bay, September 1968; *Arctic Inst. N. Amer.*, Baffin Bay-North Water Project Scientific Report No. 2, 27 p.

Two eleven-day current records were obtained in Smith Sound, northern Baffin Bay during September 1968. From the power spectra of the north and east components of these records, it was determined that the predominant harmonic currents occurred at or near the semidiurnal frequency. Estimates of the kinetic energy showed the mean flow and large scale (10 min < T < 1 hour) turbulence to contain the majority of the energy. Currents at or near the semidiurnal frequency represented 26% of the total kinetic energy at meter #171 and 12% at meter #172, even though they were the dominant periodic component.

0384 BANKE, E.G., and SMITH, S.D. - 1971
Wind stress over ice and over water in the Beaufort Sea; *Jour. Geoph. Res.*, vol. 76, No. 30, pp. 7368-7373.

A sonic anemometer-thermometer has been used in a study of Reynolds stress, sensible heat flux, and velocity and temperature spectra over ice and over water in the Beaufort Sea. The wind-drag coefficient over ice for stable conditions is $C_{10} = 0.0026$, and over water for unstable conditions $C_{10} = 0.0014$.

0385 COLLIN, A.E. 1959
Cruise report, oceanographic cruise of C.G.S. Labrador, September 1-October 22, 1959; *Polar Cont. Shelf Proj.*, internal report, 6 p.
Tentative survey programs were drawn up for several regions in the eastern Arctic including Foxe Basin, western Hudson Strait and Hudson Bay. The program was designed so that each unit, consisting of 30 to 40 oceanographic stations, could be completed in approximately 5 days.

In addition to observations of temperature and salinity at all standard depths collections of zooplankton and phytoplankton were planned at selected stations as recommended by the Arctic Unit of the Fisheries Research Board of Canada. A program of bottom sampling including surface samples and short cores was decided upon in conjunction with the requirements of the Geological Survey and after consultation with the Geology Department of Carleton University.

The proposed program consisted of 150 stations, however, it was acknowledged that if any two units of this program, a total of 80-90 stations could be completed the scientific survey would be considered entirely successful.

0386 COLLIN, A.E. - 1959
Oceanographic observations in the Canadian Arctic and the adjacent Arctic Ocean; *Abstract*, Can. Oil and Gas Ind., Dec.

0387 COLLIN, A.E. - 1960
Oceanographic observations in the Canadian Arctic and the adjacent Arctic Ocean; *Polar Cont. Shelf Proj.*, internal report, 11 p.

0388 COLLIN, A.E. - 1960

Preliminary report of 1959-60 oceanographic activities, Polar Continental Shelf Project; *Polar Cont. Shelf Proj.*, internal report, 10 p.

The 1959 oceanographic programme was designed primarily to appraise working conditions in the field, test and design the instruments that would be required, and take a short series of oceanographic observations as the opportunity presented itself. This programme was successful in that the equipment which had been planned for the 1960 project was tested and modified to fill the requirements for working under such conditions. Basically, the equipment which was used was of standard design, however, methods and precautions were perfected which enabled the field party to eliminate some of the problems caused by the low temperatures and thus increase the reliability of the observations.

The oceanographic observations which were completed during the 1959 season were restricted owing to the limited aircraft time available. A total of four oceanographic stations were completed in the Prince Gustaf Adolf Sea throughout the course of the season and several tests were carried out on the Ott current meter.

0389 COLLIN, A.E. - 1960

Oceanographic observations in the Canadian Arctic and the adjacent Arctic Ocean; *Arctic*, vol. 13, No. 3, pp. 194-201.

0390 COLLIN, A.E. - 1961

Oceanic observations in the Canadian Arctic and the adjacent Arctic Ocean; *Abstract in Geology of the Arctic*, Univ. Toronto Press, vol. 2, p. 1090.

The first oceanographic observations recorded in the Canadian Eastern Arctic were taken by Sir W.E. Parry in Lancaster Sound in 1821. Since that time oceanographic reconnaissance has been extended throughout the Eastern Arctic including Baffin Bay, Lancaster Sound, Foxe Basin, and Hudson Strait. In 1915 the Canadian Fisheries Expedition carried out oceanographic measurements in the region of Hudson Bay and Hudson Strait and in 1928 the Danish Godthaab Expedition completed an extensive oceanographic survey in Baffin Bay and the connecting passages. Two surveys have been conducted in the Western Arctic in the region of the Beaufort Sea and in 1954 oceanographic stations were occupied at intervals through the Northwest Passage.

Since 1954 the oceanographic coverage in the Canadian Arctic has been greatly extended through the activities of the Canadian ice-breaker "Labrador". Over 700 stations have been conducted from this ship in Arctic waters. In the Western Arctic, oceanographic surveys in the southern Beaufort Sea have been under the direction of the Fisheries Research Board. In the region north of M'Clure Strait oceanographic observations have been taken from the IGY drift station T-3 and more recently by parties of the Polar Continental Shelf Project of the Department of Mines and Technical Surveys.

A comparison of Arctic oceanographic measurements reveals that during the summer, temperatures of 0.0°C to 0.5°C can be expected in the Eastern Arctic above 100 m. Within the same depth range temperatures

of -1.0°C to -1.5°C are common for the Western Arctic. In the area northwest of Isachsen, Northwest Territories, water temperatures increase with depth below 200 m to a maximum of 0.4°C at 380 m. At greater depths there is a gradual decrease in temperature to 0.0°C at 1000 m. Below 1000 m water temperatures varies little from -0.3°C.

Salinity determinations in areas of continuous ice cover in the Western Arctic show that a layer of very low salinity develops under the ice during the summer and that, in general, salinities in these regions are lower than those in the Eastern Arctic within the depth interval zero to 150 m. Below 150 m salinity content is slightly higher in the Western Arctic, being approximately 34.9‰/00 at 500 m. The content of dissolved oxygen reaches a summer maximum of 10.0 ml/l at the surface in the Beaufort Sea and a consistent minimum of 6.4 ml/l occurs at 150 m. In Lancaster Sound and Hudson Strait slightly lower values were recorded in September 1957 and 1959.

0391 COLLIN, A.E. - 1961

Oceanographic activities of the Polar Continental Shelf Project, Department of Mines and Technical Surveys; *J. Fisheries Res. Bd.*, vol. 18.

One of the primary research objectives of the Polar Continental Shelf Project has been a detailed investigation of the characteristics and movement of the waters overlying the polar continental shelf and passing through the channels of the Canadian Arctic Archipelago. The programme included sub-surface observations of temperature, salinity, and dissolved oxygen. Bottom samples and plankton collections were made at all stations, and at selected locations microthermal measurements were taken within the shallow, seasonal layer which forms immediately under the ice. Since the Project was initiated in 1958, two field seasons have been completed at Isachsen, N.W.T., with encouraging results. During the summer of 1959 emphasis was placed on the development of equipment and techniques by which precise oceanographic observations could be taken on the ice using a light, single-engined aircraft as the means of transportation.

0392 COLLIN, A.E. - 1961

Oceanographic data record, C.G.S. Labrador, September 1-October 22, 1959; *Polar Cont. Shelf Proj.*, internal report, 5 p.

0393 COLLIN, A.E. - 1961

Polar Continental Shelf Project, Progress Report, Oceanography; *Polar Cont. Shelf Proj.*, internal report, 21 p.

0394 COLLIN, A.E. - 1961

Current observations, Eureka Sound, May 1961, Polar Continental Shelf Project; *Polar Cont. Shelf Proj.*, internal report, 2 p.

A series of oceanographic observations were recorded by a party of the Polar Continental Shelf Project in Eureka Sound in May 1961.

The camp was established on the ice on May 9 at a position in mid-channel due east of the southern end of Stolz Peninsula. The position, determined from dead reckoning, was 78° 36.4' North latitude, 87° 28.0'

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West longitude. The camp was evacuated on May 15. The depth of water at the camp site was 253 metres.

0395 COLLIN, A.E. - 1962

The waters of the Canadian Arctic Archipelago; *Arctic Basin Symposium*, Arctic Inst. N. Amer., Oct. 8-11, Hershey, Penn., 12 p.

The waters of the Canadian Arctic archipelago constitute a network of shallow channels connecting the Arctic Ocean with Baffin Bay and Hudson Strait. The archipelago system contains some 16 major channels that range in width from 10 to 120 Km. and in depth to over 700 metres.

Arctic oceanographic observations have been carried out in recent years by the Fisheries Research Board and by the Marine Sciences Branch of the Department of Mines and Technical Surveys. Much of this work has been directed toward fisheries research and has been concentrated in Foxe Basin and Lancaster Sound. Oceanographic observations have been recorded in all the main channels of the archipelago and in such areas as Lancaster Sound the data of 4 oceanographic cruises are now available. Almost all of this information has been obtained during the summer months of July and August and there are few marine data for winter conditions in the archipelago.

Information used in this discussion results largely from observations carried out aboard the icebreaker LABRADOR in the eastern arctic in 1956 and 1957 and at stations occupied on the sea ice on the western continental shelf and in the northwestern channels of the archipelago in the spring of 1960 and 1961. Observations taken from the ice island T-3 during the summer of 1958 have been used in the description of the oceanographic conditions of the Arctic Ocean. There is considerable variation in the depth and extent of the continental shelf surrounding the archipelago. On the Baffin Bay coast the width of the shelf seldom exceeds 55 Km. to the north of Hudson Strait and the depth is about 200 metres. On the Arctic Ocean coast the break in slope of the continental shelf occurs about 170 Km. off-shore, to the northwest of Ellef Ringnes Island, at a depth of 550 metres. The seaward edge of the Arctic Ocean continental shelf appears to be remarkably uniform and there is little indication of gulleys indenting the continental slope in the area between M'Clure Strait and Prince Gustaf Adolf Sea.

Recent hydrographic information indicates that the greatest depths occur within the Queen Elizabeth Islands in the troughs that have been discovered in Peary Channel and the Prince Gustaf Adolf Sea. These depressions, which in all cases are aligned parallel to the long axis of the channels, may reach a depth of over 700 metres and are believed to be the result of glacial deepening of the valley floor at a period when the land was at a considerably higher elevation than at present (Pelletier, 1962).

According to present information, the threshold depth of the archipelago is no more than 150 metres and occurs in Barrow Strait near Lowther Island. In Smith Sound, between Ellesmere Island and Greenland the limiting depth is 200 metres.

0396 COLLIN, A.E., and DUNBAR, M.J. - 1964

Physical oceanography in Arctic Canada; *Oceanogr. Mar. Biol. Ann. Rev.*, vol. 2, pp. 45-75.

0397 COLLIN, A.E., and ROOTS, E.F. - 1960

Notes on Arctic oceanographic activities conducted by the Polar Continental Shelf Project; internal report to Can. Comm. Ocean., 2 p.

0398 HUGGETT, W.S. - 1970

Final field report, C.S.S. "Parizeau" WA-70, July 10-September 24, 1970, Mackenzie River Delta; *Can. Hydro. Serv.*, internal report, 32 p.

0250 JOHANNESSEN, O.M., POUNDER, E.R., SERSON, H., SMITH, S.D., FINLAYSON, D., KEYS, J., WEBER, J.R., and LANGLEBEN, M.P. - 1970

Cruise report from the ice drift study in the Gulf of St. Lawrence 1970; *McGill Univ. Marine Sc. Centre*, Report No. 15, 53 p. Abstract under 0250

0399 MUENCH, R.D. - 1969

Oceanographic conditions at a fixed location in western Kane Basin, May 1969; *Polar Cont. Shelf Proj.*, internal report, 23 p.

0400 MUENCH, R.D. - 1971

The physical oceanography of the northern Baffin Bay region; Baffin Bay-North Water Project Sc. Rep. No. 1, *Arctic Inst. N. Amer.*, 150 p.

0401 MUENCH, R.D., DUNBAR, M.J., and TIDMARSH, W.G. - 1968

A preliminary report of Baffin Bay-North Water Project field work during 1968; *Arctic Inst. N. Amer.*, Baffin Bay-North Water Rep. No. 3, 9 p. Two field projects were attempted during the summer of 1968, both aimed at obtaining direct current measurements and concurrent hydrographic observations in the Kane Basin-northern Baffin Bay region.

0402 SEIBERT, G.H. - 1968

Oceanographic observations in the Lincoln Sea; *Arctic Inst. N. Amer.*, Baffin Bay-North Water Project Report No. 2, 21 p.

As part of a comprehensive study of the exchange of water between the Arctic Ocean and Baffin Bay, the Arctic Institute of North America occupied a series of 14 oceanographic stations in the Lincoln Sea (Fig. 1) during the period June 12 to June 22, 1967. One of the main objectives was to obtain some information in a previously unsurveyed area in order to determine, more precisely, the nature of the source waters moving south through Nares Strait (see Nutt and Dunbar, 1967); in particular, the relative contributions of Canadian and Eurasian Basin surface waters and, intermediate Atlantic waters. A comparison of these data with those previously collected from the Arctic Ocean and the channels leading into Smith Sound would provide a better insight into the importance of local factors in the progressive mixing of southward moving waters.

0403 TIDMARSH, W.G., CARNACK, E.C., OVERLAND, J., and MUENCH, R.D. - 1969

A preliminary report of field work during 1969; *Arctic Inst. N. Amer.*, Res. paper No. 56, 12 p. As part of its continuing comprehensive study of the "North Water" phenomenon, the Arctic Institute of

North America established and occupied an oceanographic station on sea ice in Kane Basin during the period May 3 to May 20, 1969. The objectives were to make physical measurements and obtain biological samples from an area previously unsurveyed during the winter months. Through the period of occupation, physical oceanographic measurements were made to determine the water structure in the area and the nature of water exchange through Nares Strait. Of special interest was the time dependence of net directional water transport through Kane Basin and the passage of water which could be later identified as that resulting in the formation of Baffin Bay Bottom Water. Biological samples obtained are to be examined for the presence of Atlantic and Pacific species and their occurrence in relation to the water structure found.

0404 VILKS, G. - 1970

Circulation of surface waters in parts of the Canadian Arctic Archipelago based on foraminiferal evidence; *Arctic*, vol. 23, No. 2, pp. 100-111. Planktonic foraminifera are present both in bottom sediments and surface waters on the shelf area averaging 400 metres in depth to the west of a line between Cape M'Clure and Cape Meecham, but in M'Clure Strait proper to the east of this line in the surface waters only. The evidence is used to suggest a slow net eastward movement of water from the ocean through M'Clure Strait in the past with increased rates at the present time.

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0405 ABER, P.G., and VOWINCKEL, E. - 1972

Evaluation of North Water spring ice cover from satellite photographs; *Arctic*, vol. 25, No. 4, pp. 263-271.

Satellite photographs for 2 years (March-September) have been used to study ice cover in the polynia called "North Water", and to determine whether reliable ice maps could be made from satellite data without computer analysis.

After early July the clouds become opaque and distinction between cloud and ice is impossible. It was concluded that ice distribution for short periods could best be obtained by careful photograph interpretation. The most persistent open water is found at the northern edge, at about 78°N. The southern ice edge is diffuse.

The changes in ice cover in the North are mainly caused by freezing and melting, whereas ice transport is important in the southern area.

0406 ARNOLD, K.C. - 1959

A preliminary statement of the results of the dusting programme at Isachsen, N.W.T.; *Polar Cont. Shelf Proj.*, internal report, 2 p.

0407 ARNOLD, K.C. - 1959

Report of a visit to D.R.N.O.-Fort Churchill; *Polar Cont. Shelf Proj.*, internal report, 3 p.

0408 ARNOLD, K.C. - 1961

An investigation into methods of accelerating the melting of ice and snow by artificial dusting; in *Geology of the Arctic*, Univ. Toronto Press, pp. 989-1013.

During the summer of 1959 the author conducted experiments on snow, sea ice, and lake ice surfaces in an attempt to accelerate their rate of melting by artificial dusting. Seven different types of materials were used, differing in particle size and in the presence or absence of salt or sand. Each of these materials was spread in amounts of 100, 300, 500, 700, and 1000 grams on squares one square metre in area. This gave thirty-five squares to study on each of the snow, sea ice, and lake ice surfaces. During the summer, repeated measurements were taken in each of these squares, using a level and rod to measure the departure of each square from a system of reference stakes. A comparison was also made with untreated areas, which served as a control. Cores and stereoscopic photographs were taken in each square of the sea and lake ice surfaces, illustrating the penetration of the dust into the ice surface. Meteorological readings are available at three-hour intervals in the areas studied.

The results are discussed and some comparisons made between the different surfaces and materials. Former practical applications of this method are referred to, and possible future applications are suggested.

0409 BLACK, W.A. - 1963

A preliminary study of sea-ice conditions in the Queen Elizabeth Islands' region, season 1963; *Geog. Br. Report* 407-3, 19 p.

The break-up of the sea-ice during the early part of the season in the eastern Arctic was delayed because of the backwardness of the season, but it was well-advanced in M'Clure Strait by June 23. The deterioration of the Parry Channel icefields in July continued to be slow. By August 8, the consolidated cover in Parry Channel had shattered. At this time Viscount Melville Sound, Barrow Strait and Lancaster Sound contained heavy concentration of ice, whereas, M'Clure Strait was largely open water. With the break-up of the consolidated ice cover in Viscount Melville Sound in early August the icefields gradually drifted east-southeastward.

Numerous patches and strings of polar-basin ice were observed in Lancaster Sound on August 23. The movement of this ice from Wellington Channel seems to have begun after July 20. About August 20, the consolidated ice cover in Byam Martin Channel was breached, and by August 26, polar-basin ice was passing through Austin Channel into Viscount Melville Sound. The volume of ice passing through Byam Martin Channel increased during September although freezing temperatures prevailed. In early September the drift of the icefields was southward, later swinging to the west-southwest and at the end of the month the drift was to the southeast. Much of this ice passed into McClintock Channel. The icefields moving into Barrow Strait from Wellington Channel during September followed a similar pattern of drift. The discharge of ice through Fitzwilliam Strait was light but in September a large tongue of polar-basin ice entered

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M'Clure Strait. At the end of September heavy polar-ice concentrations existed in Parry Channel. On the Arctic Front, consolidated ice-cover barriers, occupying Ballantyne, Wilkins, Sverdrup and Nansen straits, were holding at the end of August and continued to do so in September. The icefields, covering Prince Gustaf Adolf Sea and Peary Channel appeared to have fractured about August 20; by the end of the month the polar-basin pack had pushed but a short distance into these channels. The main centres of working ice in this region during August occurred in the Edinburgh Sea, Belcher Channel, and the Norwegian Bay areas with these icefields funnelling into Jones Sound and Penny Strait. In September, however, substantially greater masses of ice were discharging through Byam Martin Channel. By the end of September, ice movements within the channels had all but ceased, only the Prince Gustaf Adolf Sea icefields continuing active. The rate of drift of the ice islands 'Joan' and 'June' showed that the clockwise rotation of the polar-basin ice bordering the Arctic Front varies considerably and also that it was greatest in September.

0410 BLACK, W.A. - 1964

Sea-ice survey, Queen Elizabeth Islands region, summer 1962; *Geographical Br.*, M.&T.S. Canada, Paper No. 39, 47 p.

The aerial survey of arctic sea ice in the Queen Elizabeth Islands region from June to September 1962 is a continuation of the ice-distribution survey begun in the summer of 1961. The immediate purpose was to observe and map the coverage and distribution of the ice and to relate ice conditions to climatic factors. The long-term objective was to build an annual record showing ice and climatic relations, the variability of the ice cover and the nature of the regional ice circulation.

0411 BOURNE, I.A., ROSS, D.B., and SEGAL, B. - 1970

Phase instability in radio waves propagating across ice-covered seas; in Phase and frequency instabilities in electromagnetic wave propagation, AGARD Conf. Proc. No. 33, ed. K. Davies, Technivision Service, Slough, Eng.

Experimental measurements and theoretical calculations are presented which show that the presence of a thin layer of ice on a sea's surface can have a marked influence on the propagation of medium frequency waves across the sea. It is found that under certain conditions small changes in the ice thickness can result in marked changes in the phase of a received wave.

0412 BOURNE, I.A., SEGAL, B., and ROSS, D.B. - 1968

An investigation into some problems associated with the use of the Decca "Hi-Fix" navigation system in the Canadian Arctic; *Def. Res. Bd.*, DRTE Rep. No. 1196, 55 p. Serious difficulties were encountered in the operation of a 1.71 MHz phase comparison radio navigation system in the waters of the Canadian Arctic. Measurements of propagation conditions showed that the useful range of such a system can be severely restricted by the presence of an ice cover. This led to a theoretical investigation of radio wave propagation

over a stratified ice-water surface. Whereas a homogeneous medium with plane boundary always displays a resistive or only slightly inductive surface impedance, a rough or stratified medium may, under certain circumstances, exhibit a highly inductive surface impedance. Over such a surface the ground wave, as exemplified by the Sommerfeld attenuation function, may vary strongly and rapidly with distance, both in amplitude and in phase. It is found that for physically realizable ice-covered surfaces the ground wave field intensity at a finite distance from a transmitter may be reduced to zero and that the phase velocity of the wave at that range may become infinite. The effect is attributed to the interference between two inseparable wave components: a "Norton surface wave" similar to the wave existing over a smooth, homogeneous earth, and a "trapped wave" resulting from wave reflections at the upper and lower ice interfaces.

Calculations were made of the vertical electric field strength at the upper surface of a uniform ice layer lying on infinitely deep sea water. The results obtained for a layer four or five metres thick agreed qualitatively with measurements made in the Arctic, in the vicinity of Ellesmere Island. The ice thickness and electrical conductivity, and the wave frequency were found to be the most significant parameters in determining the behaviour of the ground wave. The calculations suggested that reducing the operating frequency of the system by a factor of two would increase the useful range of reliable operation by at least a factor of six.

0413 COACHMAN, L.K., and SMITH, J.D. - 1970

A report on the 1970 AIDJEX pilot study; *AIDJEX Bull.* No. 4, Univ. Washington, Seattle, pp. 8-38.

Arctic ice moves and deforms under the influence of the air stress above and water stress below, while stresses within the ice field modify the motion. Although many methods have been employed to measure these stresses and deformation, we do not yet know the most suitable method for the purposes of AIDJEX. This pilot study, a collaboration between the Polar Continental Shelf Project (Department of Energy, Mines and Resources, Canada) and the Department of Oceanography (University of Washington), explored possible techniques for measuring water stress on the ice and ice deformation.

Water-stress measurements require complicated equipment and personnel; thus, it is not feasible to directly define the water-stress field over a large region. The direct stress measurements must be related to the interior oceanic velocity field, so that over the AIDJEX region the stress field can be inferred from the velocity field. The portion of the interior velocity field which is geostrophic may, if sufficiently large, be readily inferred from its characteristic association with the internal distribution of mass. The required measurements are those of temperature and salinity in a number of vertical profiles; of all oceanographic measurements, these are probably the easiest to obtain, the most reliable, the most readily reducible, and the least expensive. The degree to which flow in the Arctic Ocean is in geostrophic balance is not known.

Direct measurement of the interior flow field depends on reliable current meters. A number of choices are available, but the meter best suited to AIDJEX must be selected only after extensive testing under arctic conditions. Furthermore, proper horizontal and vertical spacing of the current meters must be thoroughly explored so that the interior flow field can be mapped adequately for translating the direct stress measurements into a stress field under the ice.

0414 FARMER, D., JOHANNESSEN, O.M., KEYS, J.E., POUNDER, E.R., and SERSON, H. - 1970
Observations of ice drift from a manned drifting station in the Gulf of St. Lawrence; *J. Geoph. Res.*, vol. 75, No. 15, pp. 2863-2867.
The positioning of a drifting ice floe was recorded every 10 minutes during a six-day period by means of a Decca navigational system and by direct wind observations on the floe. The observations showed that the ice floe took part in the tidal regime. Maximum correlation between wind and residual ice drift speeds (tidal effect eliminated) was achieved in less than 2 hours.

0415 GANTON, J.H., and MILNE, A.R. - 1965
Temperature- and wind-dependent ambient noise under midwinter pack ice; *J. Acoust. Soc. Amer.*, vol. 38, No. 3, pp. 406-411.
Measurements of ambient noise under shorefast pack ice during winter revealed two distinct noise-producing mechanisms. One mechanism was the production of tensile cracks at the surface of the sea ice by thermal stresses caused by decreasing air temperatures. The resulting ice-cracking sounds produced impulsive noise. The second mechanism was the interaction of the granular ice surface with the wind, which produced Gaussian noise. Separate pressure spectra are presented for underwater noise generated by each mechanism. The spectra and the statistical properties of the underwater noise appeared to be related to the local meteorology and the temperature changes within the ice cover.

0416 HARTWELL, A.D. - 1972
Air photo analysis of sea ice deformation in the Beaufort Sea, March 1971; *AIDJEX Bull.*, No. 13, Univ. Wash. Seattle, pp. 1-33.
Ice deformation in a 175 km² area of the Beaufort Sea (location at about 74°N, 131°W) between 11 March and 23 March 1971 was analyzed by means of sequential aerial photographs. The approximate time, direction, and magnitude of deformational motion was determined by combining observations of the changes in features related to ice deformation, such as leads, fractures, and pressure ridges, and mesoscale measurements of strains and strain rates on the ice. During this period a series of compressions, extensions, and shearing motions occurred, producing numerous changes in ice morphology. The entire area was apparently under considerable lateral constraint with no observable rotation or rounding of floes. No leads wider than about 150 m were present. Shearing motion along one individual lead of up to 280 m was documented by the photographs. Relative motion along shear zones was nearly always dextral or right

lateral in accord with the clockwise rotation of the Pacific Gyral.

0417 HIBLER, W.D., ACKLEY, S., WEEKS, W.F., and KOVACS, A. - 1972
Top and bottom roughness of a multi-year ice floe; *AIDJEX Bull.*, No. 13, Univ. Wash. Seattle, pp. 35-76.
A spectral study of the snow and ice topography on a multi-year ice floe has shown that the snow cover, although attenuating the roughness amplitude of the ice surface, does not cover it completely. In general the snow surface variance is lower by a factor of 1/3 to 1/4 as compared to the ice surface variance. The correlation between snow and ice surface roughness is highly significant for long wavelengths (> 8 m), but fails to be significant for short wavelengths (< 4 m). These results agree with what might be expected intuitively in that long wavelength variations are not masked appreciably while short wavelength variations are well hidden. Although the ice sheet as a whole is in free-floating, isostatic equilibrium, pronounced local deviations from isostatic equilibrium are common. The trend is for ice drafts to deviate more than expected from isostasy for thin ice and less than expected for thick ice. Estimates are also made of the number of ice thickness measurements required to obtain the mean thickness of the multi-year floe to any specified accuracy.

0418 HIBLER, W.D., WEEKS, W.F., ACKLEY, S., KOVACS, A., and CAMPBELL, W.J. - 1971
Mesoscale strain measurements on the Beaufort Sea pack ice (AIDJEX 1971); *U.S. Army Cold Reg. Res. Eng. Lab.*, 15 p.
The deformation of a strain triangle (≈6 x 8 x 11 km) located on first-year ice in the Beaufort Sea was observed over a two-week period in March 1971. Significant strain events (≈1.5%) were observed to occur during short (≈6-hr) time periods. The long-term (one day or more) divergence rate varied between .04 and .08 x 10⁻³ hr⁻¹. Short-term divergence rates showed values as high as .29 x 10⁻³ hr⁻¹. The observed shearing motion indicated that the floes to the east were moving to the south relative to the floes to the west. This agrees with the shear pattern that might be expected considering the location of the station in the Pacific Gyre. Studies of fracture (lead and crack) orientations in the vicinity of the strain triangle indicate reasonable correlations with the orientation of the strain rate ellipse. A qualitative relation is also suggested between the fracture density and the long-term divergence rate. Correlations were also observed between the divergence of the wind field as computed from the surface pressure field and the ice divergence.

0419 HIBLER, W.D., WEEKS, W.F., ACKLEY, S., KOVACS, A., and CAMPBELL, W.J. - 1973
Mesoscale strain measurements on the Beaufort Sea pack ice (AIDJEX 1971); *J. Glaciology*, vol. 12, p. 65, pp. 187-206.
The deformation of a strain triangle (≈6 km x 8 km x 11 km) located on first-year ice in the Beaufort Sea was observed over a two-week period in March 1971. Significant strain events (≈1.5%) were observed to occur during short (≈6 h) time periods. The long-term

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(one day or more) divergence rate varied between 0.04 and $0.08 \times 10^{-3} \text{h}^{-1}$. Short-term divergence rates showed values as high as $0.29 \times 10^{-3} \text{h}^{-1}$. The observed shearing motion indicated that the floes to the east were moving to the south relative to the floes to the west. This agrees with the shear pattern that might be expected considering the location of the station in the Pacific Gyre. Studies of fracture (lead and crack) orientations in the vicinity of the strain triangle indicate reasonable correlations with the orientation of the strain-rate ellipse. A qualitative relation is suggested between the fracture density and the long-term divergence rate. Correlations were also observed between the divergence of the wind field as computed from the surface pressure field and the ice divergence.

0420 HIBLER, W.D., WEEKS, W.F., and MOCK, S.J. - 1971 Statistical aspects of sea ice ridge distributions; *U.S. Army Cold Reg. Res. Eng. Lab.*, 27 p. A theoretical distribution function for pressure ridge sail heights and keel depths is derived from fundamental assumptions about the randomness of the ridges. In addition it is shown that the distribution function for ridge spacings (distance between ridges) can also be predicted from the assumption of spatially random occurrence. The suggested distribution functions are, in form, negative exponentials of the ridge depth (or height) squared and the ridge spacing respectively. Extremely good fits were achieved to extensive data collected from sonar profiles of the lower surface of the pack ice and to laser profiles as well as visual roughness data from the upper ice surface. Using these models it is possible to completely characterize the ridging, in a one-dimensional sense, by two parameters: N , the mean number of ridges per unit length, and h , the mean ridge depth (or height). In addition a linear correlation exists between N and h . This suggests that maps showing the distribution of N or h over a pack ice covered ocean may be used to statistically characterize both the spacing and the height distribution of the ridges.

0421 HOLDSWORTH, G., and TRÄETTEBERG, A. - 1973 The deformation of an Arctic ice island; *in Proc. Sec. Intern. Conf. Port and Ocean Engineering under Arctic conditions*, Univ. Iceland, 21 p. An experiment is described in which a laser interferometer was used to measure the strain rate on the surface of Fletcher's Ice Island T 3, which is a drifting slab of shelf ice averaging 30 m thick and measuring 6 km by 11 km. The island is currently less than 100 km off the north-west coast of Ellesmere Island, and during most of the time of the experiment, it appeared to be gripped in the pack ice. According to Weertman's creep theory the maximum "effective shear stress" is 0.010 MN m^{-2} at the site of the laser experiment. Using current flow law data and some field measurements from Ward-Hunt Ice Shelf, the expected creep rate corresponding to this stress acting within the ice at an average temperature of -8.3°C is in the range 3×10^{-12} to $3 \times 10^{-11} \text{ s}^{-1}$. The preliminary strain rate data obtained over 50 and 100 m line lengths indicates that predominantly compressive stresses were acting in the general direction of the line throughout the

measurements. The compressive strain rates were of order 10^{-11} to 10^{-10} s^{-1} . Superimposed on the compression were cyclical strain oscillations, one of which had an average period of about 35 s. This was close to the average period of beam swing (37 s) of a gravity meter mounted near the edge of the island. These observations are consistent with the existence of flexural waves in the island.

0422 IIZUKA, K. - 1973 Final report (1972-1973) on HISS down looking radar; Dept. Elect. Eng., *Univ. Toronto*, 65 p. A radar which operates on an entirely new principle has been developed by a team of engineers at the University of Toronto. The radar is presently named Holographic Ice Surveying System (HISS) as it was originally designed for measuring the thickness of ice layers. It can be modified, however, for other applications.

At the risk of over-simplification, the principle may be best explained by making an analogy of the case when a boy wants to know how far he can throw a pebble into a pond. He can figure it out just by observing the pattern of the ripples that hit the shore. The farther out the point of impact, the flatter the ripples are when they reach shore, and the greater the spacing between them; so by measuring the spacing between the ripples he can find the distance of his throw.

The down-looking radar bounces microwaves off the ice. Some are reflected from the surface, others penetrate the depth of the ice and are then reflected. By measuring the differences in the two major sets of "ripples" as they return, the depth of the ice can be determined.

In the case of a conventional pulsed radar the distance is determined by the time taken for the radar wave to reach the target and to return, and the time is the key factor in determining the distance. On the other hand, in the case of the HISS radar the spatial distribution of the scattered wave is the one which determines the distance to the target. This is the point that differentiates this radar from all other conventional radars. Because of this unique principle of operation, HISS radar can achieve superiority over any of the conventional pulsed or FM radars.

0423 IIZUKA, K. - 1973 Holographic ice surveying radar; *in Engineering Forum, Fac. App. Sci. & Eng., Univ. Toronto, No. 17*. A radar which operates on an entirely new principle has been developed by a team of engineers at the University of Toronto. The radar is presently named Holographic Ice Surveying System (HISS) as it was originally designed for measuring the thickness of ice layers. It can be modified, however, for other applications.

The principle of the new down-looking radar may be best explained by making an analogy of the case where a boy wants to know how far he can throw a pebble into a pond. He can figure it out just by observing the pattern of the ripples that hit the shore. The farther out the point of impact, the flatter the ripples are when they reach shore, and the greater the spacing between them; so by measuring the spacing between the ripples he can find the distance of his throw.

The down-looking radar bounces microwaves off the ice. Some are reflected from the surface, others penetrate the depth of the ice and are then reflected. By measuring the differences in the two sets of "ripples" as they return, the depth of the ice can be determined.

In the case of a conventional pulsed radar the distance is determined by the time taken for the radar wave to reach the target and to return, time-delay being the key factor in determining the distance.

In the case of the HISS radar, it is the spatial distribution of the scattered waves that determines the distance to the target. This is the point that differentiates HISS radar from all other conventional radars. Because of this unique principle of operation, HISS radar can achieve much higher resolution than any of the conventional pulsed or FM radars. The HISS radar takes full advantage of the capability of the computer to extract the information about the depth of the ice, and hence the construction of the antennae array is substantially simpler than for conventional radars.

The radar measures the thickness of ice up to four meters, which is the maximum thickness powerful ice-breakers can penetrate. It aids ships to find favourable routes. The radar will be used also for finding safe transportation routes across frozen lakes and tundra.

This radar system was invented at the University of Toronto where its development has been financially supported by the Canada Centre for Remote Sensing of the Ministry of Energy, Mines and Resources.

0250 JOHANNESSEN, O.M., POUNDER, E.R., SERSON, H., SMITH, S.D., FINLAYSON, D., KEYS, J., WEBER, J.R., and LANGLEBEN, M.P. - 1970

Cruise report from the ice drift study in the Gulf of St. Lawrence 1970; *McGill Univ. Marine Sc. Centre, Report No. 15*, 53 p.
Abstract under 0250

0424 KOERNER, R.M. - 1970

Ice surface topography in the Arctic Ocean; *Geog. J.*, vol. 136, Part 4, Appendix 1, pp. 527-533.

The scientific programme of the British Trans-Arctic Expedition was designed to make full use of the unique opportunity provided by a complete crossing of the Arctic Ocean. The main objective of the programme was therefore a study of the regional and temporal variation of ice surface topography in the Arctic Ocean. This study, while of interest *per se*, will give further insight into total ice production in the Arctic Ocean at a time when the Arctic Ocean's influence on world climate and glaciation is exciting great interest.

0380 KOERNER, R.M. - 1970

Weather and ice observations of the British Trans-Arctic Expedition 1968-9; *Weather*, vol. 25, No. 5, pp. 218-228.

Abstract under 0380

0425 KOERNER, R.M. - 1971

Ice balance in the Arctic Ocean; *AIDJEX Bull.*, Univ. Wash., Seattle, No. 6, pp. 11-26

The problem of the ice balance of the Arctic Ocean has hitherto been considered indirectly. For example, Vowinckel (1964) determined ice export from a study of wind and current ice drift through the Greenland-Spitsbergen "gate". Ahlmann (1953), by comparing the ice thickness recorded by the *Fram* expedition with that taken by the *Sedov* personnel, concluded a negative balance for the period 1894-1938. With the advent of increasingly sophisticated remote sensing systems, it should prove feasible to determine the ice balance more directly. Put in its simplest form, the ice balance of the Arctic Ocean can be expressed by

$$B = C - A - G \quad (1)$$

where C and A are the accumulation and ablation of ice, G is the ice exported by drift out of the Arctic Ocean, and B is the net balance.

If a continuous record of ice thickness can be taken by remote sensing, then the solution to (1) can be based on data from a series of representative flights over the Arctic Ocean made at the same time each year. This is the "fixed date" method ("Mass balance Terms", *Journal of Glaciology*, 1969) often used in glacier mass balance calculations. Failing this, it will be essential to determine the relative coverage of each ice type and then obtain a best estimate of the mean thickness. From recent work (e.g., Ketchum, 1970) the LASER profiler appears the most promising remote sensor in this respect. There is to date scant information on the distribution of the various ice types in the Arctic Ocean, so that the data recorded by the British Trans-Arctic expedition in 1968 and 1969 are of value if only to bring a better perspective to the problem of ice balance.

0426 KOERNER, R.M. - 1971

Pack ice thickness and ridging; in Workshop on the action of ice on structures, Nat. Res. Council Tech. Mem. No. 101, pp. 37-38.

As the Arctic Ocean pack-ice may occasionally approach very close to shore a knowledge of the morphology of it is important to offshore operations in the Beaufort Sea. From investigations undertaken in the British Trans-Arctic Expedition the coverage of each ice-type, its mean thickness and a total mean thickness have been calculated.

In the Trans-Polar Drift Stream about 75% of the pack-ice is ice more than 1 year old, 17% is unridged ice less than a year old and 14% is ridged or hummocked ice of all ages. In the Gyral, by comparison, there is slightly more old ice and less young ice.

By considering the relative coverage and average thickness of hummocks and ponds on a multi-year floe it is calculated that in the Pacific Gyral a multi-year floe has a mean thickness of 3.5 m. The mean thickness of the whole ice cover, taking into consideration new, old, ridged and hummocked ice varies from 3 1/2 m at the end of the summer to 4 1/2 m at the end of winter.

Ridged and hummocked ice constitute an especial danger to offshore constructions. In the Trans-Polar Drift Stream there are 6 to 7 1-year old ridges a mile. Over half of the ridges are less than 2 m in height and only 1% are more than 5 m high.

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0427 KOERNER, R.M. - 1973

The mass balance of the sea ice of the Arctic Ocean; *J. Glaciology*, vol. 12, No. 65, pp. 173-185. From data taken on the British Trans-Arctic Expedition it is calculated that 9% of the Arctic Ocean surface between the North Pole and Spitsbergen was hummocked or ridged ice, 17% was unridged ice less than a year old, 73% was unridged old ice and 0.6% was ice-free. The mode of 250 thickness measurements taken through level areas of old floes along the entire traverse lies between 2.25 and 2.75 m. The mean end-of-winter thickness of the ice is calculated to be 4.6 m in the Pacific Gyral and 3.9 m in the Trans-Polar Drift Stream. From measurements of the percentage coverage and thickness of the various ice forms, it is calculated that the total annual ice accumulation in the Arctic Ocean is equivalent to a continuous layer of ice 1.1 m thick. 47% of this accumulation occurs in ice-free areas and under ice less than 1 year old. 20% of the total ice production is either directly or indirectly related to ridging or hummocking. An ice-ablation rate of 500 kg m⁻² measured on a level area of a multi-year floe is compared with the rate on deformed and ponded ice. Greatest melting occurs on new hummocks and least on old smooth hummocks. The annual balance of ice older than 1 year but younger than multi-year ice is calculated from a knowledge of ice-drift patterns and the percentage coverage of first-year ice. The same calculations give a mean-maximum drift period of 5 years for ice in the Trans-Polar Drift Stream and 16 years in the Pacific Gyral. It is calculated that for the period February 1968 to May 1969 the annual ice export was 5,580 km³.

0428 KOVACS, A. - 1972

On pressured sea ice; in *Proc. Sea Ice Conference*, Reykjavik, pp. 276-295. The formations and configurations of pressure-related sea ice-structures are discussed. Cross-sectional profiles of five structures are presented and described. It has been determined that the depth of the below-water portions of a ridge appears to be 4 to 5 times the above-water height, that a single model can not be expected to represent the imperfect symmetry of all ridges, and that the slope of ridge keels was found to average 33° while that of the surface averaged 24°.

0429 KOVACS, A., WEEKS, W.F., ACKLEY, S., and HIBLER, W.D. - 1971

Structure of a multi-year pressure ridge; *AIDJEX Bull.*, Univ. Wash., Seattle, 11 p. Three transverse profiles across a large pressure ridge located in the Beaufort Sea are presented. The ridge sail extended 4 m above sea level and the ridge keel 13 m below. The cross-sections of the ridge keel can be described as roughly semi-circular. This suggests that form drag coefficients for flow transverse to the long axes of multi-year ridges may be high (≈ 1.0). The ice comprising the ridge is extremely massive. All the inter-block voids that initially existed in the ridge at the time of its formation have been completely filled with ice. Examination of several salinity, temperature and brine volume profiles shows that much of the ice in

the ridge has a very low salinity and is quite strong. These observations, coupled with icebreaking experience indicate that multi-year ridges are, indeed, significant obstacles to even the largest icebreaking ship and should be avoided if possible. A very large first year ridge with a sail height of 12.8 m is also described. To the best of our knowledge, this is the largest free floating ridge yet recorded.

0430 KOVACS, A., WEEKS, W.F., ACKELY, S., and HIBLER, W.D. - 1973

Structure of a multi-year pressure ridge; *Arctic*, vol. 26, No. 1, pp. 22-31. Three transverse profiles across a large pressure ridge located in the Beaufort Sea are presented. The ridge sail extended 4 m. above sea level and the ridge keel 13 m. below. The cross-sections of the ridge keel can be described as roughly semi-circular. This suggests that form drag coefficients for flow transverse to the long axes of multi-year ridges may be as high as 0.8. Examination of several salinity, temperature and brine-volume profiles shows that much of the ice in the ridge has a very low salinity and is quite strong. All the inter-block voids that initially existed in the ridge at the time of its formation have been completely filled with ice. These observations, coupled with icebreaking experience indicate that multi-year ridges are, indeed, significant obstacles to even the largest icebreaking ship and should be avoided if possible. A very large first year ridge with a sail height of 12.8 m. is also described. This is the largest free-floating ridge yet measured.

0431 LANGLEBEN, M.P. - 1971

Albedo of melting sea ice in the southern Beaufort Sea; *J. Glaciology*, vol. 10, No. 58, pp. 101-104. Two Kipp hemispherical radiometers mounted back to back and suspended by an 18 m cable from a helicopter flying at an altitude of about 90 m were used to make measurements of incident and reflected short-wave radiation. The helicopter was brought to a hovering position at the instant of measurement to ensure that the radiometers were in the proper attitude and a photograph of the ice cover was taken at the same time. The observations were made in 1969 during 16 flights out of Tuktoyaktuk, Northwest Territories (lat. 69°26'N., long. 133°02'W.) over the fast ice extending 80 km north of Tuktoyaktuk. Values of albedo of the ice cover were found to decrease during the melting period according to the equation $A = 0.59 - 0.32P$ where P is the degree of puddling of the surface.

0432 LANGLEBEN, M.P. - 1972

A study of the roughness parameters of sea ice from wind profiles; *J. Geophys. Res.*, vol. 77, No. 30, pp. 5935-5944. Measurements of wind speed at five heights in geometric progression to a maximum of 4 meters were made in the Arctic for a 3-week period in the spring of 1971 at the junction of two ice floes of differing surface morphology. About 150, or 30%, of the 1-hour wind profiles conformed to the requirements of conditions of near-neutral stratification of the

boundary layer. Values of roughness length z_0 and of drag coefficient C_{10} for the wind at the 10-meter level were found to vary with wind direction, depending on whether the wind reached the site after flowing over relatively smooth ice or over rough ice.

For an upwind fetch over smooth ice in the sectors 52° - 63° and 77° - 115° , z_0 had average values of 0.051 and 0.053 cm, and C_{10} had values of $(1.66 \pm 0.08) \times 10^{-3}$ and $(1.69 \pm 0.05) \times 10^{-3}$. When the upwind fetch was over the rough ice from the sectors 240° - 283° and 284° - 327° , the corresponding values of z_0 were 0.28 and 0.30 cm, and the values for C_{10} were $(2.42 \pm 0.06) \times 10^{-3}$ and $(2.46 \pm 0.04) \times 10^{-3}$.

0433 LANGLEBEN, M.P., and POUNDER, E.R. - 1964
Arctic sea ice of various ages I Ultimate strength II Elastic properties; *J. Glaciology*, vol. 5, No. 37, pp. 93-105.

I. A comparison of polar ice (several years old) with biennial ice (between one and two years old) was made in the field at lat. 79°N ., long. 104°W . Vertical cores were extracted from the ice cover and sectioned. Their ultimate tensile strengths were measured by the ring-tensile method. Supporting measurements were made of the salinity, density, and crystal structure of the ice. Tensile strength values averaged 6 per cent higher for the polar ice and 21 per cent higher for the biennial ice than comparable results for annual sea ice. A few horizontal cores of biennial ice were analysed similarly with inconclusive results.

II. Young's modulus E and Poisson's ratio σ_0 were calculated for biennial and polar ice from measurements of the P-wave velocity in small samples and from a study of the resonant frequencies of the same samples. P- and S-wave velocities in the biennial ice cover were also found by a seismic method. The small-scale tests showed no significant differences between the two types of ice tested. Young's modulus averaged 3.6 per cent lower than the comparable figure for annual sea ice. The seismic method gave values of E and σ_0 about 20 per cent lower than the small-scale tests.

0434 LANGLEBEN, M.P., and POUNDER, E.R. - 1972
On the air drag of an Arctic ice floe; *abst.*, Amer. Geophys. Union, San Francisco.
Measurements of wind speed were made between 31 Mar. and 12 Apr. with sensitive cup anemometers at five heights in geometric progression from 25 cm to 4 m above the surface of a gently hummocked ice floe at each of two observation masts which were placed 250 m apart at the site of the main camp of the 1972 AIDJEX pilot experiments. The data were averaged for one-hour periods and have been used to determine the air drag coefficient on the 64 occasions when the vertical profile of wind varied logarithmically with height and to study the horizontal homogeneity of the wind field in the boundary layer. Mean values of the drag coefficient, for winds extrapolated to the 10 m level, were 1.58×10^{-3} at one location with a standard deviation for an individual value of 0.19×10^{-3} and $1.74 \times 10^{-3} \pm 0.25 \times 10^{-3}$ at the other. The distribution of horizontal wind gradients, in % per 100 m, averaged over the 4 m surface layer had a mean value of 2.00 ± 1.41 when logarithmic

wind profiles were obtained at both locations, and a mean value of 7.74 with a very much larger spread of ± 14.64 when neither location exhibited a logarithmic wind profile.

0435 LINDSAY, D. - 1966
Ice Island; *Ice*, No. 20 pp. 8-9.

0436 LINDSAY, D. - 1969
Report to the Workshop seminary on ice and related studies; *in* Marine Sci. Centre Report No. 13, McGill Univ., pp. 55-64.

The first portion of the ensuing report will summarize the immediate past, and the present and the future sea ice programs conducted by the Polar Continental Shelf Project (PCSP). This will be followed by a second section describing the sea ice atlas to be published by the PCSP. The drift of a few ice islands in the Canadian sector of the arctic will be generalized in the third part.

0437 LINDSAY, D.G. - 1969
Ice distribution in the Queen Elizabeth Islands; *in* The Ice Seminar, Can. Inst. Min. & Met. Spec. vol. 10, pp. 45-60.
The general summer sea ice conditions in the straits and channels of the Queen Elizabeth Islands are outlined and the seasonal variations are indicated. Patterns of break-up, movement and freeze-up are discussed and the area of sea ice exported, imported and ablated in specific areas is described.

0071 LINDSAY, D.G., COLBY, L.R., and ROOTS, E.F. - 1968
Report on tests carried out in connection with the 1968 Arctic voyage of Alexbow-equipped barge L.A. Learmonth; *Polar Cont. Shelf Proj.*, internal report, 18 p.

0438 LINDSAY, D., SEIFERT, W., and ANDERSON, N. - 1968
Ice Islands, 1967; *Arctic*, vol. 21, No. 2, pp. 103-105.

0262 MILNE, A.R. - 1966
Statistical description of noise under shore-fast sea ice in winter; *J. Acoust. Soc. Amer.*, vol. 39, No. 6, pp. 1174-1182.
Abstract under 0262

0263 MILNE, A.R. - 1972
Thermal tension cracking in sea ice: a source of underice noise; *J. Geoph. Res.*, vol. 77, No. 12, pp. 2177-2192.
Abstract under 0263.

0264 MILNE, A.R., and CLARK, S.R. - 1964
Resonances in seismic noise under Arctic sea-ice; *Bull. Seis. Soc. Amer.*, vol. 54, No. 6, pp. 1797-1809.
Abstract under 0264.

0265 MILNE, A.R., and GANTON, J.H. - 1964
Ambient noise under Arctic-Sea ice; *J. Acoust. Soc. Amer.*, vol. 36, No. 5, pp. 855-863.
Abstract under 0265.

SEA ICE RESEARCH

0266 MILNE, A.R., GANTON, J.H., and McMILLIN, D.J. - 1967

Ambient noise under sea ice and further measurements of wind and temperature dependence; *J. Acoust. Soc. Amer.*, vol. 41, No. 2, pp. 525-528. Abstract under 0266

0275 POULIN, A.O. - 1972

On the thermal nature and sensing of snow-covered Arctic terrain; unpub. Ph.D. Thesis, McGill Univ., 235 p. Abstract under 0275.

0439 ROOTS, E.F. - 1964

Ice Islands; *Ice*, No. 14, p. 10.

0440 ROOTS, E.F. - 1970

The Arctic Basin environment; *Arctic Inst. N. Amer.*, Appendix II, pp. 51-60.

0441 ROOTS, E.F. - 1971

The movement of constrained sea ice; in Workshop on the action of ice on structures; Nat. Res. Council Tech. Mem. No. 101, pp. 25-30. There have been very few careful studies of the movement of unbroken "land-fast" or constrained sea ice. Among the few is the continuing series of measurements carried out by Dr. P.F. Cooper on the one-year ice of Kugmallit Bay, at the east edge of the Mackenzie River delta. Each year since the winter of 1965-66, as circumstances and other duties have permitted, Dr. Cooper has observed the fracture pattern, measured the movement of ice at intervals during the winter, and recorded meteorological or other influences that may have influenced the behaviour of the ice. This slight but valuable study has produced unique information about the behaviour of a large homogeneous sheet of constrained ice. The study of the constrained ice of Kugmallit Bay began as a private investigation resulting from Dr. Cooper's concern about why the shoreline at the village of Tuktoyaktuk should sometimes be marked by an open crack and sometimes by a persistent pressure ridge, apparently regardless of the local wind direction. This difference of behaviour was of considerable significance to the local inhabitants who used the ice for motorized or dog sled travel and sometimes found access from the shore very difficult.

0442 ROOTS, E.F. - 1971

Shore fast sea ice; in Workshop on the action of ice on structures, Nat. Res. Council Tech. Mem. No. 101, pp. 8-20.

Most concepts associated with ice carry a confusing and often colourful series of terms as men from different backgrounds and engaged in a wide range of activities have tried to describe the various characteristics of this deceptively simple and familiar substance. The idea of shore fast sea ice is no exception. The idea is self-evident:- sea ice fastened along the shore. But what is it? - a kind of ice? - any kind of ice found in certain locations? - fastened to what, for how long, how "fast"? - what is the "shore"? A check on polar and ice literature and glossaries will show that different people have

found it useful to distinguish shore fast sea ice in different ways for different purposes.

0443 WEBER, J.R., and LILLESTRAND, R.L. - 1971
Measurement of tilt of a frozen sea; *AIDJEX Bull.*, Univ. Wash., Seattle, No. 6, pp. 1-9.

Due to the effects of winds, ocean currents, tides, and atmospheric pressure gradients and density changes in the water, the surface of the ocean is tilted relative to the equipotential surface of the earth. It has been estimated that local tilts of up to 10^{-4} radians may occur in coastal waters or near the eye of a hurricane. Extended tilts in the open ocean are probably less than 10^{-5} radians. No technique has yet been developed for measuring the tilt of an ice-free open ocean. However, it is possible to measure the tilt of a water surface relative to its local equipotential surface at the point of observation if the water is ice-covered.

0444 WEEKS, W.F., KOVACS, A., and HIBLER, W.D. - 1971
Pressure ridge characteristics in the Arctic coastal environment; in Proc. First Int. Conf. Port and Ocean Eng. under Arctic Conditions, Tech. Univ. Norway, vol. 1, pp. 152-182.

The arctic ice pack is characterized by extreme irregularities in ice thickness which are produced by the motion and resulting deformation of the sea ice. Pressure ridges and hummocks, which are the largest of the ice relief features, present formidable problems to both the design of off-shore facilities and to the operation of surface and subsurface shipping. The mechanics of ridge and hummock formation are reviewed and it is shown that several distinct types of ice deformation features occur depending upon whether the formation mechanism is marginal crushing, overthrusting or shearing. Between 1969 and the present a number of both free-floating and grounded ridges have been examined by the authors in the Bering, Chukchi and Beaufort Seas. Profiles of the upper and lower surfaces of the ridges were determined by leveling and by drilling and sonar, respectively, and the internal structure of the ridges was investigated by coring. Ice temperatures, salinities, and densities were obtained and brine volumes were computed from the temperatures and salinities. Representative profiles are presented. The present results of this program are:
1. The degree of bonding between ice blocks and, therefore, the overall structural integrity of ridge keels would appear to be variable, presumably changing with the age of the ridge and the initial temperature of the ice being incorporated into the ridge. It can be shown that during the winter the cold reserve of ice blocks being incorporated into a ridge can be sufficient to cause significant inter-block ice growth.
2. Lack of local isostatic adjustment is common in ridges. A significant portion of the ridge load is apparently supported by the surrounding ice resulting in its deflection. When ridges form by thrusting, their upper and lower portions may be laterally separated by tens of meters. This obviously results in a nonisostatic condition which is compensated by deflections of the local plate ice.

3. A representative salinity for the ice in the ridges we examined was $4^{0}/_{00}$ for first-year ridges and $3^{0}/_{00}$ for multi-year ridges. The temperature profiles were reasonably linear except in the lower parts of ridges with pronounced keels where temperatures were roughly constant at near freezing values.
4. Present information indicates that the average surface slope angle of the above-water portion of a first-year ridge (24°) is less than that of the sub-surface slope (33°). The average surface slope angle of the one multi-year ridge studied was 19° .
5. Multi-year ridges were found to be massive in size and "solid" when cored.
6. Ridges act as effective snow fences, causing large amounts of snow to accumulate both in and around their upper parts.
7. It appears doubtful that the cross-section profiles of all ridges can adequately be represented by any one geometric model.

Current data bearing on the general distribution of deformation features in time and space over the Arctic Ocean are also summarized. The data sources include the BIRDSEYE flights, recent special laser profilometer flights, and sonar traces of the lower ice surface. Prime attention is paid to the ridging characteristics in the Coastal and Offshore Sea Ice Provinces where the ice is clearly more highly deformed than the ice in the Central Arctic Basin Province. Winter and summer distributions of both sail heights and keel depths as well as the number of ridges per nautical mile are presented. Power spectra based on both laser and sonar profiles indicate marked periodicities at some spacings on both the surface and subsurface ice profiles. Although the physical reasons for some of these periodicities are understood (Sastrugi) the reason for peaks at distances such as 82.5 m in the bottom profiles is currently unknown. There are also strong indications that ridge orientation in the Coastal Province is not random. A frequency distribution of ridge keels is derived on general statistical grounds and is fitted to 49 sets of observed distributions with excellent agreement. Using this observed distribution, the probability of encountering a ridge with a keel greater than some specified value in a given length of ice pack can be approximated by a Poisson distribution. An encounter probability for keels of different depths as a function of time and the velocity of the pack is obtained. A mean lifeline calculation based upon this encounter probability is given.

- 0445 WELLER, G., BOWLING, S.A., JAYAWEERA, K.O.L.F., OHTAKE, T., PARKER, S., SHAW, G., and WENDLER, G. - 1972

Studies of the solar and terrestrial radiation fluxes over Arctic pack ice; *Geophys. Inst. Univ. Alaska*, Tech. Rep. No. 2 ARPA order No. 1783, 74 p. Our studies have to date concentrated on determining the physical characteristics of pack ice and clouds as they affect the arctic radiation regime. At Barrow, flights through stratus clouds with aircraft-mounted continuous cloud particle samples have determined number and mass density particle size distribution and ice crystal contents. Simultaneously, light intensity and reflectivity measurements have been carried out to determine the optical properties

of these clouds. Aircraft-mounted photometers have provided measurements that will allow deductions of aerosol profiles up to 13,000 feet; on two occasions these were extended up to 35,000 feet aboard flights by the NASA CV-990 aircraft to the AIDJEX camp in the Beaufort Sea. In addition to measurements of ice nuclei concentrations at Barrow, actinometric observations through frequently thick ice crystal clouds advected from open leads were made on numerous occasions on the AIDJEX camp. Routine monitoring of components of the radiation balance have been carried out at Barrow, Ice Island T-3 and the AIDJEX camp. Of particular interest were the measurements over refreezing leads, both artificially made and natural ones, showing extraordinary modification of the radiation balance during the freezing process. To synthesize all observations, theoretical and computer modeling is playing an increasingly important part in our work.

- 0046 WELLER, G.E., SHAW, G.E., PARKER, S.D., and GOLDTHWAIT, T.B. - 1972

Arctic Ice Dynamics Joint Experiment-AIDJEX; in Annual Report, Geophys. Inst., Univ. Alaska, pp. 18-19. AIDJEX is a multi-disciplinary, multi-institution program sponsored by the Office of Polar Programs of the National Science Foundation, the Office of Naval Research, other U.S. Federal agencies and the Canadian Government. Its purpose is to study in detail the stress and deformation of the pack ice in the Arctic Ocean and to provide solutions to a broad spectrum of theoretical and applied problems, ranging from improved ice forecasting for ship traffic to the determination of the effects of pack ice dynamics and stability on global weather and climate. A large-scale pilot study during March and April, 1972, has been successfully completed at three manned stations, set up 500 km north of Barrow on the pack ice of the Beaufort Sea. The main experiment, to last a full year, will take place during 1974. We have participated in the pilot study by examining the radiative characteristics and transfer processes of the various surface forms of pack ice, including open leads, pressure ridges and hummocks, and of the arctic atmosphere. The different surface features vary appreciably in the amounts of radiative energy they exchange with the atmosphere. In the case of open leads, net energy supply to the atmosphere, mainly provided by infrared radiation, exceeded that of multi-year ice by more than an order of magnitude. These factors have an important effect, not only on the modification of the atmospheric boundary layer, but also on the climate of the Arctic Basin as a whole.

SURVEYING

- 0447 HUNT, F.P. - 1959
Winter surveying with the Polar Continental Shelf Project; in Report of Proceedings, Conf. Commonwealth Survey Officers, 1959, pp. 77-81.
- 0251 JOHNSON, G.W., and LILLESTRAND, R.L. - 1972
Deviation of solar culmination from meridian transit in polar regions; *The Can. Surveyor*, vol. 26, No. 4, pp. 357-368.
Abstract under 0251

SURVEYING

0448 LILLESTRAND, R.L. - 1969

Interim report on Project NORD-1969: position of Kaffeklubben Island; internal report to Polar Cont. Shelf Proj. by Control Data Corp. 31 p.
The objective of Project Nord-1969 was to establish cartographic control points in Northern Greenland in the region north of 80°N latitude. As a result of work performed during Project Nord-1968 as well as work done by others in prior years, a series of ground control points had previously been established. The uniformity of these points, however, left much to be desired. It was, therefore, our goal during the 1969 program to fill in several of these areas where very little ground control was available. We were particularly interested in the region extending from Kaffeklubben Island to the west, since this was within the range of accessibility of our aircraft which was stationed at Alert. Based on measurements made on April 18, 1969, the computed position of the northern extremity of Kaffeklubben Island was found to be

LATITUDE = 83° 40.1' N
LONGITUDE = 30° 37' W

Based on measurements made during Project Nord-1968 and 1969, as well as other earlier measurements, we have adopted a provisional value for the northern extremity of Cape Morris Jesup of

LATITUDE = 83° 39.7' N
LONGITUDE = 33° 25' W

These results place Kaffeklubben Island a distance of about 0.4 nautical mile further north than Cape Morris Jesup, and as such it becomes the most northerly point of land discovered thus far. In longitude this places Kaffeklubben Island about 18.5 nautical miles (or 2° 18') to the east of Cape Morris Jesup.

0449 LILLESTRAND, R.L. - 1970

Letter on the accuracy of Peary's position fix at Cape Morris Jesup, Greenland; *Can. Surveyor*, vol. 24, No. 2.

0258 LILLESTRAND, R.L. - 1970

General constant of refraction when using a Roelofs prism; *Control Data Corp.*, internal report CDC TM95243-6, 17 p.
Abstract under 0258

0450 LILLESTRAND, R.L., and JOHNSON, G.W. - 1971
Cartography of North Greenland; Surv. & Mapping, vol. 31, No. 2, pp. 233-250.

Northern Greenland is one of the few remaining parts of the world where large mapping errors are known to exist. The magnitude and direction of these errors are given for two basic map series. This is done by combining astronomic and satellite position observations at widely separated sites in northern Greenland (north of 80°N latitude) with position data from other sources. The results of this work indicate map errors up to 15 nautical miles and lead to the conclusion that northern Greenland is approximately 2500 square nautical miles larger than heretofore shown. In addition to describing field operations and results, a brief cartographic history of this part of the world is presented.

0451 LILLESTRAND, R.L., JOHNSON, G.W., and WELLS, D.E. - 1968

Analysis of measurements made in northern Greenland during Project Nord-1968; *Control Data Corp.*, Minneapolis, 99 p.

During this investigation a number of ground control points were established which will aid in the drawing of more accurate maps of northern Greenland. As a result of comparisons with existing maps we find a more or less consistent displacement of the east coast (above 80°N) averaging about 10 n. miles is necessary for map rectification. In north central Greenland errors tend to be smaller and without any particular pattern. On the west coast less data is available but a displacement ranging up to six or seven n. miles toward the west on some maps is indicated. As a result of these changes the size of northern Greenland is larger than present maps show by an amount which is about 2500 square nautical miles.

A considerable amount of effort was expended during this project in gathering together other sources of data. These have helped in forming a more complete picture of map deviations and are generally consistent with the pattern of errors revealed by our measurements. Most existing maps for this region are based, in part, on older data collected during the 1900 to 1925 time period. Surprisingly, in certain locations the older maps show greater conformity with the results of recent studies than do more recently drawn maps. This occurred in the area of Ingolfs Fjord, Kap Eiler Rasmussen, and Kap Morris Jesup.

0452 LILLESTRAND, R.L., ROOTS, E.F., NIBLETT, E.R., and WEBER, J.R. - 1970

Position of Kaffeklubben Island; *Can. Surveyor*, vol. 24, No. 1, 6 p.

Based on measurements made during the Spring and Summer of 1969, we have obtained a value for the latitude of the northern extremity of Kaffeklubben Island of 83°40'.0N. Our measurements show that the northern extremity of Cape Morris Jesup, Greenland, is 83°39'.8N. These results place Kaffeklubben Island a distance of 0.2 nautical miles farther north than Cape Morris Jesup and, as such, it becomes the most northerly point of land discovered thus far. Kaffeklubben Island is 18 nautical miles to the east of Cape Morris Jesup.

0453 SEBERT, L.M. - 1970

The history of the 1:250,000 map of Canada; *Can. Cartographer*, vol. 7, No. 1, pp. 15-26.
This paper traces the progress and development of the 1:250,000 map series of Canada from its inception in 1923 through to publication of the final map sheet in 1970. Originally, the maps were published at 1:253,440 up until 1949 when, by international agreement, Canada converted its basic map series from duodecimal scales to the present 1:50,000, of a national mapping program to a uniform sheet-line system that replaced the previous uncoordinated mapping of the country by different government agencies. The author discusses the selection of a map projection for the series, former topographic mapping methods, the development of the photo-topographic technique, the impact of air photography on the mapping of Canada, and the extension of ground control.

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