GEOPHYSICAL AND GEOLOGICAL EXPLORATIONS IN THE ARCTIC OCEAN REGION

Summary of the most important expeditions
and surveys that have contributed to the geophysical
and geological knowledge of the Arctic Ocean

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INTRODUCTION

This is a summary of the important expeditions and surveys that have contributed to geophysical and geological studies of the Arctic Ocean, carried out from ships, ice stations and submarines. For a more complete history of the geographical discovery and scientific exploration of the Arctic Ocean region the reader is referred to chapter 2 in Decade of North American Geology, Volume L: The Arctic Ocean Region by Weber and Roots (in press), where additional references to the activities described in this article will be found.

I have divided the text into three periods: Early Explorations, the period of sailing ships, dog-sledding and manhauling, from Phipps' eighteenth century expedition to Stefansson's Canadian Arctic Expedition; Modern Explorations, the period that started with Papanin's 1937 flight to the North Pole, in which aircraft, icebreakers and submarines became the standard means of transportation; and The Cooperative Era, the period of multi-institutional, multinational expeditions, from LOREX and Fram I to the present. The most important of these expeditions and surveys that have been carried out in the Arctic Ocean region from the beginning to the present are listed in Table I.

All the place names mentioned in the text are indicated on the maps in Figure 1 (Amerasia Basin) and Figure 2 (Eurasia Basin). These two bathymetric maps were compiled by the author for the book The Arctic Seas, edited by Y. Herman (Weber, in press).

EXPEDITIONS AND SURVEYS IN THE ARCTIC OCEAN REGION

Phipps (Spitsbergen, Fram Strait)	1773
Nordenskjöld <u>Vega</u> (Northeast passage)	1878-79
Nansen <u>Fram</u> (Eurasia Basin)	1893-96
Storkerson (Beaufort Sea)	1918
Papanin (Eurasia Basin - Fram Strait)	1937
<u>Sedov</u> (Eurasia Basin)	1937-40
Soviet airborne expeditions (Mendeleev Plain)	1941
Soviet NORTH-Series airborne expeditons (annual)	1948-
Soviet NORTH POLE-Series drifting stations (ongoing)	1950-
U.S. airborne expeditions (Amerasia Basin)	1951-52, 1960-69
U.S. drifting ice stations:	
<u>Fletcher's Ice Island</u> (<u>T-3</u>)	1952-74
<u>Station Alpha</u>	1957-58
<u>Station Charlie</u>	1959-60
<u>ARLIS II</u>	1961-65
U.S. submarine expeditions (unclassified)	1957-62
British submarine expedition <u>Sovreign</u>	1975, 1976
U.S. seismic ships' surveys:	
<u>Burton Island</u> (Alaskan-Chukchi shelf)	1951, 1965
<u>Staten Island, Northwind</u> (Alaskan shelf)	1957
<u>S.P. Lee</u> (Alaskan Shelf)	1977
<u>Polar Star</u> (Northwind Ridge)	1988
Canadian bathymetric & gravity surveys (polar shelf)	1960-83, 1985-87
Norwegian bathymetric surveys (Barents Sea)	1945-
Canadian North Pole Expeditions	1967,1969
AIDJEX (Beaufort Sea)	1975-76
LOREX 79 (Lomonosov Ridge)	1976
Fram I to IV operations (Eurasia Basin)	1979-82
CESAR 83 (Alpha Ridge)	1983
<u>Hobson's Choice</u> Ice Island (Queen Elizabeth Shelf)	1984-
Cruises of scientific research ships:	
<u>Hudson</u> (Beaufort Sea)	1970
<u>Ymer</u> (Eurasia Basin)	1980
<u>Polarstern</u> (Eurasia Basin)	1987
Landbased continental shelf seismic transects	1961, 1965, 1967

<u>Table I</u>

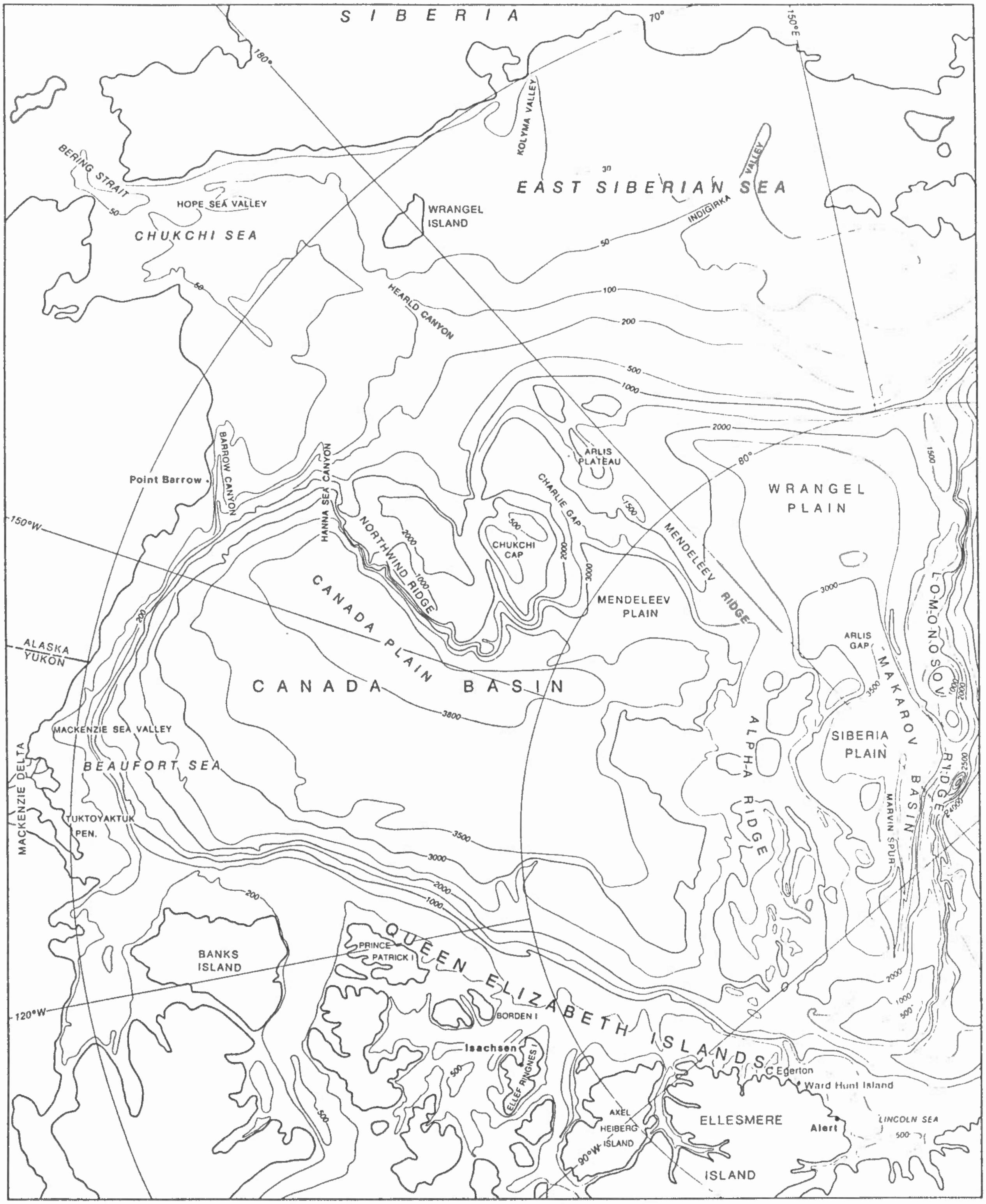

Figure 1. Bathymetric map of the Amerasia Basin. Except for some modifications of the contouring over the Alpha Ridge, based on CESAR data, the contours agree with those of Perry et al. (1986).

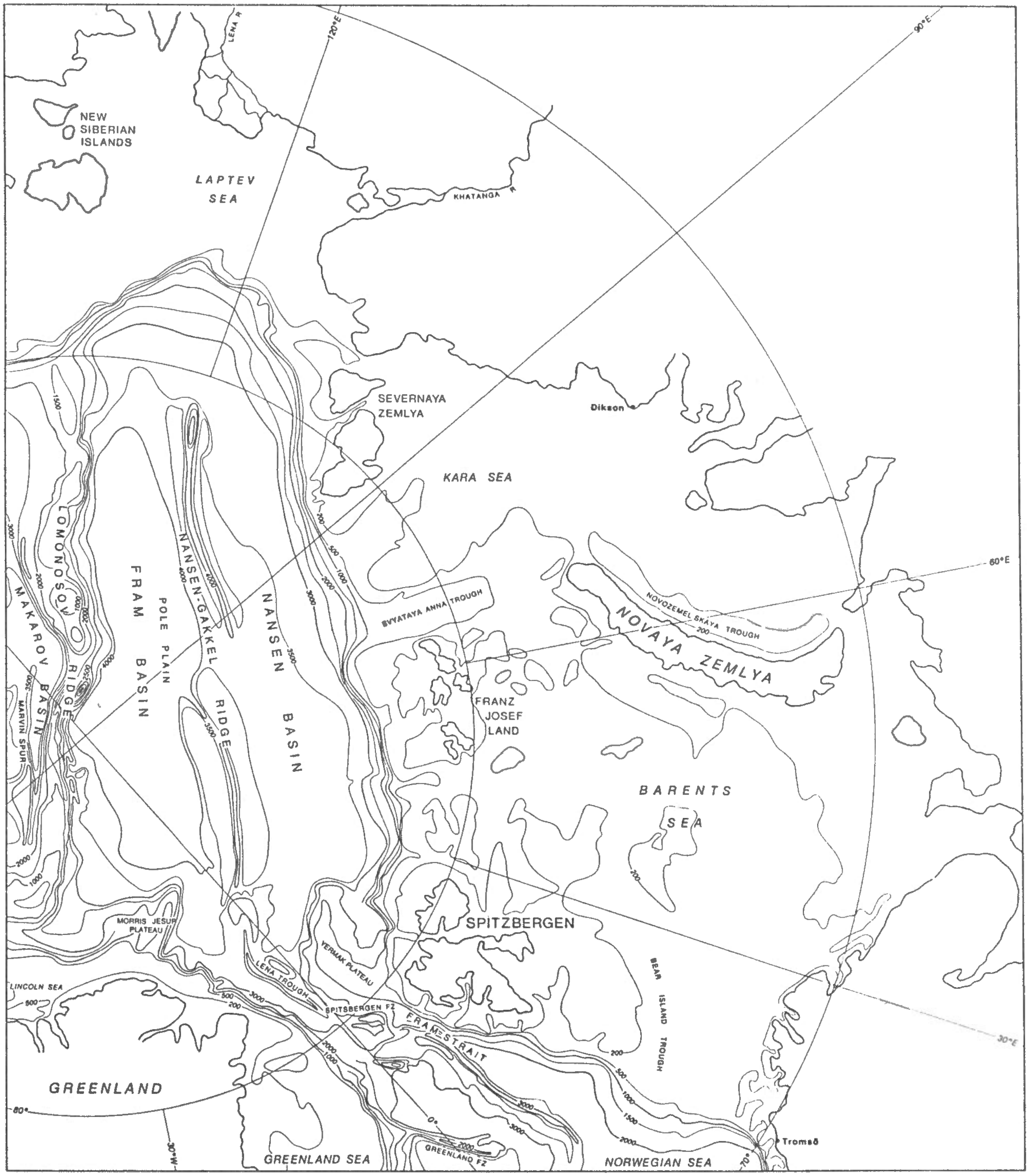

Figure 2.. Bathymetric map of the Eurasia Basin. The contouring of the Nansen-Gakkel Ridge has been modified and differs from Perry et al. (1986).

EARLY EXPLORATIONS 1773-1918

Phipps 1773

The first truly scientific attempt to penetrate the Arctic Ocean was the voyage lead by the Hon. Captain Constantine John Phipps in 1773. The plan was for "a voyage made towards the North-Pole to be of service to the promotion of natural knowledge" and was sponsored by the Royal Society of London and approved by the Admiralty and George III. According to the views held at the time the polar pack ice was formed by river water that emptied into the Arctic Ocean and was confined to regions near shore; it was believed that the central Arctic Ocean was ice-free. The expedition is little known because it had limited interest for geographers and historians. The two sloops Racehorse and Carcass explored the ice edge between Greenland and Spitsbergen, but were stopped by heavy ice north of Spitsbergen and made no new geographical discoveries. However, it is outstanding in its scientific preparation and execution, and it was perhaps the first truly multidisciplinary field research expediton in the modern sense: its program included studies in oceanography, hydrography, magnetism, gravity, meteorolgy, and a full range of biological observations.

Among the better known geoscience results of Phipps' expediton were the measurement of the difference in the force of gravity between northernmost Spitsbergen and Greenwich, the first measurements of the West Spitsbergen and East Greenland currents, and the first temperature and salinity profiles and depth soundings of Arctic Ocean water. On their return, investigators presented their results directly to the Royal Society and other scientific organizations. Phipps' voyage provided the first scientific information on the Arctic Ocean and Fram Strait, and its scientific success set the pattern for 19th century Arctic and Antarctic expeditions.

Nordenskjöld, 1878-1880

From 1878 to 1880 the Swedish explorer, Baron A.E. Nordenskjöld circumnavigated Asia by sailing his 357-ton steam and sailing ship, Vega, from Tromsö, Norway, along the northeast passage into Bering Strait, while scientists from five nations carried out research in geography, oceanography, geology, meteorology and biology. The Vega overwintered in a secure island anchorage, which Nordenskjöld named Dikson Island. He correctly prophesied that the anchorage would "one day be of great importance for commerce of Siberia". The site is the modern port of Dikson. The Vega's voyage along the coast provided information on the Siberian continental shelf and a reconnaissance of the natural history of the Arctic Ocean region.

Nansen, 1893-1896

From 1893 to 1896 Fritjof Nansen's ship Fram, under the command of Captain Otto Sverdrup, drifted with the pack ice from near the New Siberian Islands across the Eurasia Basin to near Spitsbergen. Scientists on board made meteorological, auroral, magnetic and astronomical observations, took depth soundings, measured water temperature and salinity (using Nansen bottles), and collected biota. They also carried two Sterneck four-pendulum gravity apparatus on board with which they made the first gravity measurements at sea. The results showed that the free-air anomalies did not significantly differ from those observed on continental lowlands. From this, the physicist O.E. Schiöltz reasoned that the mass deficiency of the water must be compensated at depth, thereby confirming Airy's hypothesis on isostasy. These are, a century later, still the only published gravity measurements from that part of the Eurasia Basin.

On the basis of the Fram bathymetric data, many oceanographers concluded that the Arctic Basin was a single oceanic deep. However, the American oceanographer R.A. Harris postulated from tidal observations, in 1904, that the Arctic Ocean was divided by a ridge into two separate deep basins.

Stefansson, 1914, and Storkerson, 1918

In 1914, during his Canadian Arctic Expedition, Vilhjalmur Stefansson made wire-line soundings on an over-ice journey from Martin Point, near the Yukon-Alaska border, to Banks Island. In 1918, Storker Storkerson, a member of Stefansson's expedition, occupied, for several months, an ice island measuring 7 by 15 miles in the Beaufort Sea. He made oceanographic and glaciological observations and took numerous depth soundings. There is a little known sequel to these wire-line soundings. Both Stefansson and Storkerson had only a limited amount of wire (911 and 1386 m, respectively). Where the water depth exceeded the wire length, the figures on their charts gave minimum, not actual depths. It appears that the Soviet cartographers in their 1954 bathymetric map compilation misinterpreted the soundings as water depths and interpreted the Beaufort Sea as being underlain by a wide, albeit deep, continental shelf. This "Beaufort Terrace", as it was called, was copied on all later bathymetric maps until 1968.

MODERN EXPLORATIONS 1937-1978

Soviet Activities

Papanin, 1937

On May 7, 1937, a Soviet expedition, under the leadership of Ivan Papanin, was air-lifted to the North Pole. During the next nine months Papanin and his three companions carried out oceanographic, magnetic and gravity measurements while their ice floe drifted across the Eurasia Basin and through Fram Strait. They were picked up by an icebreaker near Jan Mayen Island in February, 1938. This Soviet expedition marked the beginning of the use of aircraft in Arctic exploration.

Soviet airborne expeditions, 1941

During April 1941, personnel from the Soviet Arctic Institute made three successive flights from Wrangel Island in a ski-equipped four-engine aircraft and established three stations in the region of Wrangel and Mendeleev abyssal plains. They occupied each station from 4 to 5 days, taking soundings, measuring water temperature and salinity, and sampling the water column and the sea bed.

NORTH-Series

In 1948 the Soviet Arctic Institute began a program of systematic exploration of the whole Arctic Ocean, carrying out what they called "High Latitude Air Expeditions". Aircraft landed parties at a number of points on the floating ice during periods of about six weeks in the spring. While the aircraft waited, salinity, temperature, bathymetric, magnetic, gravimetric and meteorological observations were made and sediments were collected from the seafloor. The stations were occupied from a few hours to a few days. The Soviet survey revealed that, far from being a flat abyssal plain, the Arctic Basin has a very complicated structure with depressions, submarine ridges and plateaus. The most significant discovery was made on April 17, 1948, in the central basin, where a relatively shallow depth of 1290 m was recorded. Later soundings revealed the outline of a massive submarine mountain range that rises 3000 m above the sea floor and extends 1800 km from Ellesmere Island to the New Siberian Islands. The Soviet investigators named this feature Lomonosov Ridge. The discovery of the Lomonosov Ridge was kept secret until the publication in 1954 of the first Soviet bathymetric map of the Arctic Ocean. These spring-time, High Latitude Air Expeditions, later re-named NORTH-series, have taken place each year from 1948 to the present.

NORTH POLE-Series

In 1950 the Soviet NORTH POLE-series operations, involving the use of ice camps, were initiated. In contrast to the annual, short-period NORTH-series projects, the NORTH POLE (NP) stations are occupied from one to several years either until they exit into the Atlantic Ocean via the Greenland current, or they otherwise lose their usefulness. By 1960, the year when NP-10 was launched, the Soviets had obtained some 20,000 depth soundings and published their second bathymetric map. Geophysical information and sea-bottom samples had been obtained at many of the hydrographic sounding stations.

The NORTH POLE-series are still in operation today. In 1983, during the CESAR Expedition, a party of Canadian scientists visited NP-25, which was located some 300 km west of the CESAR study site. In the spring of 1988, NP-28, then located in the vicinity of the North Pole, was host to a reception for the Soviet-Canadian Polar Bridge Ski Expedition, which was also attended by the Canadian Minister of Energy, Mines and Resources, the Hon. Marcel Masse.

Studies carried out on the NORTH- and NORTH POLE-series operations include meteorology, bathymetry and various geophysical, geological, oceanographic and biological investigations. Unfortunately, many of the data collected on these operations, such as bathymetry and gravity, are classified. The results of most other investigations are scattered throughout the Soviet literature and have not been translated into western languages; they are, in general, not easily accessible to western readers.

<u>American activities</u>

Airborne expeditions

In April 1951, U.S. scientists joined in the exploration of the Arctic Ocean by mounting two airborne, brief-landing type expeditions to the Beaufort Sea. Using ski-equipped DC-3 aircraft, they carried out a number of oceanographic observations north of Alaska between latitudes 73° and 76°. Other investigations also included seismic refraction and reflection soundings, gravity measurements and determination of the ice drift. The observations showed that water temperature and salinity values differed significantly from those obtained by Nansen on the <u>Fram</u>. From these observations, the American oceanographer L.V. Worthington concluded, in 1953, that "there is a submarine ridge, running roughly from Ellesmere Island to the New Siberian Islands, that separates the deepest water of the Beaufort Sea from the remainder of the basin", and that "the sill depth of the ridge should not exeed 2300 m". The Americans were unaware of the Soviet NORTH- and NORTH POLE-series operations and that the Lomonosov Ridge had been discovered five years earlier.

U.S. airborne reconnaissance surveys were resumed in 1960 by the Geophysical and Polar Research Center of the University of Wisconsin. Using Cessna 180 aircraft, they landed on the ice of the Beaufort Sea, Chukchi Sea and Canada Basin to take soundings and gravity measurements. This program was carried out each spring for ten years. By 1969 more than 800 stations had been established.

Drifting ice stations

The brief-landing type airborne surveys were supplemented in 1952 by year-round occupation of drifting ice floes and ice islands. The best known of the ice islands is Fletcher's Ice Island, or T-3, and was occupied at various intervals between 1952 and 1974. Other drifting stations were established on the ice floes Alpha (1957/58) and Charlie (1959) and on the ice island ARLIS II (1961-65). T-3 and Alpha, equipped with precision depth recorders, served as U.S. stations during the International Geophysical Year (IGY) . In addition to bathymetry, investigations from the drifting stations included meteorology, gravity, magnetics, seismic reflection and refraction, heat-flow measurements, seabed sampling, underwater photography, oceanography, ice dynamics, glaciology, study of sound propagation in ice and water, and biological observations. From T-3 alone, 580 seabed cores were collected. Station Alpha was occupied during a 3000 km drift across the Mendeleev Plain and part of a major ridge which was mapped in comparative detail and subsequently named Alpha Ridge. From 1961 to 1965 ARLIS II made an almost complete circuit of the Arctic Basin, drifting across the Chukchi Cap, Mendeleev Plain, Alpha Ridge, Makarov Basin, Lomonosov Ridge, Fram Basin and Morris Jesup Plateau. These U.S. operations on drifting ice stations, carried out over a period of 22 years, yielded a tremendous amount of data on the morphology, sediment cover, shallow structure, gravity field and heat flow of the Amerasia Basin.

AIDJEX

Most notable in research from drifting ice stations during the early and mid- seventies was the Arctic Ice Dynamics Joint Experiment (AIDJEX), a project in which logistics and some funding was provided by the Polar Continental Shelf Project. Although AIDJEX was primarily concerned with the interaction of atmosphere, ice cover and fluid ocean, the Earth Physics Branch of the Canadian Department of Energy, Mines and Resources(EMR) also carried out geophysical studies. Recording echo sounders, gravimeters and magnetometers were operated at the 1972 and 1975/76 main camps, and a crustal seismic refraction survey was conducted. The refraction data showed that the basin is underlain by oceanic crust.

Two years later, U.S. investigators conducted a seismic refraction survey in the Beaufort Sea some 200 km to the west of the AIDJEX survey. The results confirmed the presence of an oceanic crust below the Canada abyssal plain. These are the only seismic refraction data from the Canada Basin.

Submarine expeditions

Between 1957 and 1962, U.S. nuclear powered submarines criss-crossed the Arctic Ocean. Detailed sounding profiles along the submarine tracks gave a wealth of new information about the morphology of the basin. Positioning of the submarines was obtained by dead-reckoning, by the ships' inertial navigation system, and by celestial fixes when possible. The data from the depth sounders were used extensively in the compilation of bathymetric maps, although inaccuracies in the positioning of these early submarine tracks resulted in positional errors of up to 70 km. The echograms confirmed for the first time in some detail the existence of the Nansen-Gakkel Ridge, which had been predicted by Heezen and Ewing eight years earlier on the basis of earthquake epicenters. All U.S. submarine-collected bathymetric data since 1963 have been classified.

Canadian activities

The Polar Continental Shelf Project

Some 40 years after Stefansson's Canadian Arctic Expedition, Canadian exploration of the Arctic Ocean Basin resumed, in 1955, with the Geological Survey of Canada's Operation Franklin, a geological reconnaissance of the Canadian Arctic Archipelago (Fortier et al., 1963). The operation included airborne magnetometer and scintillometer surveys across the continental shelf into the Canada Basin. Operation Franklin demonstrated the need for concerted and systematic investigations of the geology, geophysics, oceanography and bathymetry of the area and led, indirectly, to the creation, in 1958, of the Polar Continental Shelf Project (PCSP or 'Polar Shelf'). The success of this project placed Canada among the leaders of Arctic Ocean research. Since its establishment, the Polar Shelf has supported some 3000 research projects conducted by governments, universities and industry, and by other agencies and individuals.

"Camp 200" Activities

Since 1960, as part of the Polar Shelf program, the Canadian Hydrographic Service and the Gravity Division of the Earth

Physics Branch, formerly the Dominion Observatory, have been conducting joint bathymetric and gravity surveys over the Arctic continental shelf and inter-island channels. In the course of seven separate seasons, betweeen 1961 and 1970, base camps on the pack ice served as forward bases for hydrographic and gravity surveys over the continental shelf and for oceanographic, marine geological and biological studies. All of the continental shelf has now been charted (Fig. 3). The first camp, situated some 200 miles (320 km) from Polar Shelf base in Isachsen, on Ellef Ringnes Island, acquired the radio call sign "Camp 200"; a name that was retained for all the offshore ocean camps.

The 1967 and 1969 North Pole expeditions

In 1967 and 1969 the then Dominion Observatory conducted two small-scale expeditions, supported by Polar Shelf, to the vicinity of the North Pole . These were the forerunners for the LOREX and CESAR expeditions (described later). Investigations included the testing of new astro- and satellite-navigational methods, and sonar ranging from the ocean floor. Plumbline deflection measurements and gravity observations suggested that the nearby Lomonosov Ridge had deep, low-density roots, which supported the hypothesis that the ridge is a continental fragment.

Hudson 70

The Canadian government research vessel CSS Hudson, in 1970, completed a scientific voyage during which North and South America were circumnavigated. Hydrographic, oceanographic, geological, geophysical and seabed sampling surveys of the Beaufort Sea were carried out during the voyage. Sonar and seismic profiling results for the first time revealed the presence of numerous submarine pingos and the effects of ice scouring on the seafloor.

Crustal studies over the North American continental Margin

A Geological Survey of Canada seismic party, in 1961, completed a refraction profile that extended along the west coast of Ellef Ringnes Island and 50 km onto the continental shelf. In 1965, seismologists from the Dominion Observatory conducted an unreversed crustal seismic refraction profile from Brock Island, between Prince Patrick and Borden islands, and 192 km on to the continental shelf. Two years later they completed a similar 220 km long profile on to the continental shelf from Prince Patrick Island. The results from the three surveys showed a thinning of the crust seaward across the margin,

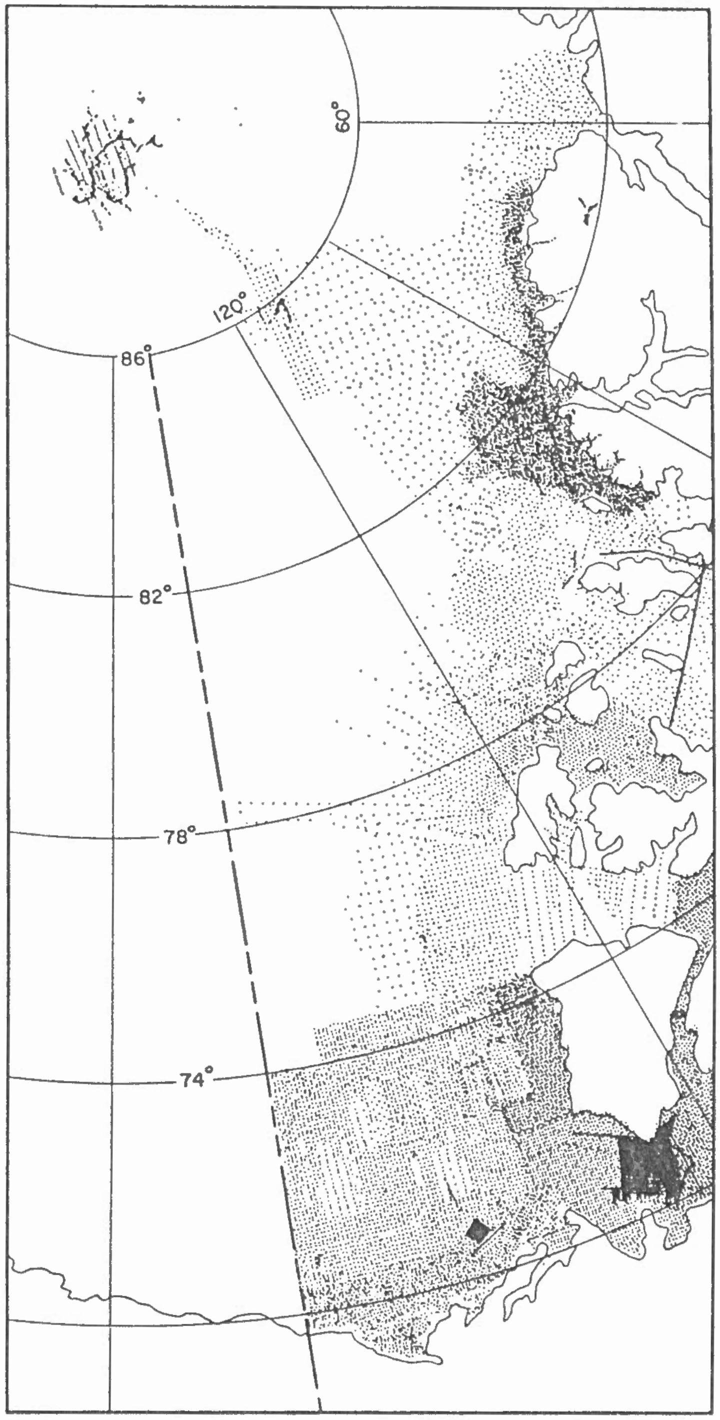

Figure 3. Plot of Canadian bathymetric and gravity stations established on the Arctic Ocean and adjoining inter-island waters as of 1987.

supporting other evidence for an oceanic origin of the Canada Basin.

In 1961, seismologists from the University of Wisconsin and Lamont Geological Observatory shot a 320 km long reversed seismic refraction profile, parallel to the continental shelf, from Pont Barrow to the ice island ARLIS II which was then in the Chukchi Sea. Four years later, using the ice breaker USS Staten Island as a base, U.S. Navy seismologists shot an unreversed seismic refraction profile from Point Barrow across the continental margin into the Beaufort Deep. A thinning of the crust from some 30 km to 15 km was determined.

A shipborne offshore seismic reflection survey was conducted in 1977 by the U.S. Geological Survey along the Alaskan continental shelf and slope from the Chukchi Sea to the Canadian border. Results suggested that the Beaufort Sea is bordered by an Atlantic-type continental margin.

Norwegian bathymetry

The first Norwegian bathymetric maps of the Western Barents Sea were published in 1919. Regular bathymetric surveys of the Barent Sea, north of 74°N, have been carried out by the Norwegian Polar Institute since WW II. Since 1963, using a Decca HiFix navigational system, Norwegian ships attached to the Norwegian Polar Institute, the Petroleum Directorate and the Fisheries Research Institute have collected bathymetric data over the continental shelf of the Barents Sea as far east as Novaya Zemlya. These data were incorporated into Perry and Fleming's bathymetric map of the Arctic Ocean produced in 1986. In 1984 the resposibility for bathymetric surveys was transferred to the Norwegian Hydrographic Survey.

THE COOPERATIVE ERA: 1979-

The year 1979 marks the beginning of a new era in Arctic Ocean science: one of unprecedented cooperation, both among institutions and nations and between scientific disciplines. The cooperation is in part due to necessity - arctic logistics have become very expensive and for most are affordable only through pooling of resources - but it also reflects the widespread acceptance that the interaction of physical, chemical and biological processes regulates, not only the polar regions, but the total Earth system. Geophysics and geology, especially, have played an important role in recent, advances in knowledge and understanding of the planet.

Drifting ice stations

LOREX 79 Expedition

In 1979, the Department of Energy, Mines and Resources (EMR) conducted an expedition to the vicinity of the North Pole to study the nature and origin of the Lomonosov Ridge, codenamed LOREX 79 for Lomonosov Ridge Experiment. The study was coordinated by the former Earth Physics Branch, with logistic support by Polar Shelf and the Canadian Armed Forces. Over a two-months period some 42 scientists and technicians representing 11 government and university institutions from Canada and the U.S. cooperated in the fields of geophysics, marine geology, navigation, ice dynamics, acoustics, physical and chemical oceanography and biology. The geophysical and geological studies confirmed the hypothesis that the Lomonosov Ridge is a continental sliver that broke off the Barents and Kara continental margins.

The Fram Operations, 1979-1982

From 1979 to 1982 the U.S. Office of Naval Research sponsored four spring-time, multidisciplinary, multinational expeditions (Fram I to Fram IV) into the Eurasia Basin. The investigators, which included scientists and technicians from the Geological Survey of Canada, carried out geophysical, geological, hydroacoustic, physical and chemical oceanographic, biological and sea-ice studies. It was found that the ocean crust near the Nansen-Gakkel Ridge is very thin and is accreting at a rate of less than 1 cm per year. This rate is lower than any other known active spreading ridge.

The CESAR 83 Expedition

In 1983, encouraged by the success of LOREX, the Department of Energy, Mines and Resources sponsored the Canadian Expedition to Study the Alpha Ridge (CESAR). The expediton was of about the same scale as LOREX, and was again coordinated by the Earth Physics Branch and supported by Polar Shelf and the Canadian Armed Forces. The scientific program, conducted by several Canadian government agencies and by Canadian and U.S. universities, was similar to that carried out on LOREX. Results of the geophysical and marine geological investigations suggest that the eastern part of the Alpha Ridge may be a massive accumulation of mafic rocks formed by the passage of a ridged crust over a hot spot.

Hobson's Choice

In 1984, Polar Shelf established a research station on a large, tabular iceberg, or ice island, then located off the mouth of Nansen Sound (between Axel Heiberg and Ellesmere islands). The ice island, as T-3 nearly forty years previously, had broken off Ward Hunt Ice Shelf and was the first large tabular floe to become available since the early 1960's. It was accordingly nicknamed Hobson's Choice (after Thomas Hobson, who in the seveteenth century, in Cambridge, England, owned livery stables and let horses in strict order according to their position near the door - "a choice of taking what is offered or nothing at all". Thomas Hobson, however, is no known relation of George Hobson, Polar Shelf's director from 1972 to 1987!).

Geophysical and marine geological work undertaken from the island has included single-shot seismic reflection from an array across the island, sediment sampling and sea-bottom biology. The island has also been used as a base for bathymetric and gravity surveys over the continental shelf and margin and for seismic refraction surveys over the continental shelf. By July, 1988, Hobson's Choice had moved southwest to a position off Ellef Ringnes Island. It is expected that over the next two to four years it will drift along the North American continental margin to the Chukchi Sea, and across the Chukchi Cap, as did its predecessor, T-3.

Cruises of Scientific Research Ships

Ymer 80

In 1980, in commemoration of Nordenskjöld's 1878-1880 circumnavigation of Asia in the Vega, the Swedish government sponsored a scientific cruise that was carried out in the ice breaker Ymer through Fram Strait, over the Yermak Plateau, and into Barents Sea. Researchers from nine countries cooperated in studies comprising marine biology, oceanography, marine geology, geophysics, air chemistry, meteorology and glaciology.

Polarstern

In 1987 the German research vessel RV Polarstern of the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, succeeded in penetrating the pack ice of the Eurasia Basin to within 424 km of the North Pole. Fifty scientists and technicians from ten countries carried out a complex program of oceanographic, meteorologic, biologic and geoscientific studies. This was the first time a modern mobile research platform reached the central part of the Eurasia Basin. Preliminary studies of the 7 to 9 m long sediment cores revealed a sedimentation rate of 40 mm/ka, and detailed seismic studies of the Nansen-Gakkel Ridge disclosed a deeply incised, block-faulted ridge valley that is more than 5500 m in depth. The Polarstern cruise included investigators from the Geological Survey of Canada.

Sibir

The same year (1987), starting from Murmansk, the Soviet nuclear powered icebreaker Sibir succeeded in reaching the North Pole. On the way to the Pole she visited the Soviet ice station NP-27 land supplies and exchange personnel. According to a magazine article (Tschertkow and Kaminski, 1987) the cruise included scientific observations. This was the second Soviet icebreaker to reach the North Pole; the first ship to reach the top of the world was the nuclear powered Arktika in 1977.

Polar Star

In September, 1988, the U.S.Coast Guard icebreaker Polar Star conducted a geophysical and geological survey over the southern part of the Northwind Ridge. Investigators from the U.S. Geological Survey obtained seismic reflection and refraction, and sea gravity meter profiles, carried out individual gravity measurements, and collected box and piston cores. Preliminary results suggest that the Northwind Ridge - Chukchi Cap complex was once part of an ancestral Chukchi or East Siberian continental shelf and was rifted by locally acting plate-tctonic processes to its present position (Grantz, 1988).

COMMENTARY

Phipps' expediton into the fringe of the Eurasia Basin in 1773 marked the beginning of Arctic Ocean research in the modern sense - that is, scientific investigations were carried out for their own sake. Earlier expeditions were primarily voyages of geographical exploration carried out for political or commercial reasons, although some included scientific studies.

The International Polar Year of 1882-83, about a century later, saw a rigorous, synchronized program of observations on selected subjects at a few high latitude sites, but none of these lay in the Arctic Ocean. The wealth of oceanographic, geophysical, geological and biological data collected by Nansen's expedition in the Fram across the Amerasia Basin, a decade later, remained the only scientific data from the Arctic Ocean Basin until the Soviet investigations of the late 1930's and early 1940's. The use of aircraft, pioneered by the Soviets, marked a revolution in Arctic Ocean research; it made possible the establishment and maintenance of drifting ice stations which have been drifting across the Arctic Ocean continuously from 1950 to the present.

The advent of the LOREX and Fram I expeditions in 1979, two centuries after Phipps' led the first scientific expedition into the Arctic Ocean, initiated the beginning of an era of multidisciplinary, multi-national and multi-institutional research. Increasingly, the Arctic Ocean region is being viewed in a global setting. Studies no longer focus on the Arctic Ocean alone, but include such global subjects as tectonics, upper atmosphere and magnetosphere research, dynamics of the water masses and their interaction with Atlantic and Pacific waters, oceanic and atmospheric transport of chemicals into and out of the polar regions (Adams et al., 1987; Roots, 1988), to mention just a few. The study of Arctic Ocean water and atmosphere play a key role in the global sense of the International Geosphere-Biosphere Program (IGBP).

Considerable credit for advances in our knowledge of the Arctic Ocean region that have taken place during the last quarter century must be given to the the Polar Continental Shelf Project. Without Polar Shelf hundreds of research projects might never have taken place, and Canadians might still have but a minor part in Arctic Ocean research. Polar Shelf helped Canada to the forefront of Arctic research, through its participation in, or contribution to, most major Arctic Ocean research projects of the last two decades (AIDJEX, the Fram Operations, Eurasia Basin Experiment (EUBEX), Marginal Ice Zone Experiment (MIZEX), the U.S. Arctic Buoy Program, etc.). Today, very few organizations outside the USSR, regardless of nationality, would undertake a major research project in the Arctic Ocean region without consulting, or seeking advice or assistance from Polar Shelf. In fact, PCSP has become a circumpolar organization.

Major advances in Arctic Ocean geophysics and geology will be made in the future through such ativities as:

(1) making year-round use of <u>Hobsen's Choice</u> while the ice island is drifting around the Canada Basin, by upgrading its technical facilities (computers, navigation, installation of a SEA BEAM type sounding device, data link to the south) and by soliciting participation of investigators from other countries on a cost-sharing basis. Important is the reaching of an agreement with the Soviet authorities on shared use of the facilities before the island moves into the Soviet sector.

(2) carrying out carefully selected and planned cooperative programs to attack well defined major problems, either from the ice or from icebreakers.

(3) extending the Ocean Drilling Program (ODP) into the Arctic Ocean region.

New technologies, such as the global positioning navigational system (GPS) and Arctic remote sensing, will help to push back the frontier of our knowledge on the Arctic Ocean regions.

During the last three decades the Department of Energy, Mines and Resources has played an active role and has contributed enormously to Arctic science and especially to the understanding of the geological and tectonic processes that have formed the Arctic Ocean Basin. It is hoped that EMR will continue to play a leading role in the scientific exploration of the Arctic Ocean region.

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