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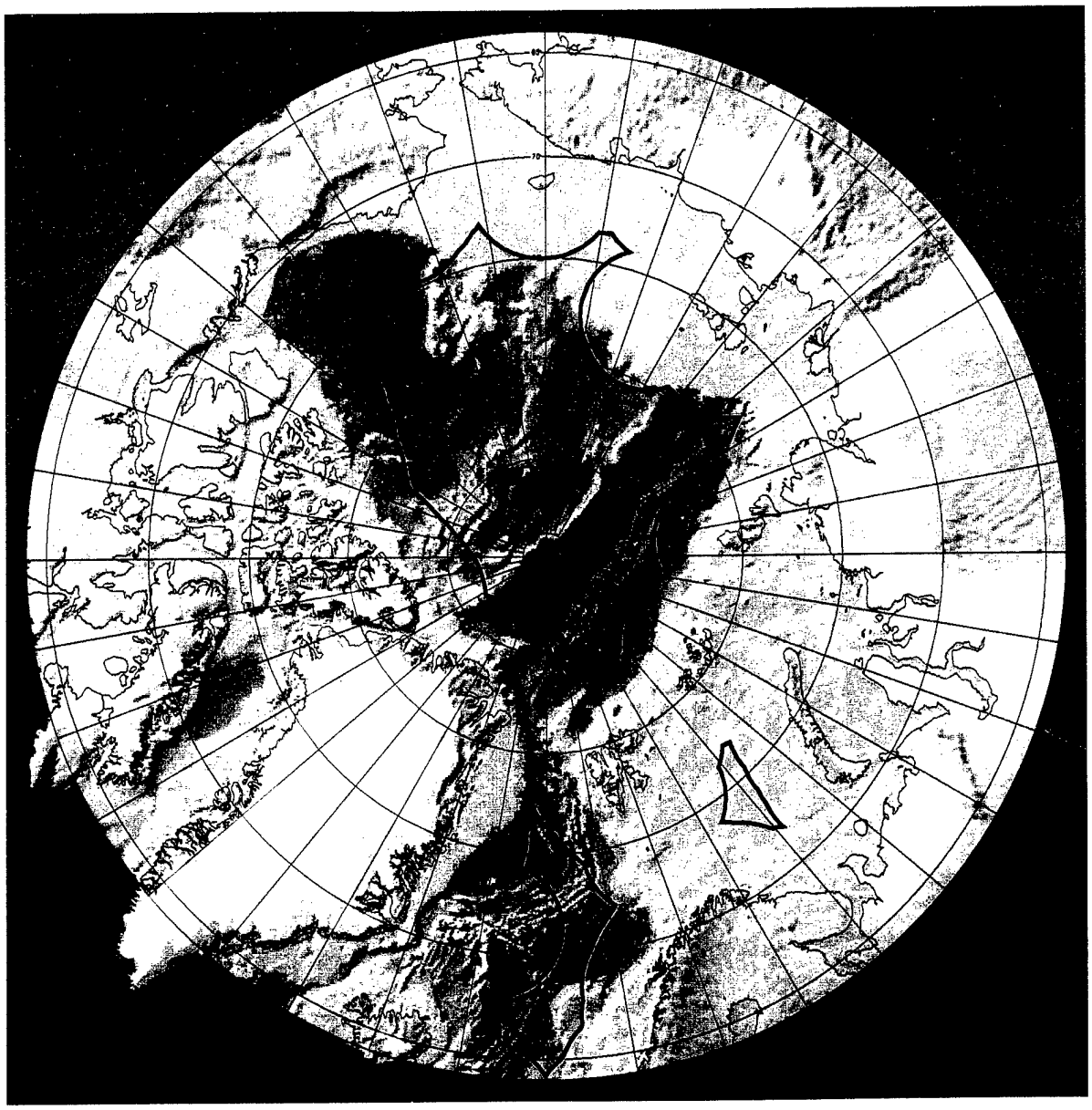
# IOC/IASC/IHO Editorial Board for the International Bathymetric Chart of the Arctic Ocean

## Report of Meeting: Copenhagen, Denmark; October 19-20, 1998





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# IOC/IASC/IHO
# Editorial Board for the International Bathymetric Chart of the Arctic Ocean

*Report of Meeting*
*Copenhagen, Denmark*
*October 19-20, 1998*

*Chairmen:*

***Ron Macnab***
*Geological Survey of Canada*
*Dartmouth NS, Canada*

***Arne Nielsen***
*Royal Danish Administration*
*of Navigation and Hydrography*
*Copenhagen, Denmark*

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Geological Survey of Canada Open File 3713
January, 1999

***Cover figure**: Computer-drawn version of Sheet 5.17 of the General Bathymetric Chart of the Ocean (GEBCO), which has provided a standard for Arctic bathymetry since 1979 (Geological Survey of Canada, 1994). This example portrays shaded relief of the land and seabed north of 64N, and corresponds approximately to the area encompassed by a proposed digital data base that will serve among other purposes to construct a replacement for Sheet 5.17. The magenta lines represent the approximate limits of the three International High Seas zones in the study area. All maritime areas outside these limits (excluding the Gulf of Bothnia) fall within the jurisdiction of six coastal states: Canada, Denmark, Iceland, Norway, Russia, and the United States of America.*

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## PRELIMINARIES

**Welcoming remarks: Admiral Søren Torp Petersen, Director-General of RDANH**
(delivered at the Gendarmen Cafe/Restaurant)

Gentlemen and colleagues,

The Royal Danish Administration for Navigation and Hydrography is honoured to host this the second Arctic Bathymetry Workshop.

This Workshop as well as the first one held in St. Petersburg, Russia, in September of 1997 is one result of a marvellous co-operation between the International Arctic Scientific Committee, the International Hydrographic Organization and the Intergovernmental Oceanographic Commission.

The International Hydrographic Organization and the Intergovernmental Oceanographic Commission have co-operated for many years under the GEBCO umbrella and have achieved great results concerning the compilation and production of bathymetric charts of the oceans. These compilations, however, are time consuming. Any supplementary initiative taken to speed up the process is warmly welcomed.

The action taken by the International Arctic Scientific Committee to develop a digital database that contains all available bathymetric data north of 64 degrees N is one such initiative - and a very important one.

The Arctic Ocean may hold the key to the proper understanding of the development of the climate on this planet. Over the past 10 years or so we have learned that the residence time of the water in the deeper parts of the World Ocean may be as low as 500 years and not 2000 years as we have thought previously. The proper representation of the bathymetry of the ocean is crucial in this context. Therefore, the initiative taken by the International Arctic Scientific Committee is important and appreciated.

The active commitment from IHO and IOC should guarantee the success of the project. However, dear colleagues - just to be on the safe side - there is no harm in drinking to the success of the joint efforts of the International Arctic Scientific Committee, the International Hydrographic Organization and the Intergovernmental Oceanographic Commission. To the success of the International Bathymetric Chart of the Arctic Ocean ...

**Opening statement: Dr. Dmitri Travin, IOC**

On behalf of IOC Executive Secretary Patricio Bernal, Dr. Travin welcomed participants and outlined the status and future development of the IOC Ocean Mapping Program. He stressed that Ocean Mapping is one of the more successful IOC projects; Member States of IOC maintain a strong intention to implement Resolution XIX-3 of the 19th Session of the IOC Assembly, and to provide necessary support for the International Bathymetric Chart of the Arctic Ocean (IBCAO).

Dr. Travin thanked Ron Macnab, Chairman of the Editorial Board of the IBCAO, and Arne Nielsen of the Royal Danish Administration of Navigation and Hydrography for their efforts to organize this first meeting of the Board.

**Opening statement: Admiral Neil Guy, IHO**

Noting that IHO and IOC have enjoyed a long and fruitful relationship, Admiral Guy described the Editorial Board as another manifestation of the two organizations' joint commitment to promoting international cooperation in meeting regional challenges, and expressed full support for the task at hand. He spoke of Hydrography's evolving role as a purveyor of bathymetry for a variety of applications that transcend the traditional aspects of safety of navigation, pointing out that much of the information that is collected and used in the production of standard charts can serve other purposes, e.g. scientific and engineering studies, fisheries management, maritime boundary definition, and so forth. Indeed, it was a similar realization that nearly a century ago inspired Prince Albert I of Monaco to establish the General Bathymetric Chart of the Ocean (GEBCO), which continues to provide an authoritative portrayal of the ocean floor on a global basis.

**A historical review: Ron Macnab, GSC**

In recent decades, it has been well recognized that published portrayals of the sea floor north of the Arctic Circle, particularly in the deep central basin of the Arctic Ocean, are not totally accurate, and that in certain areas, there are significant discrepancies between observed and charted depths. The principal cause of this situation has been the lack of sounding information needed to construct reliable and detailed charts: certain regions remain inadequately mapped on account of difficult operating conditions, or because critical data sets have not been made available for widespread public use.

Prospects for improving this state of affairs have brightened considerably in recent years through two important initiatives of the US Navy: (1) the SCICEX program, which since 1993 has been sponsoring unclassified mapping and research missions aboard nuclear submarines operating beneath the polar pack; and (2) the de-classification of historic data sets collected in the same region during submarine patrols beginning in the late 1950's. Whether modern or historic, these sources of information are providing important new insights into the depth and morphology of the floor of the Arctic Ocean, and are making it possible for marine scientists and cartographers to undertake the creation of data bases that can be applied, among other purposes, to the construction and publication of better charts.

The present initiative to create a modern digital data base of Arctic depth observations had its genesis during an informal Workshop held October 16-18, 1996 at the Polar Marine Geosurvey Expedition in St. Petersburg-Lomonosov, Russia. Under the joint chairmanship of Yuri Kazmin of the Russian Ministry of Natural Resources and Ron Macnab of the Geological Survey of Canada, this Workshop assembled specialists from the five coastal states that border the Arctic Ocean (Canada, Denmark, Norway, Russia, and the United States of America) to discuss

scientific and technical issues relating to the preparation of continental shelf claims beyond 200 nautical miles, according to the provisions of Article 76 of the Law of the Sea. Appendix C provides an overview of the deliberations that took place during that Workshop.

The implementation of Article 76 rests fundamentally upon the analysis and interpretation of bathymetric and geological information. During the course of the 1996 Workshop, it was recognized that all five coastal states have valid grounds for developing continental shelf claims beyond their 200 nautical mile limits, and that the possibility, if not the likelihood, existed of overlapping claims between neighbouring states. A unanimous conclusion of the Workshop attendees was that neighbouring claims based upon incompatible data sets would only add to the levels of contention in situations where overlaps existed, and that many problems in this respect could be minimized if claims were based upon common data sets. Hence Workshop attendees recommended that coastal states around the Arctic Ocean consider joint action to develop integrated data bases for continental shelf delimitation by pooling their respective information data holdings.

Subsequent to the 1996 Workshop, parties charged with the implementation of Article 76 in the Arctic Ocean agreed to organize a second technical Workshop that would partially implement the above recommendation by initiating an international collaboration for the development of a modern bathymetric data base. As envisaged, the data base would incorporate in digital form all available bathymetric information north of 64N, for the benefit of mapmakers, researchers, and others whose work requires a detailed and accurate knowledge of the depth and shape of the Arctic seabed.

Invitations to participate were extended to investigators from all nations with interests in Arctic bathymetry, in recognition of the fact that institutions from other than the five coastal states are also involved in important work in the region. Under the sponsorship of the International Arctic Science Committee (IASC), the Workshop was held September 18-19, 1997 at the Institute for Geology and Mineral Resources of the Ocean (VNIIOkeangeologia) in St. Petersburg. It was chaired jointly by Garrik Grikurov of VNIIOkeangeologia and Ron Macnab of the Geological Survey of Canada (Macnab and Grikurov, 1997).

Participants at the 1997 Workshop described the contents and status of their Arctic bathymetry data sets, and agreed upon a broad plan for consolidating some or all of these data sets into a single, coherent data base. Participants also nominated national representatives from among their midst to serve as members of a proposed IASC Project Group for Arctic Bathymetry. With IASC backing and support, it was further agreed to seek formal affiliation with the Intergovernmental Oceanographic Commission (IOC) and with the International Hydrographic Organization (IHO), on the grounds that formal endorsement by these organizations would lend weight and credibility to the project while raising its profile in the appropriate sectors of the international community.

In the months following, Odd Rogne, Executive Secretary of IASC, oversaw the necessary transactions and communications to formalize IOC and IHO affiliations, whereupon the IASC Project Group was re-named the *IOC/IASC/IHO Editorial Board for the International*

*Bathymetric Chart of the Arctic Ocean* (EB-IBCAO). Recognizing the position of Iceland as the sixth coastal state north of 64N, representation from that country was added to the Editorial Board at about the same time. The present composition of the Editorial Board is listed in Appendix D.

## REPORTS

### Sergei MASCHENKOV, VNIIOkeangeologia

*New digital bathymetric compilations at VNIIOkeangeologia*

A computer derived model of sea-floor topography of the North Eurasian shelf and High Seas Arctic has been built at VNIIOkeangeologia (St. Petersburg) on the basis of digital compilation of bathymetry data. The data base contains depth measurements collected in the course of aircraft supported and shipborne geophysical surveys carried out during the past three decades in the Russian Arctic Seas and in the Central Arctic basin (Figure 1). Seafloor depths were measured using echo-sounding and seismic observations with an average error not exceeding 2% of depth. In most areas of the Eastern Arctic (Laptev, East Siberian, and Chukchi Seas) the average distance between point observations is about 10 km; the Western Arctic (Barents and Kara Seas) is covered by shipborne surveys with trackline spacings of about 10 km.

Initial data stored in both map and catalogue forms were digitized, edited and processed using original and commercial software. Additional point observations for the Western Arctic in digital form were received from the US National Geophysical Data Center (Boulder, Colorado) and the Alfred Wegener Institute (Bremerhaven, Germany) and included in the coherent data base. After error-checking and comparing where applicable with published hand-contoured bathymetric maps (i.e. Cherkis et. al, 1991; Matishov et al., 1995) the data were gridded using a minimum curvature with continuous spline tension algorithm (Smith & Wessel, 1990). In some unsurveyed areas the gridded data set was supplemented with existing public domain digital data such as ETOPO5 (Loughridge, 1986), new Arctic Bathymetry and Topography (Oakey et al., 1996), and the GEBCO Digital Atlas (Jones et al, 1994). The final 10x10 km grid has been rendered as a set of shaded relief, color, and contour maps at scale 1:6000000 for the entire Russian Arctic Shelf, using software developed at the Geological Survey of Canada. In several areas the grid was displayed in more detailed scales and utilized for 3-D gravity modeling in order to estimate the gravity effect of seafloor topography.

In a recent development, this bathymetry data base was enhanced with newly digitized GUNiO data in Canada Basin, which were incorporated in the compilation in gridded form with the approval of Russian authorities.

This computer derived model of seafloor relief supplements significantly the existing knowledge of the bathymetry of the North Eurasian Shelf and the Arctic High Seas, and could be used as basic digital information for various geological and geophysical applications.

**Ron MACNAB, Geological Survey of Canada**

*Mapping the channels of the Canadian Arctic Archipelago*

Over the past several decades, the Geological Survey of Canada (GSC) and the Canadian Hydrographic Service (CHS) have collected a significant quantity of observations in the inter-island channels of the Canadian Arctic Archipelago. Efforts began in 1997 to assemble these for use in the overall Arctic compilation, and preliminary results were presented during the last Workshop in St. Petersburg (Figure 2). Since then, attention has focussed on locating and retrieving data sets to fill gaps in the existing accumulation, and on rationalizing the assembled observations through a series of systematic adjustments.

Current coverage still includes blank areas in some channels and inlets, however searches continue through GSC and CHS archives in the expectation of retrieving plotting sheets or digital data sets that will help fill these gaps. In the meantime, the quality and coverage of the adjusted data were deemed sufficient for the purposes of physical oceanographers, whose investigations require a general description of channel morphology with a view to understanding patterns of circulation and water transport between the Arctic Ocean and Baffin Bay. Accordingly, a preliminary 5 km grid has been constructed over the Archipelago and its adjacent waters, and has been provided to modellers for interim use in these studies. Unexpectedly, the same grid has also proved useful to marine biologists who are attempting to understand the migratory patterns of beluga whales.

**Hilmar HELGASON, Icelandic Hydrographic Service**

*Bathymetric mapping and data holdings off Iceland*

Because this is the first meeting where Iceland is represented in the IOC/IASC/IHO Editorial Board for the International Bathymetric Chart of the Arctic, this presentation offers a brief overview of the Icelandic Hydrographic Service (IHS).

IHS is a special department of the Icelandic Coast Guard and is responsible for surveying and charting around Iceland. IHS is divided into three departments: survey, charting, and wholesale. IHS has a staff of twelve people, increasing to sixteen during the survey season. The Service has one 20m survey vessel for coastal surveys, and uses Coast Guard vessels for deep water survey.

Most of the deep water bathymetric data inside the Icelandic EEZ is available in digital form from the GEBCO and GEODAS databases distributed on CD-ROM. In addition to this data, a deep water survey was done in 1972 and 1973 around Iceland. This data is in analog form and has not been digitized so far, but it will be converted as soon as possible. The track lines from this survey are shown as bold lines on Figure 3; the black areas shown near the coast are not current, however the coverage shown in Figure 4 is up to date.

Purple areas in Figure 4 represent the coverage of nearshore digital single beam data. Most of the

other IHS data sets exist in the form of charts and analog records that need to digitized. It will take some time to convert all this information, and it is not known when that task will be completed.

Unfortunately little or no surveying has been done in some areas around Iceland. IHS is aware of different companies and institutes that hold some data from different surveys around Iceland. IHS has been working to obtain all available data for this project, and will continue to do so.

**Garrik GRIKUROV, VNIIOkeangeologia**

*A new 1:5,000,000 Bathymetry Map of the Arctic Ocean, produced by GUNiO*

The Bathymetry Map of the Arctic Ocean was compiled in 1998 by HDNO in close collaboration with VNIIOkeangeologia specialists, for eventual incorporation in "The Atlas of the Oceans". The map encompasses the Polar region in a stereographic projection at 1:5,000,000 scale (at 75N). The 50, 100, and 200 m isobaths are shown on the shelf, whereas farther down the slope and in deep water, the contour interval is maintained at 200 m. The map consists of four A3-size sheets which will be included in the new atlas and published together with the rest of its contents in the foreseeable future.

The map is based essentially on GUNiO data holdings, but also incorporates relevant information contained in GEBCO materials, as well as topographic data from land areas. The bathymetric data coverage includes observations accomplished over more than 4 million square km with a density of no less than 15-20 km between data points, and with much closer spacing in some better studied areas. The accuracy of positioning of data points was 500 m and better, while the precision of depth sounding was 0.5% of the measured depth.

GUNiO and VNIIOkeangeologia have jointly undertaken to print a limited amount of one-sheet copies of this map prior to the publication of the entire Atlas. The first 600 copies (300 in Russian, 300 in English) will hopefully be printed in spring 1999. It is anticipated that part of this amount will be distributed free of charge among national, international and foreign organizations which are involved in the Arctic bathymetry project and/or which may need such due to their activity profile. The remaining copies may have to be offered to interested professional groups and individuals for purchasing at a moderate price in order to compensate, if only partly, for the costs of printing.

**Martin JAKOBSSON, University of Stockholm**

*A bathymetric and topographic grid over the Barents and Kara Sea region*

A grid model representing the bathymetry and topography over the Barents and Kara Sea region has been compiled by using published bathymetric maps from NRL (Naval Research Laboratory, Washington) together with land elevation data from U.S Geological Survey's global land elevation model, GTOPO30. The World Vector Shore line (WVS) was used to represent the coast

shoreline. The model consists of a uniform 1 km X 1 km Cartesian grid of depth and height values. This Cartesian grid is built on a Polar stereographic projection with the true scale at 75 N. Gridding was done in a two step operation by using Intergraph's Terrain Analyst software: 1) Delauney triangulation; 2) Gridding through a planar bicubic interpolation where a plane is fitted through the three vertices of a triangle and the z-value (height or depth) for a grid cell is calculated by solving the equation for the plane. As illustrated in Figure 5, the final model yields a convincing shaded relief portrayal of the Barents and Kara Sea region.

**Norm CHERKIS, US Naval Research Laboratory**

*Treatment of declassified submarine data from 1957-1982*

Since the last meeting in Saint Petersburg, the digital bathymetry for 22 US nuclear submarine tracks in the Arctic region have been obtained. Of these, 17 are considered to be of adequate quality for use in assisting the compilation of a new bathymetric chart of the Arctic Ocean.

Requirements: When the US Navy agreed to release the data to the scientific community, it was with the proviso that the data be "sanitized," removing any and all references to the name of the vessel collecting the data and the dates in which the mission was carried out. Further, the data were to be grouped into three time periods: 1958-1962; 1966-1972; and 1973-1982.

Procedures: Once the classified data were obtained from the Navy, they were reformatted, removing all references to the name of the vessel and the dates of the mission. Thus, the data files were reduced to contain only latitude, longitude and depth. The data were then examined to ensure that only data in the deep Arctic Ocean basin were used. This rule was relaxed for data on the Canadian shelf, since Canada participated in some of the cruises. In the rare instance where tracks may have crossed into the EEZ of another nation, the tracks were terminated at the shelf-break. Because these submarines navigated by using inertial navigation systems, navigation errors crept into the data. Some of these were so severe that the entire cruise data set was discarded. However, as the time period progressed, the navigation was deemed to be of increasingly good quality.

Once the geographic editing was completed, the data were given a cursory examination at points where they crossed. If these crossings generally agreed in depth value, they were retained. In areas where crossover agreement was unsatisfactory, other data (where available) were consulted to try to ascertain the better of the two tracks. If no other data were available, the crossover areas were either eliminated totally along both tracks, or, based upon prior knowledge of the area in question, one track was given a higher weight than the other, and the lower weighted track was eliminated, at least until it regained credibility. Therefore, the data reflect human bias in some cases. However, since bathymetry is normally an interpretive effort, data tends to be used as dictated by instinct. It is unlikely that a gridding procedure could resolve the crossover problem any better.

Dissemination: Release of the data set is imminent. All of the US Navy's requirements have been satisfied, and briefings have been given to the proper offices. It is expected that the data will be placed on a CD (in ASCII form) within a week, and forwarded to World Data Center "A" in Boulder, Colorado for public-domain dissemination. Hopefully, this will occur early in 1999.

Additional information: The Royal Navy has been contacted concerning surface and under-ice echosounding data collected during several cruises of British nuclear submarines in earlier years. The RN has agreed *in principle* to declassify and release these data sets in the same manner, using the requirements set down by the US Navy. However, if released separately, these would be identified only as Royal Navy tracks. Instead, British authorities have proposed that the RN data sets be subjected to the same sanitization procedures as the US Navy data, and that they be included as part of the overall release. The RN data sets are already held in digital form, so the effort would be minimal. This request is completely feasible, introducing a delay of about one week in transmitting the CD to World Data Center "A," while the data sets are sanitized and incorporated data into the database. The public-release letter will be amended to state that the data sets contain Royal Navy submarine data as well as those from US Navy submarines.

It is hoped that this action will prompt owners of other proprietary soundings from the Arctic to follow suit and to release their holdings in a similar, timely fashion.

**Robert ANDERSON, US Arctic Submarine Laboratory**

*U.S. Navy decision to declassify and publicly release additional submarine acquired Arctic bathymetry*

T'he U.S. Navy has recently agreed to the declassification and release of submarine acquired bathymetry data in the Arctic Ocean. Norman Cherkis of Naval Research Laboratory has reported upon the agreement to declassify and release such data acquired between 1958 and 1982; earlier this year, the Navy agreed to declassify and release additional data. The new data set includes all data acquired through the end of 1988, in the area of the Arctic which lies outside non-U.S. Exclusive Economic Zones.

The data sets applicable to the new agreement have been surveyed. About half the data already exist in digital form, and the mechanisms and funding to process the data for declassification and release are in hand. Figure 6 is a chartlet which shows the tracklines within the agreed-upon data release area which exist in digital form. The releasable tracklines comprise about 45,000 km.

The remaining data, the tracklines of which are shown in Figure 7, exist only in analog sonogram records and position logs. Approximately 25,000 km of tracklines are in this additional data set. Mr. Cherkis has discussed with personnel at National Imagery and Mapping Agency the desirability of having this additional data digitized so that it can be contributed to the new Arctic bathymetry map. This task is being considered by Mr. Andreasen and Mr. Martino of NIMA.

**Semme DIJKSTRA, Alfred Wegener Institute for Polar and Marine Research**

*POLARSTERN data from the Norwegian-Greenland Sea and the High Arctic*

During the summer of 1997, *RV Polarstern* conducted a systematic survey of the Lena Trough using the Atlas Hydrosweep multibeam sonar. Future plans are to extend this survey to the north and the south, with possibly an extension of the systematic survey of the Fram Strait (Figure 8).

In 1998, bathymetric data was collected in support of geological and geophysical programs (Figure 9). For this work the updated DS-2 version of the Hydrosweep was used. Although problems with data loss and system hang-ups were encountered, many useful data were collected; these are of a better quality than the earlier DS data because they do not include some of the systematic artifacts that occurred in the latter observations.

**Bernard COAKLEY, Lamont-Doherty Earth Observatory**

*Swath Mapping the Arctic Ocean from US Navy Submarines; Installation and Performance Analysis of SCAMP Operation During SCICEX 1998*

The 1998 SCICEX cruise aboard the USS Hawkbill spent the month of August conducting oceanographic and geophysical surveys in the Arctic Ocean. This cruise was the first deployment of the SCAMP (Seafloor Characterization And Mapping Pods) sonars which enabled us to conduct swath surveys and collect sub-bottom profiler data throughout the Arctic basin. The gravity, sidescan, swath bathymetry, and chirp sub-bottom data that were collected along approximately 17,000 km of track will be used to study and better define the geology of the Arctic basin (Figure 10).

SCAMP is one of the most complicated civilian instruments ever installed on a U.S. Navy submarine. Its installation required the coordinated efforts of personnel from LDEO, Johns Hopkins Applied Physics Lab, Electric Boat, HMRG and Norfolk Naval Shipyard Divers and the unfailing cooperation of the Navy personnel of USS Hawkbill, Submarine Squadron One, and COMSUBPAC. Fabrication, installation and testing of the SeaMARC-type swath system and data logging computers and testing and installation of the sub-bottom profiler were funded entirely by the NSF Arctic Program. Additional support from the Geological Survey of Canada and the Palisades Geophysical Institute funded acquisition of the sub-bottom profiler and some engineering work. The Norwegian Petroleum Directorate is assisting with support for data acquisition and processing.

While the geophysical objectives of the cruise were focused on the ultra-slow spreading Gakkel Ridge, data were collected continuously during all phases of the program, including along the cross-Arctic transit, and over portions of the Alpha-Mendeleyev Ridge, the Lomonosov Ridge, and the Chukchi Cap. These data sets provide the first 3-D characterization of these features, significantly increasing the geologic database for the Arctic Basin. The data collected by SCAMP while crossing the Arctic Ocean provides a geophysical cross-section from the North American

continent to the Nansen Basin. The five day survey of the Gakkel mid-ocean ridge, the slowest spreading center on the planet, has produced swath bathymetry, sidescan, sub-bottom, and gravity data for 100km across-axis and 280km along-axis from 86 N 30 W to 86.5 N 75 W . The Atlantic-Pacific frontal survey over the Alpha-Mendeleyev Ridge has provided multiple crossings of the ridge crest along the eastern portion of the ridge. The two phase SHEBA ice survey and the final exit from the Arctic covered the northern edge and western edges of the Chukchi Cap.

Plans for the 1999 SCICEX cruise include extending the continuous bathmetric mapping along the axis of the Gakkel Ridge, detailed mapping over segments of the Lomonosov Ridge, survey of the Chukchi Borderland for iceberg scours and mapping along the northern Alaskan continental slope. These data will provide the means to understand the development of the Arctic Ocean basin as well as supporting other long-term objectives for Arctic science, including seafloor sampling.

## DISCUSSION

### Candidate data sets

A quick inventory was undertaken of known data sets that could figure in the construction of the digital data base. This inventory was partitioned geographically, representing availability within the EEZ's of the six coastal states and the three High Seas zones (Figure 11). It seems reasonable to assume that public domain data sets exist within all partitions, and that they will be freely available for use in the most appropriate fashion; these data sets are obtainable from data centres, or directly from originating institutions.

Proprietary data sets appear to exist in several areas, however a consensus emerged that if these were to figure in the compilation, they would be used only in the EEZ's of the owner states.

### Intended products

Project outputs were the subject of protracted discussion. The following paragraphs list the types of products that were identified, with comments and observations.

*Digital data base of original observations*

The data base will include original soundings collected in the form of point, profile, and swath observations, and which have been cleared for release into the public domain; historically, most point soundings and many profile soundings were recorded manually or in analog form, but once converted into computer-readable form, they are easy to assimilate with observations that have an all-digital pedigree. Whether logged initially in analog or digital form, data sets in the digital data base will for the most part feature times and positions for each observation point. Wherever feasible, metadata will be included to fully describe the circumstances of acquisition: platform, sponsoring organization, method of navigation, assumed sound velocity, etc. The guiding

principle in designing and implementing the data base will be to assemble and preserve all public domain observations in a form that is as complete as possible in order to facilitate future maintenance and upgrade tasks.

A question was posed as to whether these data bases would also include corrected observations: several, if not many, data sets will likely be subjected to corrections and adjustments for a variety of reasons. Another issue that was raised touched upon the archival format of multibeam data. These and related topics were relegated for more detailed consideration and recommendations (if possible by year end) by a data base working group consisting of Norm Cherkis, Bernard Coakley, Elena Daniel of VNIIO, and Ron Macnab.

Potential by-products of the undertaking might consist of separate data bases of proprietary observations developed for use within certain EEZ's where their release could not be condoned, and which would presumably remain within the custody of their controlling institutions.

*Data base of digitized contours*

In many parts of the study area, contour maps exist that incorporate a rich legacy of older observations that may be sparse, lost, or otherwise unavailable, and whose production represents a substantial investment of time and skilled effort. If the information describing the construction of these maps is sufficient to perform an assessment of their reliability and of the quality of their constituent data sets, it may be expedient to convert the contours to digital form for subsequent computer manipulation. Digitized contours should be preserved for possible future use, e.g. procedural review and verification, updates, visualization, and so forth. It was left to the data base working group (members listed in the previous section) to discuss and recommend format specifications for archiving this type of information.

*Digital derivatives*

This heading covers the digital outputs of processes that operate upon the above data bases of original observations and digitized contours. Derivatives may be developed in several forms (e.g. DTM's, profiles, contours) but to achieve the primary objective of the undertaking, the essential derivative product will consist of a regular grid of depth values covering the entire project area. Developing a useful grid from a disparate collection of data sets such as those outlined above will require a judicious selection and application of techniques, along with compromises in the final grid spacing. In many respects, this operation remains an art form where a skilled operator must rely upon experience to make the best choices. It was suggested that questions relating to gridding methodology and to the selection of an optimum grid interval might best be entrusted to a grid working group, who would consider the topics in detail and make recommendations; Semme Dijkstra, Martin Jakobsson, Greg Kurras, and Sergei Maschenkov agreed to take this on and to submit a report in the first quarter of 1999.

*Paper maps*

A properly-developed grid lends itself easily to the construction of satisfactory maps, as long as limitations relating to grid quality and resolution are taken into account. One stated objective of the project is to undertake a re-construction of GEBCO Sheet 5.17, which is based upon a polar stereographic projection of the region north of 64N at a scale of 1:6,000,000 (see Cover Figure). This rendition could be developed as a traditional contour map, or as a more contemporary shaded relief portrayal, or both: given the appropriate visualization and printing tools, it makes little difference which format is selected, or which factors e.g. contour interval, colour and shading parameters, are chosen. Clearly in developing the cartographic outputs of this project, every effort will be made to adhere to the standards of IOC and IHO.

Within the project framework, it may prove desirable and/or necessary to consider other forms of maps, such as 1:1,000,000 and 1:5,000,000 projections to maintain compatibility with existing IOC schemes, or special-purpose maps that portray bathymetry in certain areas. Decisions to proceed with the latter will be made as and when requirements appear, however in all cases, they will be subject to the resolution and quality considerations mentioned above.

*Documentation*

The preparation of a thorough and well-organized Project Report is an integral part of this undertaking, and it must be seen as an essential priority at all stages. Participants were therefore urged to make clear and copious notes of all pertinent information relating to data sets and to the procedures invoked in their manipulation. The project report needs to be more than a catalogue of data sets or a simple record of operations: in committing facts to paper, it is important to describe not only what is done, but also why, so that future users who need to do so may assess the quality and reliability of the final products by reading a full account of the steps taken in their development. This information will also provide a reliable departure point for future initiatives that set out to upgrade the data base and its derivative products by adding new data or by re-processing the old.

**Distribution media**

Final decisions on this subject are still some way off, however it is envisaged that products will be distributed in three forms:

*Digital.* CD-ROM or suitable media will be used to archive copies of: public domain data bases of original observations and digitized contours; derivative products (e.g. grids); plot files for selected map products; documentation (text and graphics); and possibly a selection of standard software tools to support basic operations such as data conversion, manipulation, and visualization. Presumably it will be possible to enlist the assistance of a data centre in recording and distributing copies of this type of media.

*Electronic.* The same products that are stored on CD-ROM could be archived at one or more

sites and made accessible through the World Wide Web, for selective downloading as needed.

*Paper.* Paper maps could be printed in quantity for distribution in the traditional manner, but this would likely entail some non-trivial cost considerations. Alternatively, maps could be printed on demand with optional provision for user-specified parameters, e.g. area, scale, contour interval, colour, shading, etc. The latter approach might best be entrusted to a data or service centre that would charge a nominal printing fee.

**Partitioning the project geographically**

In light of considerations relating to data sensitivities, workload, and resources, it was agreed that project tasks would be partitioned between the EEZ's of the six coastal states and the three High Seas zones (Figure 11). Institutional responsibilities for each of the six national EEZ's were provisionally allocated as follows:

| | |
|---|---|
| Canada | Geological Survey of Canada; Canadian Hydrographic Service |
| Denmark | Royal Danish Administration of Navigation and Hydrography |
| Iceland | Icelandic Hydrographic Service |
| Norway | Norwegian Petroleum Directorate; Norwegian Hydrographic Service |
| Russia | Head Department of Navigation and Oceanography; Research Institute for Geology and Mineral Resources of the World Ocean |
| USA | Naval Research Laboratory; Tulane University |

Following a suggestion by Neil Guy, joint responsibilities for the three High Seas zones were proposed on a national, rather than institutional basis:

| | |
|---|---|
| Arctic Ocean | Canada, Russia, USA |
| Norwegian-Greenland Sea | Denmark, Iceland, Norway |
| Barents Sea | Norway, Russia |

While this approach to partitioning gives prominence to coastal states, it should be emphasized that it is not meant to be exclusionary: investigators from institutions in non-coastal states, e.g. Sweden, Germany, and other countries with Arctic interests, have amply demonstrated their competence in these matters, so their involvement will be encouraged and very welcome. Also, it should be clearly understood that the partitioning scheme is not to be construed as the erection of barriers to cooperation and to the exchange of information: it will be essential to maintain active and constant interaction among all partitions to harmonize operational procedures, to negotiate data exchanges, to discuss problems of mutual interest, to seek advice and consultation, to maintain the compatibility of outputs, etc., etc.

**General procedures for handling digital data**

It is recognized that participants, for the most part, are already using computer systems and data handling procedures that work effectively, so it would seem counterproductive to insist that a

common suite of software tools and data operations be instituted at all project sites. Presumably, there will be ongoing discussion and consultation between participants to compare their respective methodologies and to assess their results. In the end, it is important that operators in each partition develop sets of products, e.g. digital data bases and derivatives, that adhere to a common set of specifications.

In these initial stages of the project and as described below, data handling procedures will apply largely to observations that are situated within project partitions and which already exist in digital form, or which can be easily converted to digital form. The procedures may be grouped loosely into four categories:

*Assembling and converting.* Data sets are identified, located, and acquired. Analog data are converted to digital form, digital data are re-formatted to a standard format. Where necessary, observations are reduced to a common sound velocity, and prior corrections for sound velocity variations are removed.

*Verifying and adjusting.* Data sets are reviewed and corrected for obvious errors; where appropriate, crossover analyses are performed to assess the horizontal and vertical accuracies of each data set by evaluating its self-consistency, and of all data sets by evaluating their mutual discrepancies. Where there is sufficient justification, data points may be adjusted vertically to account for sounding errors, and horizontally to account for positioning errors.

*Merging and gridding.* Original, adjusted, observations are combined. An agreed-upon gridding algorithm is applied to create a grid. Alternatively, digitized contour information may be used to produce a grid. Depending upon the data sets, portions of the grid will likely need to be assembled, patchwork fashion, from several smaller grids, with special care to minimize seams in the final result.

*Managing and archiving.* Data sets are thoroughly documented with respect to content and treatment, and are preserved in a secure inventory system that protects the information from loss or destruction while maintaining ease of access.

**Related topics**

*Standard coastline.* Problems remain in several parts of the Arctic where there is lack of agreement between proprietary or public-domain digital terrain models (DTM's) and public-domain coastlines such as the World Vector Shoreline (WVS). This cannot be solved in the short term, however the US National Imagery and Mapping Agency (NIMA) is said to be working on a successor to WVS that may eliminate some of the existing discrepancies. Clearly this is a matter that will have to be addressed within the project context. In the interim, project participants are asked to remain aware of developments that might ameliorate the situation in certain areas, such as the construction of new official coastlines by national mapping and cadastral agencies.

*Digital terrain model (DTM).* GTPO30 is a global DTM that portrays land relief at intervals of

30 arc-seconds. A modified version of GTOPO30 has been used to good effect by Martin Jakobsson to complement his bathymetry map of the Barents and Kara Seas. To add an element of realism to Arctic maps and to provide a morphological basis for studies of regional onshore-offshore correlations, it is suggested that the bathymetric grid for the entire project area be similarly complemented with a modified GTOPO30 grid. This raises the question of grid compatibility between land and sea areas: whereas GTOPO30 can readily provide a one-kilometer grid, the bathymetric grid is unlikely to approach that. It was left to the grid working group to consider how best to deal with this issue.

**Work plan and timetable**

The following project milestones were suggested:

*October 1998 to September 1999*

Working groups examine grid and data base issues and make recommendations
Assemble data sets within each partition
Develop interim products in each partition, e.g. databases, grids, maps

*October 1999: meeting*

Review interim products
Identify and resolve problems
Develop plan for joining grids along partition boundaries
Discuss outline of documentation and assign writing tasks

*October 1999 to September 2000*

Refine derivative products (i.e. grids) within each partition
Combine grids from all partitions to create one grid for the entire region north of 64N
Prepare documentation

*October 2000: meeting*

Review/approve the combined grid
Initiate distribution procedures
Design and implement long-term procedures for maintaining the data base

## CONCLUSION

*Funding needs and strategies*

Relying upon the volunteer efforts of a committed group of enthusiasts representing organizations in Europe and North America, this activity has no formal budget. Project spending so far has focussed primarily upon the costs associated with organizing and attending last year's meeting in St. Petersburg, and this year's meeting in Copenhagen. This funding has been achieved on an ad-hoc basis, with some expenses covered by participants drawing upon their own institutional resources, and other expenses underwritten by generous sponsors. With the project

moving from planning to implementation, it would be desirable to establish a more structured arrangement for covering costs of an operational nature, particularly those relating to the exchange of visits among participants who need to work closely together in order to harmonize and to integrate their data sets. Accordingly and in consultation with Members of the Editorial Board, the Chairman offered to develop a provisional budget for the next two years, and to approach prospective sponsors seeking support.

*Long-term issues*

Participants were encouraged to take the long view through all phases of this project, and to think beyond the immediate objectives. If this initiative is to serve as the establishment of a long-lived, accurate, and dynamic data base, it will be necessary to make provision for its ongoing maintenance, which implies that all data, metadata, and procedural descriptions must be preserved in way that will facilitate the future integration of new observations with older holdings. By the end of the project, it would be highly desirable therefore to have a mechanism and a methodology in place that would ensure periodic updates to the data base.

*Plans for circulating the report*

It was proposed that the proceedings of this meeting would be released formally through the Open File system of the Geological Survey of Canada. Printed copies of the former would be available from the GSC office in Dartmouth NS, while an electronic version would be accessible through the project's website operated by the US National Geophysical Data Center in Boulder, CO:

(http://www.ngdc.noaa.gov.mgg/bathymetry/arctic/arctic.html).

*1999 meeting*

It was proposed to schedule the next meeting of the Editorial Board for October 1999, in Monaco. Neil Guy offered the use of the facilities of the International Hydrographic Bureau, and Dmitri Travin indicated that he would request funding from the Intergovernmental Oceanographic Commission to underwite some or all of the meeting costs. Details will be promulgated in due course.

*Acknowledgements*

By endorsing the aims and objectives of the Editorial Board, the project's three sponsoring bodies - IOC, IASC, and IHO - have given this initiative a high profile and significant respectability in the international community. Full attendance at this meeting was due in no small measure to financial support received from the US Office of Naval Research. Through effective planning and logistics, RDANH staff set a good stage for a smooth meeting; special thanks are due to John Woodward, Birthe Cumberland Dahl, Finn Larsen, and Henrik Holm. Gary Grant of GSC Atlantic constructed the report's front cover.

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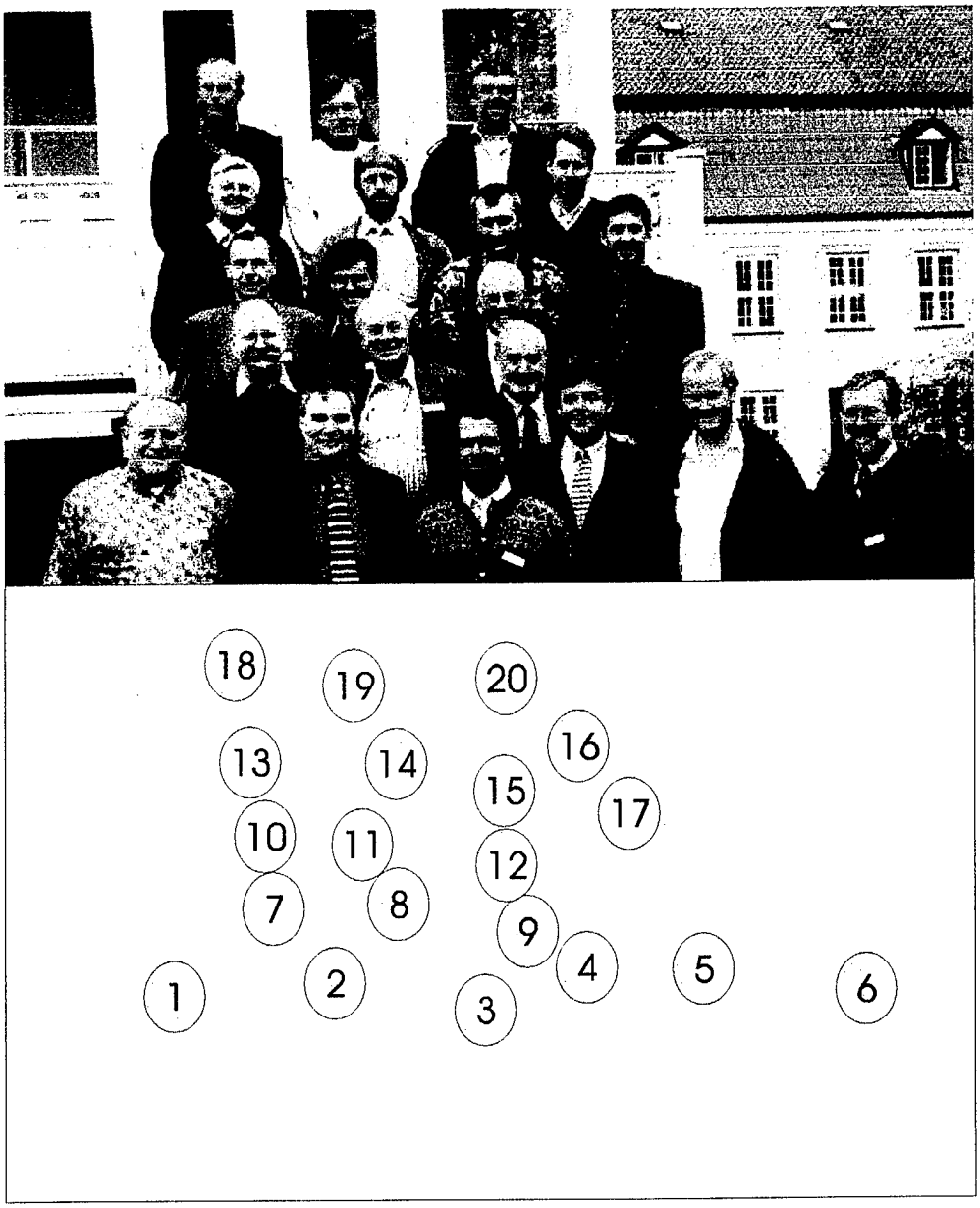


1. Robert Anderson
2. John Joseph
3. Bernard Coakley
4. Dmitri Travin
5. Semme Dijkstra
6. Erling Hansen
7. Ron Macnab
8. Garrik Grikurov
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14. Harald Brekke
15. Sergei Maschenkov
16. Martin Jakobsson
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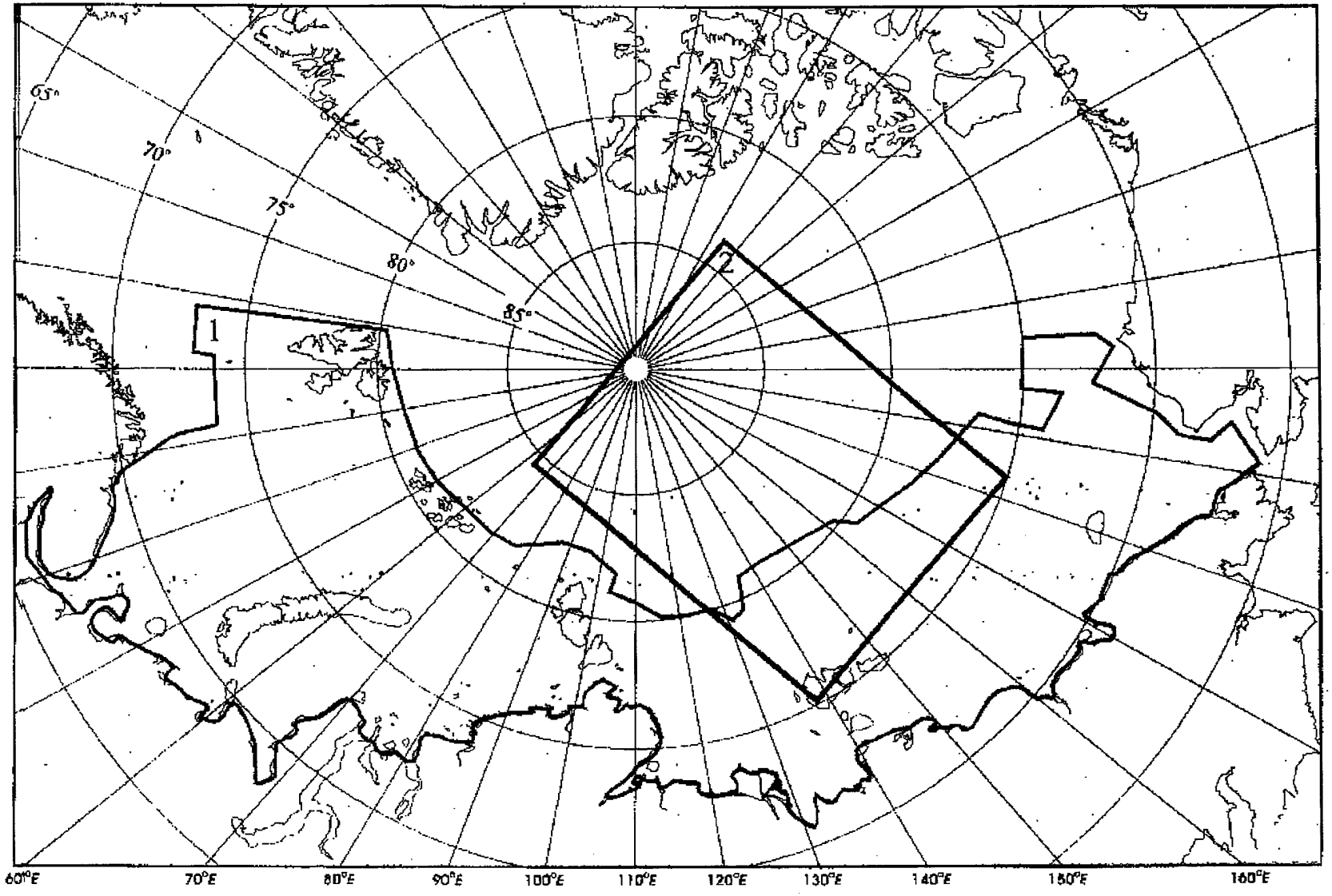


Figure 1. Portions of the Arctic Ocean seabed that are included in the integrated bathymetric grid produced at VNIIOkeangeologia. 1: Northern Eurasian Shelf. 2: Central Arctic Basin. (Maschenkov)

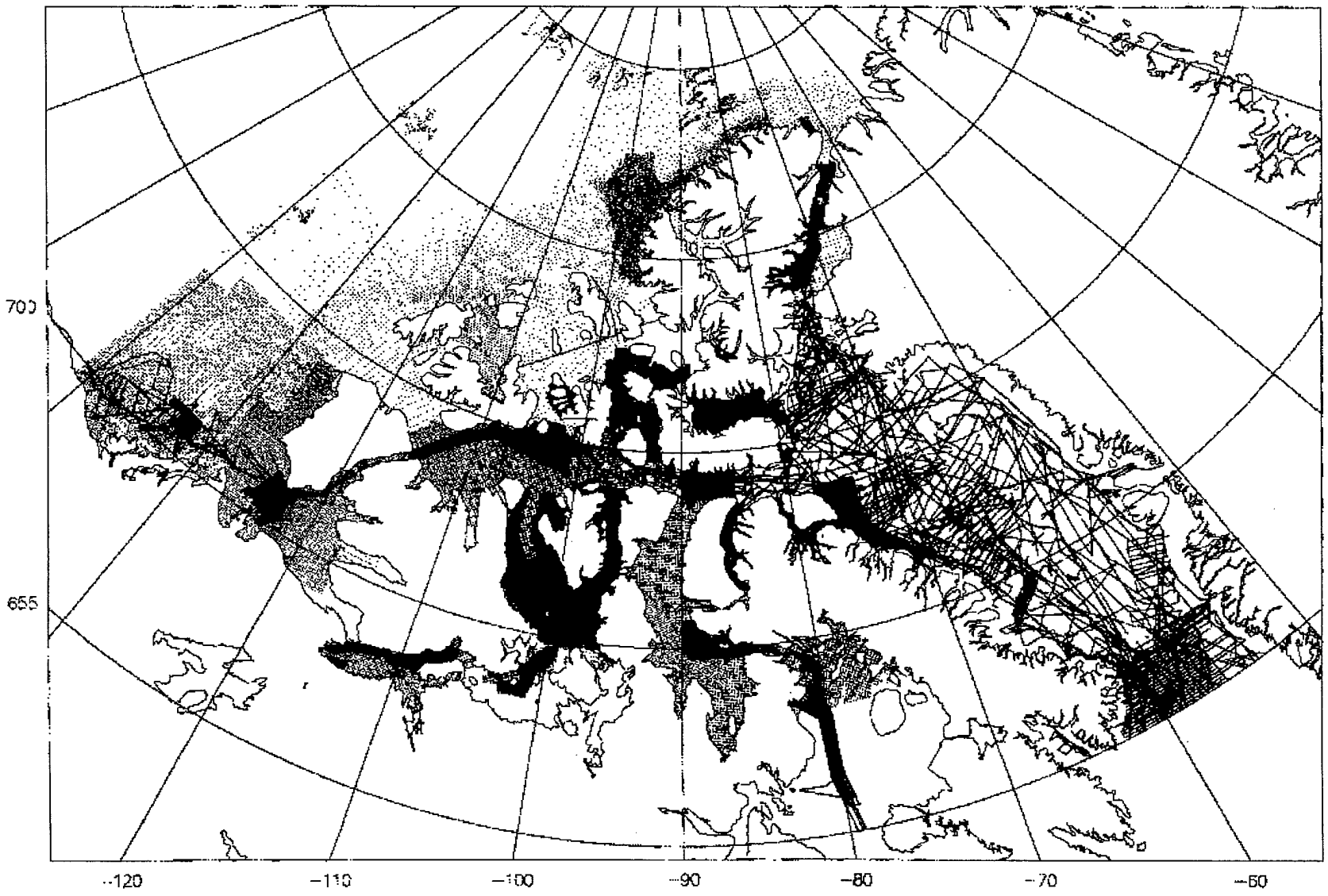


Figure 2. Locations of depth observations in and around the Canadian Arctic Archipelago, extracted from the digital archives of the Geological Survey of Canada and the Canadian Hydrographic Service. (Macnab)

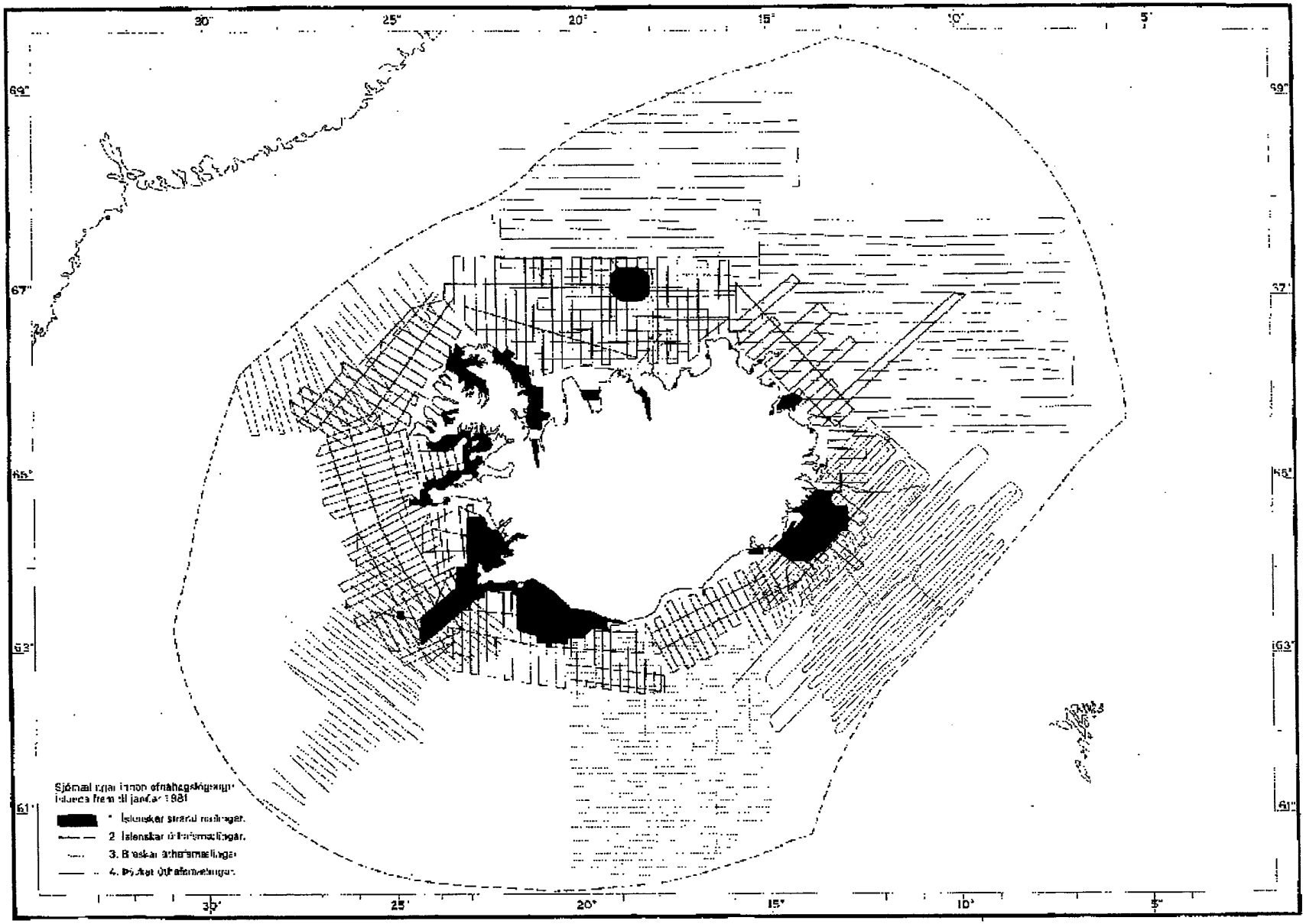


Figure 3. Sounding lines off Iceland. Black areas near the coast are not current. (Helgason)

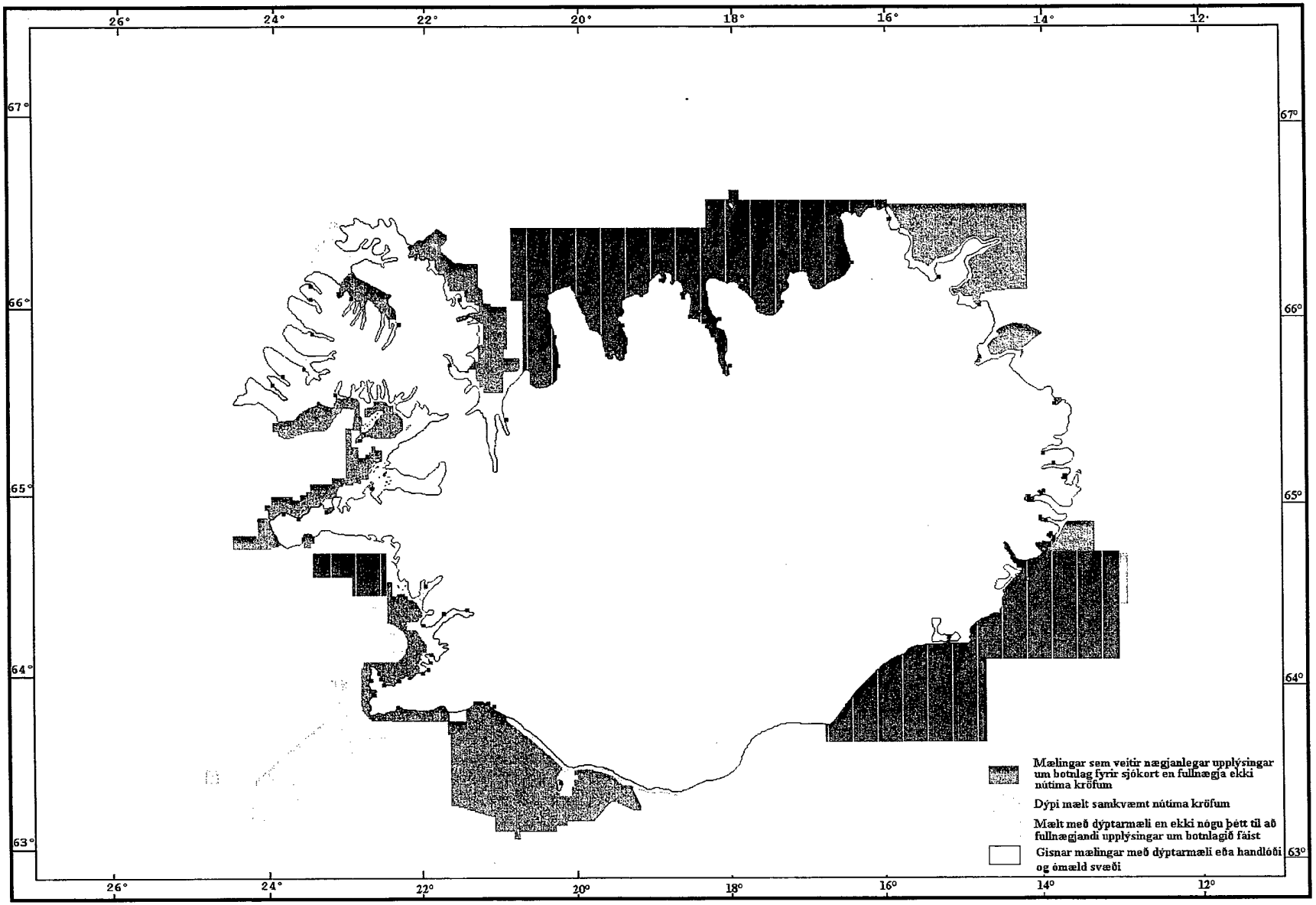


Figure 4. Near-shore sounding coverage off Iceland. (Helgason)

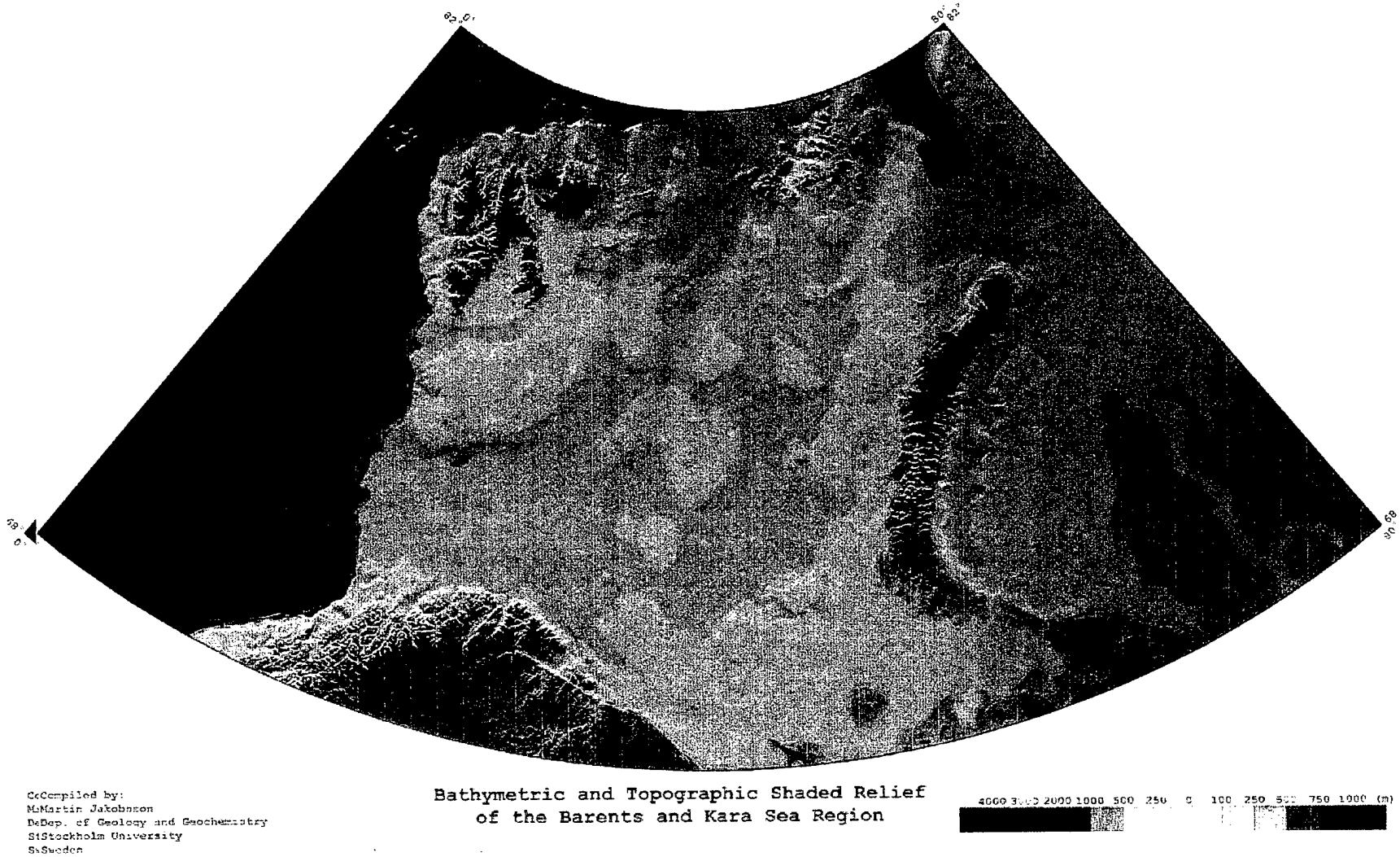


Figure 5. Relief map portraying a grid developed from published bathymetric maps, complemented by the GTOPO30 topographic grid. (Jakobsson)

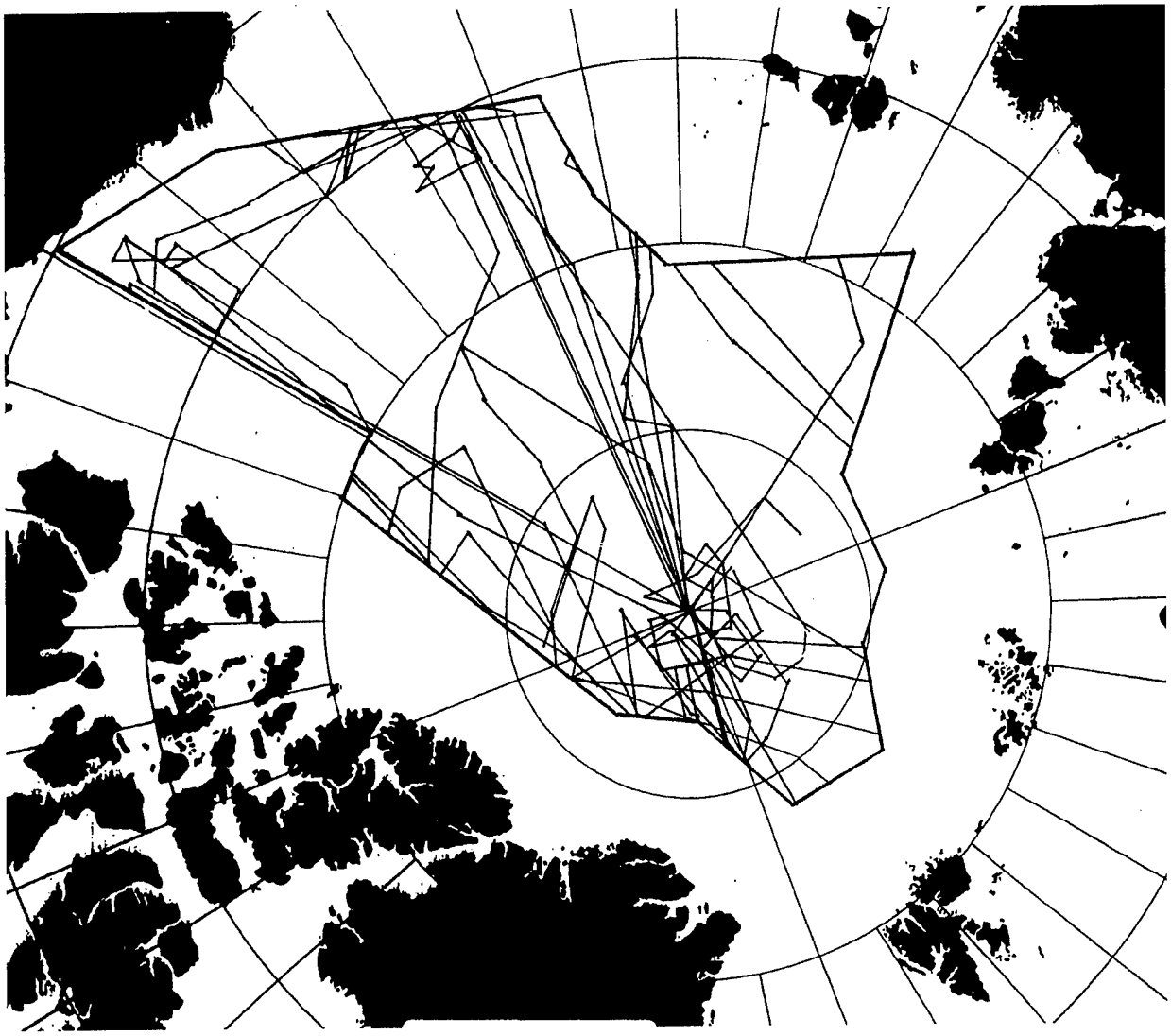

Figure 6. Sounding tracks of US Navy submarines from 1983 to 1988; data sets exist in digital form. (Anderson)

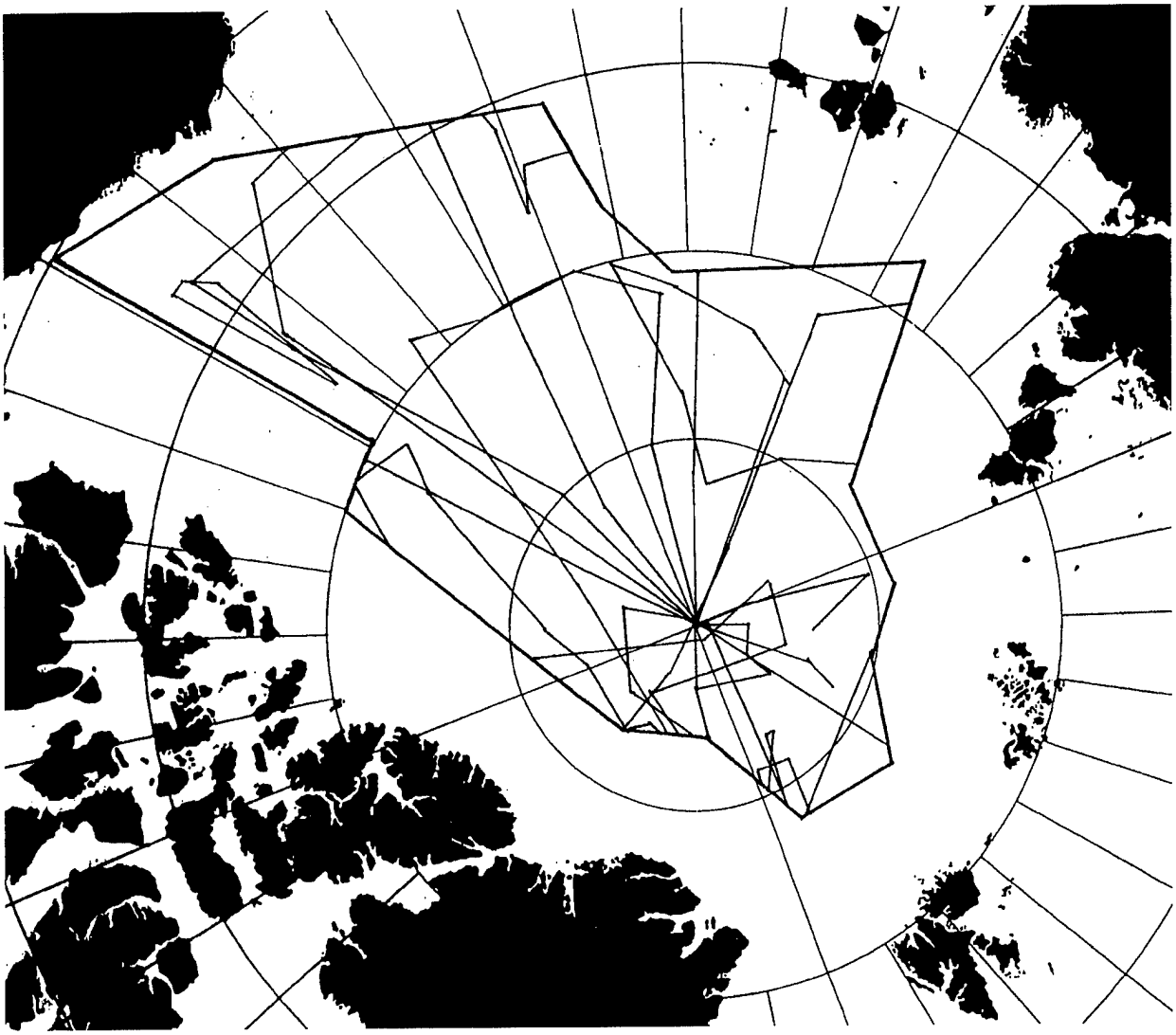

Figure 7. Sounding tracks of US Navy submarines from 1983 to 1988; data sets exist in analog form. (Anderson)

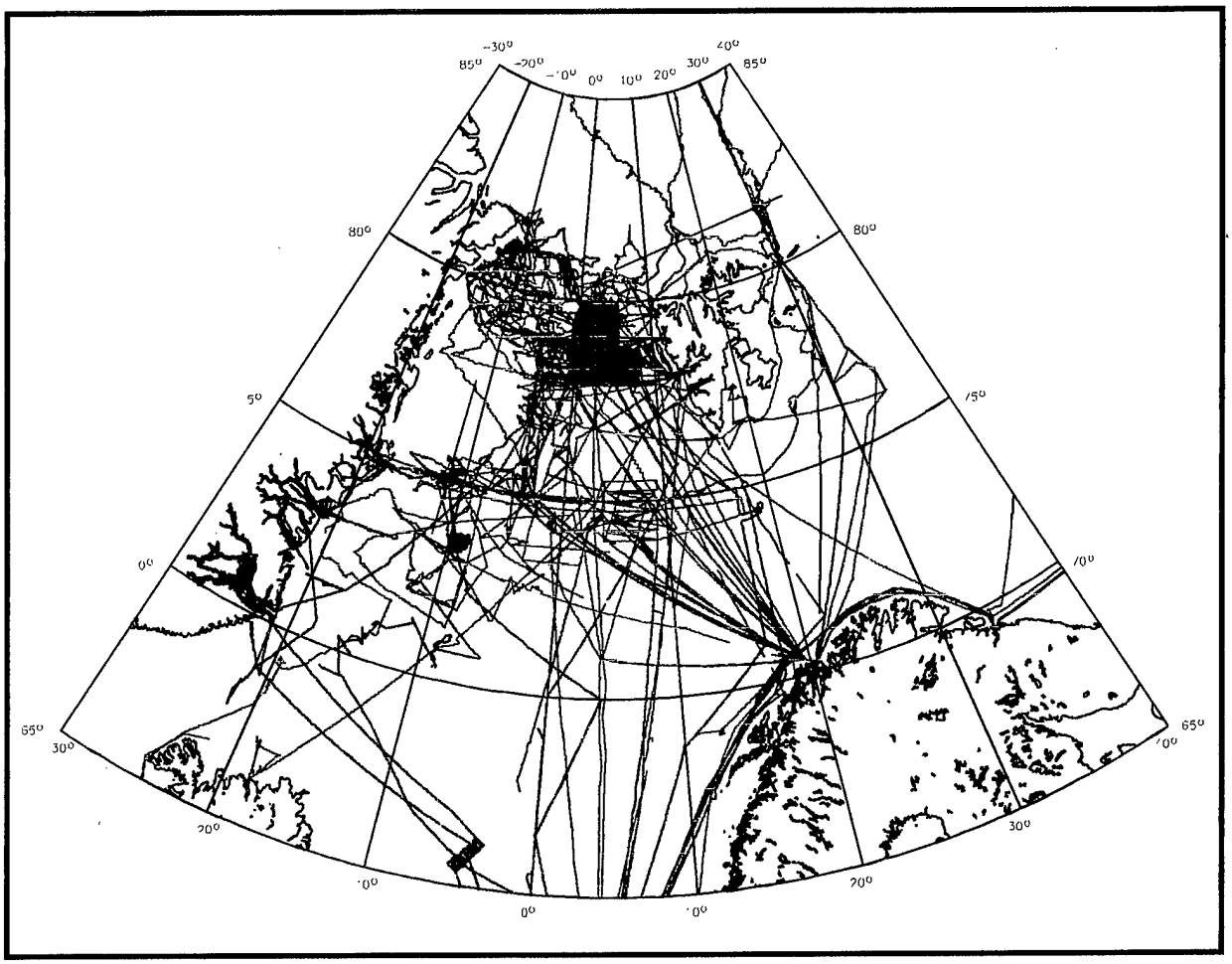


Figure 8. Narrow beam (red) and multibeam (green & blue) sounding tracks of Polarstern cruises in Fram Strait, from 1984 to 1997. (Dijkstra)

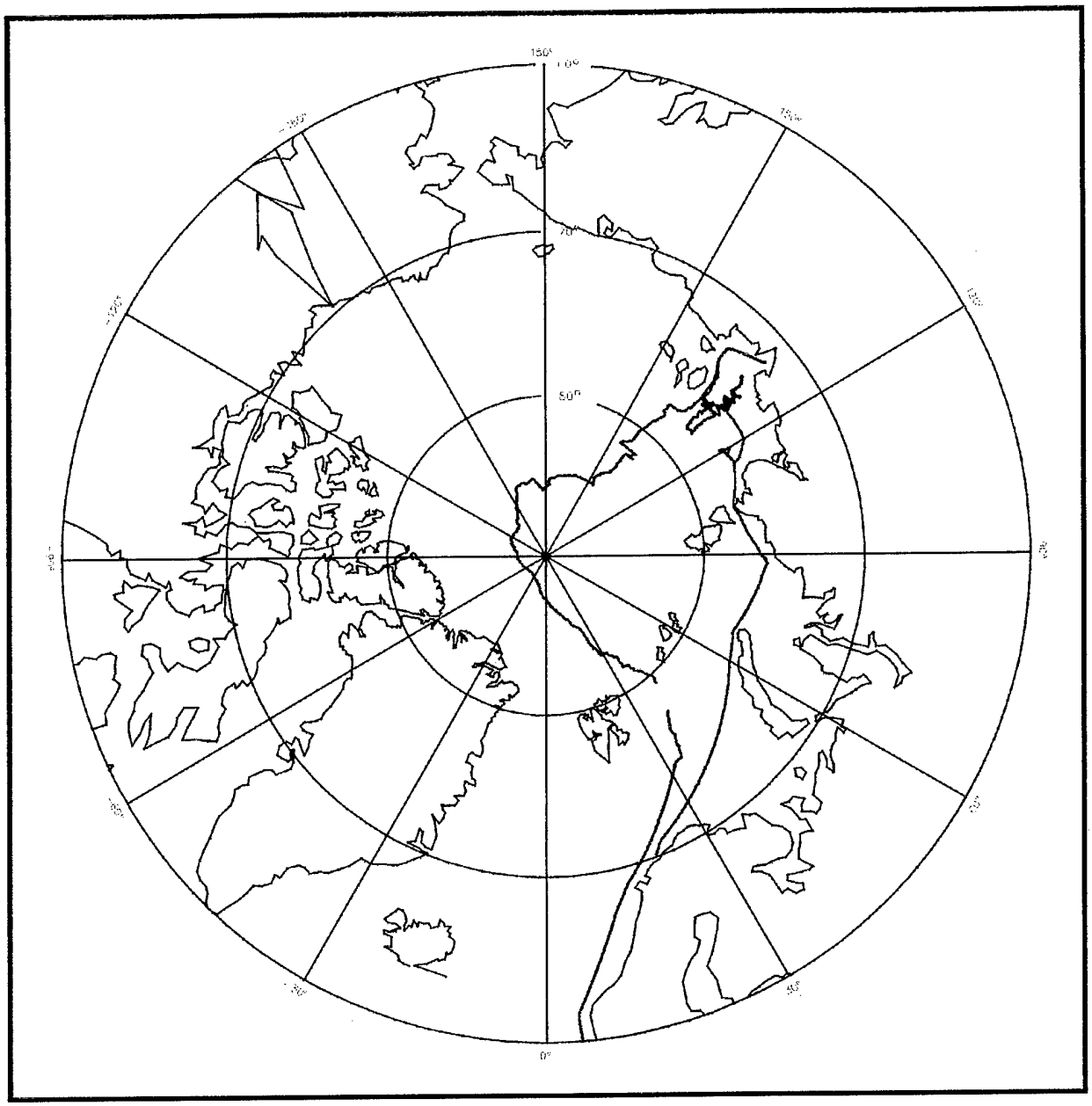

Figure 9. Sounding track of Polarstern cruise to the Arctic, 1998. (Dijkstra)

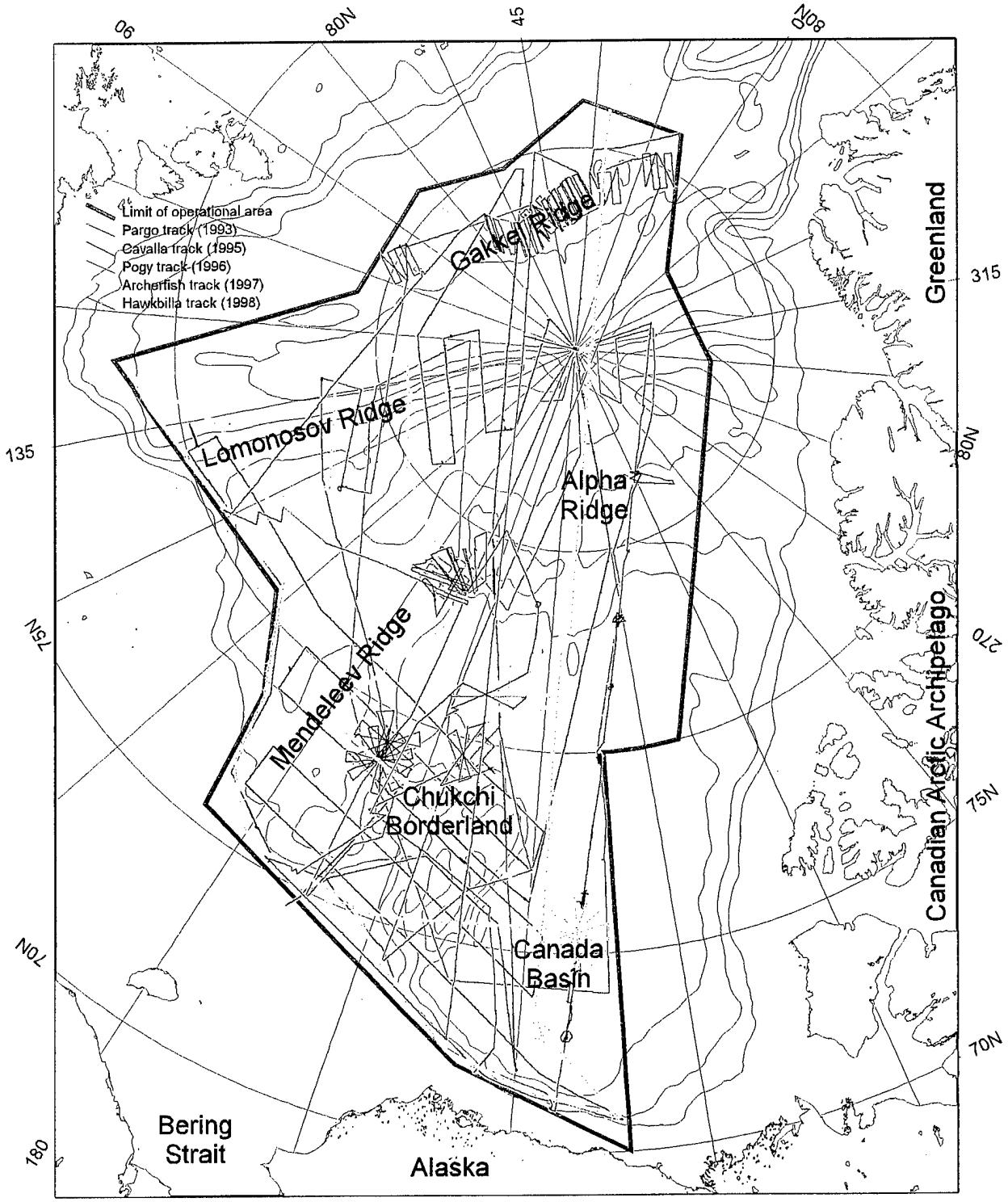


Figure 10. Sounding tracks of the US Navy's unclassified SCICEX expeditions from 1993 to 1998. (Coakley)

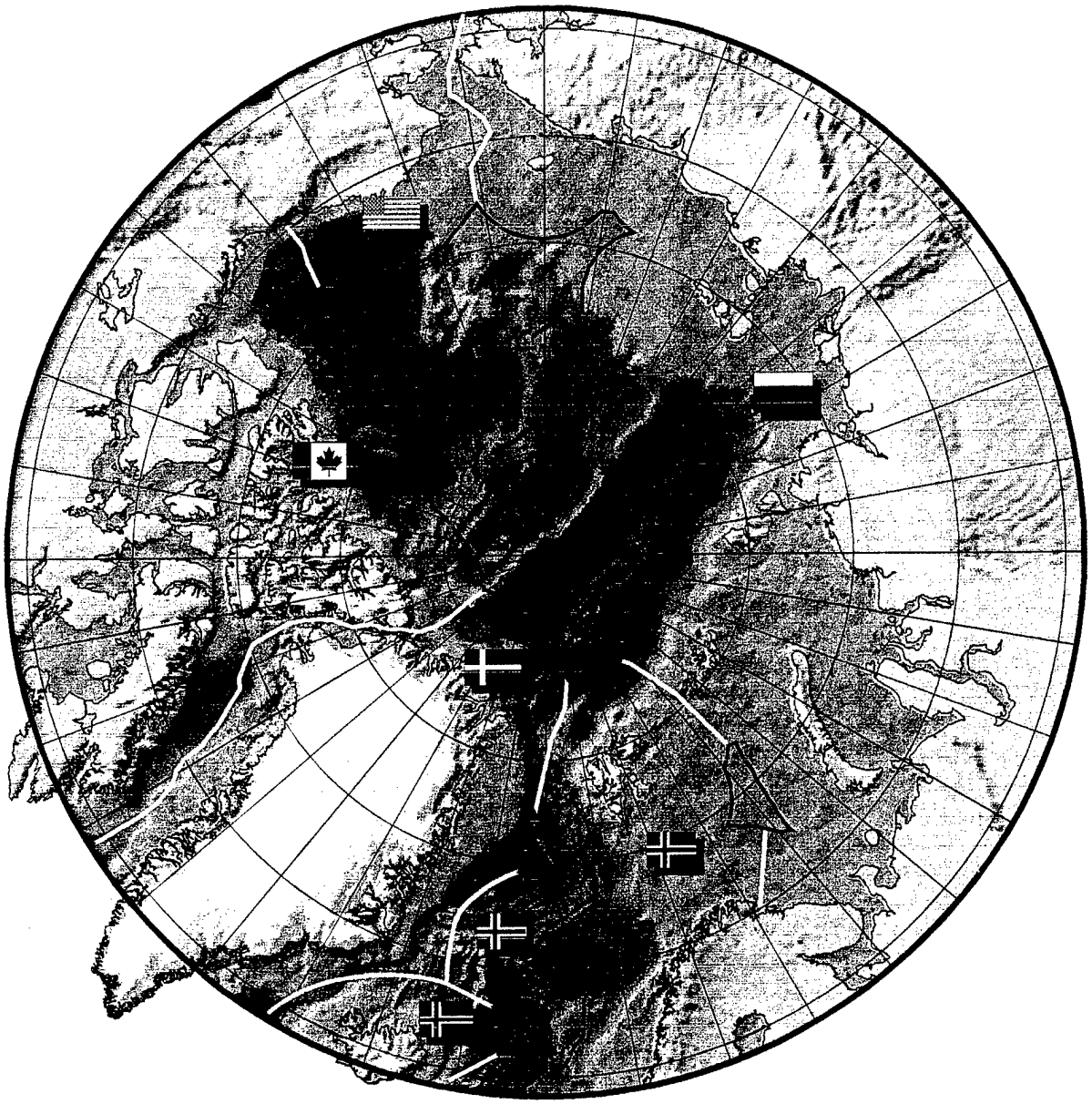

Figure 11. Approximate limits of the Exclusive Economic Zones (EEZ's) of the Arctic coastal states, illustrating a proposed scheme for partitioning the project. Bilateral limits are shown in green, High Seas limits in pink. Each coastal state would assume responsibility for managing the compilation of public-domain and proprietary bathymetry within its own EEZ. Contiguous states would assume a cooperative responsibility for compiling public-domain data in each of the three High Seas Zones. (Macnab)

## APPENDIX A

### AGENDA

IOC/IASC/IHO Editorial Board for the
International Bathymetric Chart of the Arctic Ocean

Royal Danish Administration of Navigation and Hydrography
Copenhagen, October 19-20, 1998

**Chairmen:** Ron Macnab, Geological Survey of Canada
Arne Nielsen, Royal Danish Administration of Navigation and Hydrography

**0900-0930 MONDAY: OPENING ACTIVITIES**

Call to order
Introductions
Welcoming remarks
Administrative items
Revisions to agenda

**0930-1230 MONDAY: REPORTS**
(Developments and new information since the St. Petersburg Workshop)

Sergei MASCHENKOV, VNIIOkeangeologia
New bathymetric compilations at VNIIOkeangeologia

Ron MACNAB, Geological Survey of Canada
Mapping the channels of the Canadian Arctic Archipelago

Hilmar HELGASON, Icelandic Hydrographic Service
Bathymetric mapping and data holdings off Iceland

Hans Werner SCHENKE, Alfred Wegener Institute
New data arising from Polarstern's 1998 cruise

Valeriy FOMCHENKO, Head Department of Navigation and Oceanography (GUNiO)
A new contour map of Arctic bathymetry

Martin JAKOBSSON, Stockholm University
Developing a bathymetric grid for the Eurasian shelf

Norm CHERKIS, Naval Research Laboratory
Treatment of 1957-1982 submarine data

Bob ANDERSON, Arctic Submarine Laboratory
Prospects for declassification of post-1982 submarine data

Bernie COAKLEY, Lamont-Doherty Earth Observatory
SCICEX 1998 and SCAMP

**1400-1700 MONDAY: DISCUSSION**
(Based loosely upon the contents of the Strategic Plan)

Candidate data sets
already known
newly identified

Intended products
digital data bases: public and proprietary observations
gridded depth values
paper maps
documentation
distribution media: digital, electronic, paper

Partitioning the project geographically
the High Seas
Zones of National Interest (ZINs)
allocation of responsibilities in the High Seas and ZINs
bi- and multilateral cooperation with data exchange

**0900-1200 TUESDAY: DISCUSSION**

General procedures for handling the data
assembling and converting
verifying and adjusting
merging and gridding
managing and archiving

Related topics
standard coastline
digital terrain model

Work plan and timetable

**1330-1500 TUESDAY: CONCLUSION**

Funding needs and strategies
Long-term issues
Plans for drafting and circulating the Meeting report
Proposals for 1999 Meeting
Acknowledgements

## APPENDIX B

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## APPENDIX C

## THE CONTINENTAL SHELF BEYOND 200 NAUTICAL MILES IN THE ARCTIC OCEAN

A Scientific/Technical Workshop
co-chaired by Yuri Kazmin and Ron Macnab

## SUMMARY REPORT

1. From October 16 to 18 1996, a workshop was held at the Polar Marine Geosurvey Expedition in Lomonosov-St. Petersburg, Russia. Experts in hydrography and marine geoscience attended from various agencies of the five Arctic coastal states: Canada, Denmark, Norway, the Russian Federation, and the USA. The list of participants is shown in Annex I.

2. The experts discussed various technical and scientific aspects of delimiting the juridical Continental Shelf beyond 200 nautical miles in the Arctic Ocean within the legal framework defined by the UN Convention on the Law of the Sea. The topics discussed during the workshop are listed in Annex II.

3. Below are the main points that emerged from the discussions:

a. The severe climatic and ice conditions in the Arctic Ocean make it difficult to apply some of the existing methods and technologies that are generally easy to use in other oceans, in order to obtain the information that is necessary for establishing the outer limits of the Continental Shelf.

b. The floor of the Arctic Ocean is characterized by the existence of at least four large submarine elevations that could be considered to be submerged prolongations of the continental margins beyond 200 nautical miles: Chukchi Plateau, Mendeleyev Ridge, Lomonosov Ridge, and Alpha Ridge. Adequate sets of geological and geophysical data, together with bathymetric and morphological information, are seen as critical to establishing that such elevations are indeed natural components of the continental margin.

c. To avoid duplication of effort and to promote cooperation among experts charged with the technical implementation of Article 76, it is highly desirable to consider a consolidation of information and data sets that presently exist in a variety of forms and in many separate locations. Such action would create a coherent and unified description of the bathymetric and geological characteristics of the sea bed and the sub-seabed; subject to proprietary and other considerations, the free circulation of this information would also contribute to an understanding of the region's tectonic framework and history.

d. Consequent to the above description of common scientific interests in the Arctic Ocean, it would seem appropriate for the five Arctic coastal states to work together towards the resolution of common scientific problems, and to the achievement of common goals within the Article 76 context. Further meetings should be organized to continue the exchange of information that was initiated in the Workshop, and to develop a body of reports, etc, that would provide a scientific and historical background to Article 76 investigations in the Arctic.

(Approved by all attendees; original signed by co-Chairmen)

## ANNEX I: THE CONTINENTAL SHELF BEYOND 200 NAUTICAL MILES IN THE ARCTIC OCEAN

### PARTICIPANTS

| | | |
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| Translators | Maria Ivanova<br>Elena Miloradovskaya | |

## ANNEX II: THE CONTINENTAL SHELF BEYOND 200 NAUTICAL MILES IN THE ARCTIC OCEAN

### AGENDA

| | |
|---|---|
| **1. INTRODUCTION** | Kryukov |
| a) Acknowledgements | |
| b) Aims of the Workshop | |
| c) Timetable | |
| **2. REVIEW AND DISCUSSION: THE LEGAL FRAMEWORK DEFINED BY THE LAW OF THE SEA** | Kazmin, Macnab |
| a) Article 76: methodology for delimiting the continental shelf beyond 200 nautical miles | |
| b) Article 77: rights of the coastal state with respect to resources of the continental shelf | |
| c) Article 123: cooperation of states bordering enclosed or semi-enclosed seas as they exercise their rights and perform their duties | |
| d) Annex II: commission on the limits of the continental shelf | |
| e) Short summary | General discussion |
| **3. BASIC DESCRIPTIONS** | |
| a) Main geological features and peculiarites of the Arctic Ocean structure and evolution | Pogrebitsky |
| b) Geological nature of the main morphological structures of the Arctic Ocean | Jackson |
| c) Geomorphological analysis of sea bed relief in the Arctic Ocean | Gramberg, Naryshkin |
| d) Scientific investigations inthe Arctic Ocean from submarines | Coakley |
| e) Gas and oil resources of the Arctic Ocean | Gramberg, Suprunenko, Lazurkin |
| f) Exchange processes in the Arctic Ocean | Raskatov |
| **4. PRESENTATIONS AND DISCUSSION: IMPLEMENTING ARTICLE 76** | |
| a) Identifying 'natural prolongations': known or inferred nature of the Chuckchi Borderlands, the Mendeleyev Ridge, the Alpha Ridge and the Lomonosov Ridge, and their relationships to the continental margin | Poselov, Macnab |

| | |
|---|---|
| b) Determining the foot of the slope: methodologies for tracing the point of maximum change in the sea floor gradient | Naryshkin, Solodov |
| c) Determining the 2500-m contour: measuring bathymetry accurately in the deep ocean | Naryshkin, Solodov |
| d) Determining the 'Gardiner Line': identifying points where thicknes of sedimentary rock is at least 1% of the distance back to the foot of the slope | Poselov |
| e) Results of completed and/or current investigations: work that has been done to date for shelf edge delimitation beyond 200 nautical miles | Sorokin, Macnab |
| f) Proposed investigations for Article 76 purposes, including field work; prospects for international collaboration | General discussion |
| **5. PRESENTATIONS AND DISCUSSION: DATA BASE TOPICS** | |
| a) Status of existing data bases: bathymetric and sediment thickness observations available for determing the foot of the continental slope, the 2500-m isobath, and the so-called 'Gardiner Line' | Solodov, Narishkyn, Jackson, Madsen, Brekke, Macnab |
| b) Prospects for consolidating and rationalizing current data bases from various national and public domain archives | General discussion |
| **6. DISCUSSION (TIME PERMITTING): RELATED TOPICS** | Kazmin, Macnab |
| a) Submissions to the UN Commission on the Limits of the Continental Shelf<br>b) Potential seabed resources beyond 200 nautical miles<br>c) Environmental management/stewardship | |

## APPENDIX D

## MEMBERS OF THE EDITORIAL BOARD FOR THE INTERNATIONAL BATHYMETRIC CHART OF THE ARCTIC OCEAN

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January 1999


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## APPENDIX E

# PROPOSED STRATEGIC PLAN FOR DEVELOPING A MODERN DATA BASE AND MAP OF ARCTIC BATHYMETRY

The IASC/IOC/IHO Editorial Board for the
International Bathymetric Chart of the Arctic Ocean

October, 1998

## INTRODUCTION

This document outlines a general approach for a project to assemble all available bathymetric data north of 64°N, for the purpose of constructing a coherent digital data base and an accurate map of the sea floor. The ideas presented here were developed from information presented at the Arctic Bathymetry Workshop held September 18-19, 1997 in St. Petersburg, Russia (Macnab and Grikurov, 1997) and from subsequent exchanges between members of the Editorial Board.

## CANDIDATE DATA SETS

Appendix 4 of the Workshop Report contains encapsulated descriptions of known data sets that were identified as potential components of the proposed data base. Collected, compiled, and archived by various agencies in the countries represented at the Workshop, these data sets for the most part are physically stored in numerous separate locations. They define ocean depths across a broad range of continental shelf and deep sea localities, having been acquired with varying levels of accuracy as point soundings taken through the ice cover, as sequential single-beam observations collected by surface vessels and submarines, and to a lesser extent as surface multibeam measurements.

The combined holdings cover a time span that ranges over the past several decades. With some data sets preserved in digital form and others in analog form, these holdings comprise a substantial mix of storage media and formats: paper sounding records; paper maps inscribed with point observations or contour lines; and digital files holding original observations, processed observation, contours, or grids. Levels of data treatment are highly variable and inconsistent, with some observations having been thoroughly processed for mapmaking and research purposes, and others remaining, to all intents and purposes, in their raw, original form. Some data sets have been placed in the public domain and are readily accessible, while others remain proprietary with restrictions on their release and distribution.

A particular instance of information in the public domain is the published map that represents the best efforts of a group or of an individual to assemble, combine, and interpret all available data. Part or all of the map's constituent data sets may not be releasable into the public domain, however if sufficient information is available to qualify the map and to provide a measure of confidence in its overall reliability, then that map might be acceptable as a valid data source for the project.

In addition to the data sets that have already been collected, the US Navy's unclassified SCICEX program has this year mobilized a swath mapping capability, which can be expected to increase significantly the quantity and quality of unclassified observations that will be incorporated eventually in the Arctic data base.

## PARTITIONING THE PROJECT ALONG GEOGRAPHIC LINES

Under ideal conditions, a project such as the one envisaged here would be the responsibility of a single organization that possessed both the capability and the resources to perform effectively all the constituent tasks. This approach would have two major advantages: (1) simplified project management and control; (2) consistent treatment of the data sets.

Realistically, however, there are three significant constraints to implementing this approach: (1) while most if not all of the participating organizations possess the technical capacity to undertake the entire project, few if any appear to have at their disposition all the necessary human and financial resources, or to enjoy a formal mandate for assuming total responsibility for an activity of such broad international scope; (2) in the form of original observations, certain data sets have restricted mobility, and are unlikely to be released for free and unrestricted exchange; (3) in certain areas, the results of the undertaking could have significant implications with respect to continental shelf delimitation, giving prospective claimant states a strong incentive to assess original data sets, and to be directly involved in their handling and interpretation.

A proposed solution is to partition the project between the international High Seas and the Zones of National Interest (ZNIs) that pertain to each participating coastal state. These are shown in generalized form in Figure 1. In essence, each coastal state would assume the primary responsibility for assembling and treating proprietary and public data within its ZNI; the High Seas would be treated on a collective basis, using public data only. Where their ZNIs were contiguous, states would be encouraged to exchange data with their neighbours, and to work together closely to ensure a seamless portrayal of the sea floor from one zone to another – hence Canada would share data with the USA and Denmark, Denmark would share with Canada and Norway, and so on. The precise methodology for handling and treating data in the central portion of the Arctic Ocean would require further discussion and definition.

The above plan would respect regional data sensitivities within ZNIs, while promoting the free exchange of information in the regions that fall within the High Seas.

## PRODUCTS

As envisaged, the project will develop a range of products subject to varying degrees of distribution:

- Digital data bases comprising a mix of original observations (public and previously unreleased measurements) collected within each national zone of interest; depending on national policies, these may or may not be released into the public domain for unlimited distribution.

- A digital data base containing original public observations from the High Seas areas; this will be released for unlimited distribution and periodic updating.

- Digital bathymetric values distributed over a uniform grid that covers the entire project area (the spacing between grid values and the technique for their derivation will be determined by consultation among all project participants); this information will likely be distributed on CD-ROM, along with original data sets that are deemed releasable for unlimited circulation.

- Printed map(s) that portray bathymetry in isobath and/or shaded relief form, preferably at a scale of 1:6 Million to replicate GEBCO Sheet 5.17, however other scales are possible.

- Documentation that describes the data sets, the distribution of observations, and the treatments applied to develop the gridded data set. The documentation will be released for unlimited circulation in printed form and as a text/graphic file on the CD-ROM bearing the gridded data.

## GENERAL PROCEDURES

As a general rule, observations in digital form are preferable to analog information. However it is recognized that numerous legacy data sets are likely to exist in analog form only (original sounding records, posted depths, contour maps, etc) and these should be converted to digital form at an early stage of the operation. Thereafter, a consistent suite of digital techniques should be used to treat data sets at all subsequent stages. These operations include: converting all data sets to a common format; identifying and correcting errors; analyzing observational discrepancies at track intersections; adjusting and re-levelling data sets to achieve agreement where they abut or overlap; and deriving general statistical parameters for qualifying the overall data base.

Depending on the density and other characteristics of the data, one or more gridding algorithms may be needed to construct surfaces that contain a statistically significant percentage of all original data points within specified limits. For instance, where original data points are numerous and accurate, grids will be derived directly from these observations; where data points are sparse or of poor quality, it may prove necessary to derive grids from hand-drawn contours that incorporate varying levels of human judgement and interpretation. Members of the Editorial Board will collectively review gridding algorithms with a view to selecting those that are best suited to the demands of the application.

## RELATED TOPICS

*Standard coastline.* While it is probably the most available of global coastlines in the public domain, the digital WVS (World Vector Shoreline) demonstrates in many Arctic locations a significant lack of agreement with shorelines derived from other sources, such as national maps and publications. Accordingly, members of the Project Group are encouraged to consider ways of rendering the Arctic shoreline at the highest possible accuracy. This will likely entail efforts to obtain the latest and most reliable information from national mapping authorities, and to composite that information in a manner that yields a significant improvement over existing public domain portrayals.

*Digital Terrain Model (DTM).* Land areas occupy a sizeable portion of the proposed map. For uniformity of presentation and to facilitate correlation between marine and continental features, it will be desirable to portray morphology both above and below sea level at comparable levels of resolution. Land elevations in several regions of the proposed map are already defined by digital DTM's that exist in the public domain; elevations for the remaining regions may be obtainable from national sources.

## PROVISIONAL TIMETABLE

Anticipated progress will depend upon several factors, however a desirable objective for 1999 is to have project components completed, to a preliminary stage at least, in the High Seas and in the zones of national interest. Following an internal review by members of the Project Group, these components will be consolidated with a view to creating final products for public distribution by the year 2000.

Following is a provisional outline of milestones and operations:

will be consolidated with a view to creating final products for public distribution by the year 2000.

Following is a provisional outline of milestones and operations:

*October 1998.* First meeting of Project Group/Editorial Board: define specifications; establish work plan; identify individuals who will assume responsibility for specific project components.

*November 1998 to September 1999.* Participants assemble information and develop components for which they have accepted responsibility.

*October 1999.* Second meeting of Project Group/Editorial Board: review completed components; identify problem areas and devise solutions; develop plan for merging components and for developing final products.

*November 1999 to September 2000.* Refine and combine components, construct final products, document data sets and procedures.

*October 2000.* Third meeting of Project Group/Editorial Board: review and approve final products; initiate their distribution; develop a long-term strategy for ongoing maintenance of the data base, and for regular updates to the grid and map.

Progress will be posted regularly on the Project's Website, operated by the US National Geophysical Data Center: http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/arctic.html

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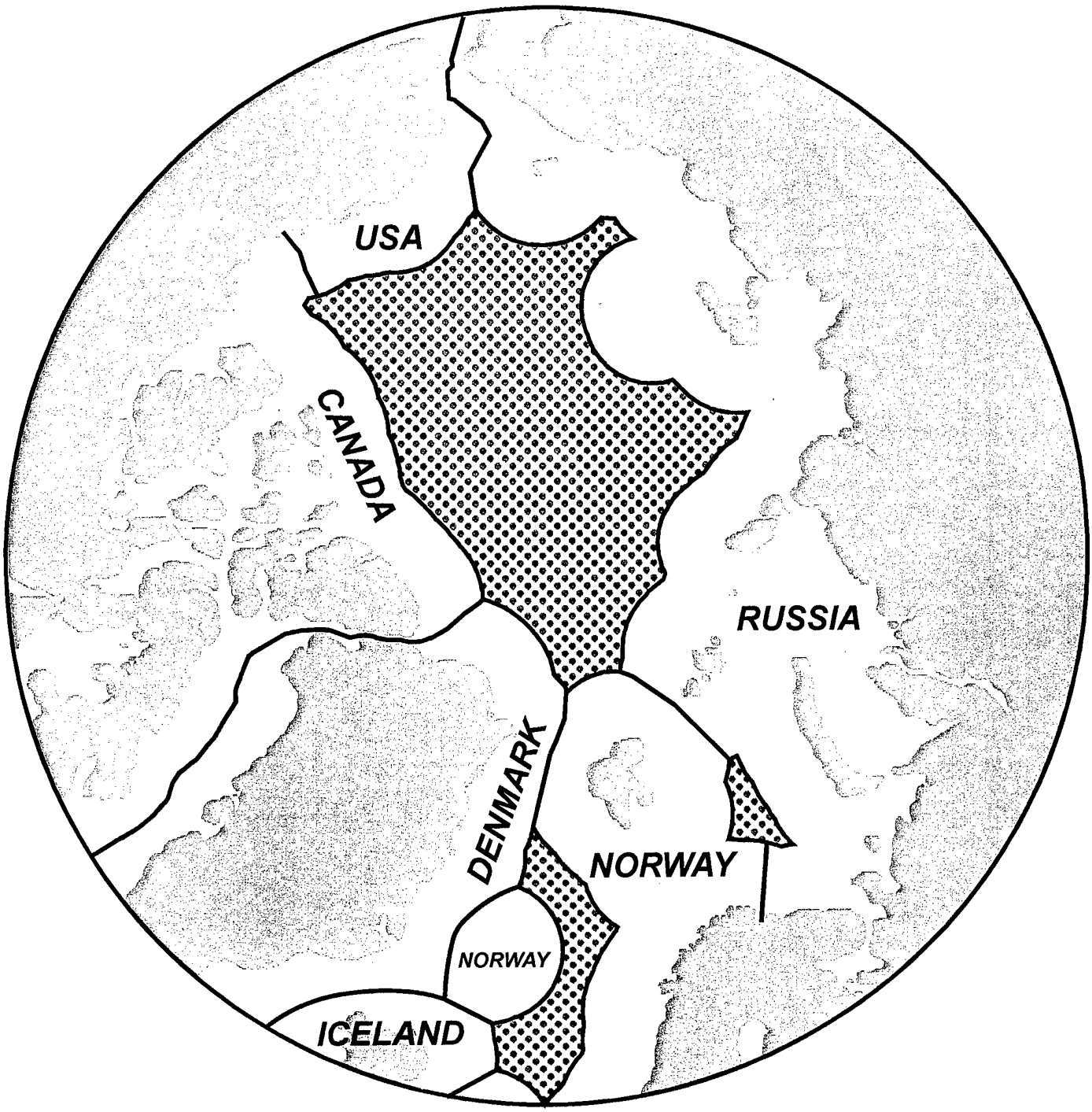


Figure 1. High Seas (patterned) and approximate limits of Zones of National Interest (ZNIs) north of 64N.