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A New Computer Bathymetric Model of the Arctic Ocean

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THEME 15: Geodynamics of the Arctic Region

Summary: A new digital bathymetric model of the Arctic Ocean has been created in VNIIOkeangeologia under Civilian Research and Development Foundation grant as part of IOC/IASC/IHO project activity. This model for the first time incorporated abundant systematic analog Russian data which have been digitized and merged with other available digital information. Processing procedures required for compilation were developed specifically for individual areas differing in bottom topography and input data.

INTRODUCTION

The paper presents a new bathymetric model covering the area consisting of the Deep Arctic Basin and surrounding continental shelves, and the Norwegian-Greenland Basin of the North Atlantic. Such wide bathymetric coverage of the Arctic area is necessary for presenting all interconnected structures of this unique and varied part of the Earth lithosphere. Considerable amount of existing bathymetric data have been gathered during systematic surveys carried out by Russian researches from VNIIOkeangeologia, Polar Marine Geosurvey Expedition (PMGE), Murmansk Arctic Geological Expedition and Russian Navy (GUNiO). The collection, editing, adjustment and gridding of these data and their merging with available western data using the modern computer technology has been accomplished in VNIIOkeangeologia and resulted in a new bathymetric model of the Arctic Ocean. This model reliably characterizes the regional peculiarities of the ocean floor relief and throws new light on its most important features in comparison with earlier published small-scale maps and global bathymetry compilations, it was proposed for use in international digital Arctic bathymetry project (BOCHAROVA et al. 1997, KOMARITZYN et al. 1997). New features of the ocean bottom geometry and bathymetry identified from our model have been interpreted together with potential field data for the purpose of studying the lithosphere structure (DANIEL et al. 1997, ZAYONCHEK et al. 1998).

Input data

Digital data base of the Arctic Ocean bathymetry was developed using three main types of input data (Fig. 1): (a) original analog point observations acquired by the Russian expeditions and digitally captured in the course of this compilation; (b) grids either developed from GUNiO data under project supported by Civilian Research and Development Foundation (CRDF) or obtained from public domain data; and (c) digitized contours from published bathymetric maps.

Original analog observations conducted in the course of Russian geological and geophysical investigations resulted in acquisition of three types of point data (Tab. 1). The methods of observations, applied technical facilities, and accuracy of navigation and bottom depth estimations were mainly chosen subject to natural features of the study areas. The eastern part of the Russian Arctic Shelf and deep Arctic Basin were covered by aircraft supported surveys with density of landings ranging from 10-15 to 30-40 km. The ice-free Barents and Kara Seas were studied by systematic shipborne surveys with lines and stations spaced at 10-20 km and 3-7 km, respectively. Bottom depths estimations and their adjustment were performed in accordance with commonly accepted hydrographic standards. In the Deep Arctic Basin depths measurements were acquired at 1-3 km intervals from "North Pole" drifting ice-camp stations (KISELEV 1986). Additional information was provided by German R/V "Polarstern" (FÜTTERER 1992, 1994) in the form of raw digital data; despite continuous digital acquisition along extended observation lines, this set contained a large amount of random errors and was only partly included into our compilation. Characterization of input digital data is given in Fig.1.

DATA PROCESSING

Data were processed using the software developed in Geological Survey of Canada (VERHOEF et al. 1995) for digital compilation of potential fields and other geophysical data. The processing included the following succession of operations: 1) editing, correlation and preliminary gridding of Russian point observations data; 2) visual comparison of contours derived from Russian gridded point data with other available contours data and developing of intermediate grids; 3) integration of all obtained gridded data sets to a final grid.

Differences in field surveys methods resulted in variety of procedures for editing of initial data. Observations of type 1 (Tab. 1) in the areas of overlapping surveys were sorted out manually for mutual compliance. In nearshore zones these observations were additionally examined for conformity with World Vector Shoreline (WVS) data provided by the software. Russian

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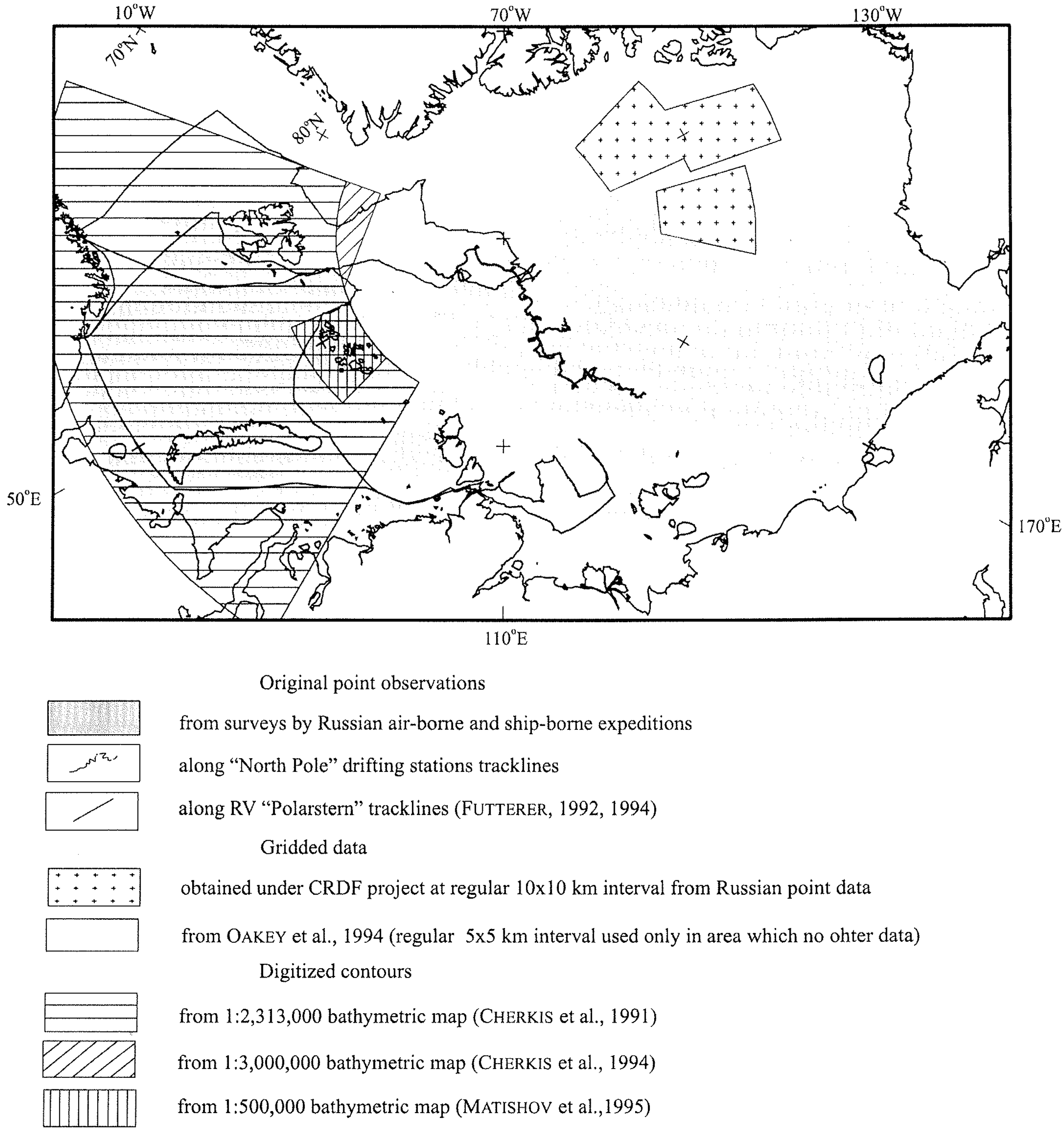

Fig. 1: Location diagram for input data used in digital bathymetric model

shipborne data were adjusted by means of cross-over analysis. Coherent data were prepared by correcting the depth values to make discrepancies not more than 3-5 m in the depth range less than 100 m and not more than 10-15 m in depths greater than 100 m. After correlation of all shipborne surveys data sets the root mean-square error of the surveys conducted within the depth range about 20-600 m accounted for 5 m. Observations of type 3 (Tab. 1) and R/V "Polarstern" raw data were edited by procedure of detection and removal of spikes using fourth order difference calculation. After correlation all "North Pole" data were included in the data set, whereas R/V "Polarstern" data were used mainly in deep sea areas. The edited and adjusted point data sets were gridded by Minimum curvature (SMITH & WESSEL 1990) and Kriging (CRESSIE 1990) methods using various grid intervals. The primary grid intervals secured by the real observations density were from 3 to 15 km.

Type of observations	Navigation (type, accuracy)	Depth estimations (method, accuracy)
1. Landings on ice (regular coverage) in East-Siberian Sea, Laptev Sea, Chukchi Sea, Arctic Basin	Radio Navigation - ±200-±600 m Integrated Radio Navigation and Astronomy ±600 m	Single channel seismic 0.1 % - 1 % depth Echosounding 0.5 - 1 % depth Lead ±5m
2. Systematic shipborne surveys in Barents Sea, Kara Sea	Satellite ±300 m Radio Navigation ±200 m Astronomy ±1000 m	Echosounding 1 % depth Lead ±5m
3. Observations from „North Pole" drifting stations	Satellite ±300 m Astronomy ±1000 m	Single channel seismic 0.1 % - 1 % depth

Tab. 1: Types of Russian bathymetric point observations in the Arctic Ocean.

The next step was to test the contours derived from Russian gridded point data for compatibility with other available bathymetric information. For that purpose the contours plotted from newly developed Russian grids were visually compared with published bathymetric maps (ATLAS OF THE OCEANS 1980, PERRY et al. 1986, CHERKIS et al. 1991, 1994, MATISHOV et al. 1995) and contours plotted from public domain grids (COAKEY et al. 1994, NOAA 1988). It appeared that, in comparison with isobaths obtained from new Russian grid, the data of ATLAS OF THE OCEANS (1980), PERRY et al. (1986) and NOAA (1988) were much more generalized, whereas maps published by CHERKIS et al. (1991, 1994) and more detailed map of MATISHOV et al. (1995) demonstrated good agreement and therefore were used in full extend for western Eurasian margin area. This also confirmed reliability of our new grid and justified using it as the basis for digital compilation in the entire area covered by Russian point observations. Data of OAKEY et al. (1994) mainly based on digital contours from GEBCO Sheet 5.17 (JONES 1994) which also existed in the same area were found less informative, and for that reason this digital set was included in the final compilation only where no other evidence was available.

After selection of all input data sets it was necessary to develop intermediate grids for separate seabed portions differing in principal features of bottom relief. The following specific seabed portions were recognized: (i) nearshore zone, (ii) western shelf and slope, (iii) eastern shelf and slope, (iv) Norwegian-Greenland Basin, (v) Gakkel Ridge, (vii) Alpha-Mendeleev Ridge, (viii) Chukchi Borderland, and, finally, (ix) deep water basins of the Arctic Ocean.

In the nearshore zone straightforward compilation results in appearance of numerous artifacts caused by a jagged configuration of coastline. Hence it was found practicable to form the specific 1.5 km grid in this zone from our input bathymetry data supplemented by land component of NOAA (1988). It allowed to minimize the discrepancies between zero-depth grid values and WVS data. Deeper and more differentiated western shelf/slope and Norwegian Greenland Basin were gridded using the minimum curvature method with various tension factors at 2.5 km interval, in shallower and flatter eastern shelf/slope the same method was applied with high tension factors. Because of differences in bottom topography and general geometry of the bathymetric highs in the Deep Arctic Basin (NARYSHKIN 1995) the respective data sets were processed using individual combination of grid parameters. In all cases directional gridding by Kriging method was applied at the intervals between 3 and 10 km which enabled to enhance the anisotropic appearance of these bottom features. Deep water basins were found sufficiently uniform to allow similar processing procedure by minimum curvature method at 10 km interval. The above specific grids were merged in a single gridded data set which was subsequently integrated with OAKEY et al. (1994) data to form a final 5 km grid.

DISCUSSION

A color contour image of the digital model of the Arctic Ocean relief is presented in Figure 2. The color depth scale is chosen to portray the main relief features, whereas additional contours display smaller details.

A new bathymetry compilation is the next stage of updating the international digital bathymetry of the Arctic Ocean. Our digital model is based on much greater amount of source data than earlier digital compilations, and in our view, offers the opportunity to produce a computer print-out at 1 : 5 000 000 scale which for the first time will be truly backed by the quality and density of original information. For the Eurasian Arctic shelf the creditability of input data is even higher and allows reliable hard-paper visualization at 1 : 2 500 000 scale. The control of trustworthiness of our model is provided by its good agreement with newly published manual 1 : 5 000 000 map (BOTTOM RELIEF OF THE ARCTIC OCEAN 1999).

Many features of the Arctic Ocean seabed that are important for regional tectonic interpretations and geopolitical issues (such as

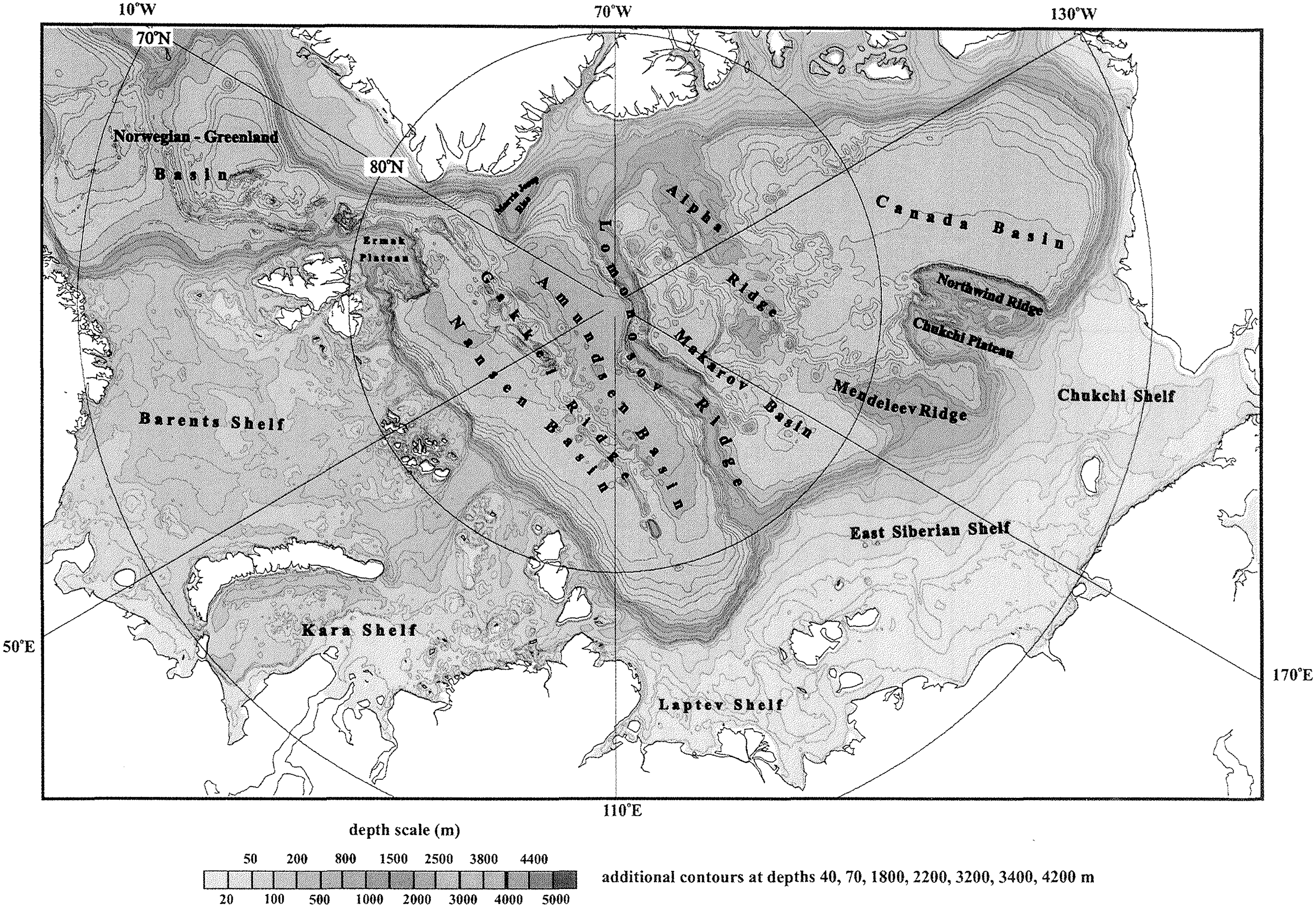

Fig. 2: Digital color image of the bottom relief of the Arctic Ocean

delimitation of the outer extent of the continental shelf in Law of the Sea context) but only preliminary outlined in earlier compilations can now be recognized with greater confidence. This refers in the first place to deep water portion of the Arctic basin where coherent geometry of the Gakkel and Lomonosov Ridges and separating basins is combined with clearly expressed segmentation of the Gakkel Ridge and apparent heterogeneity of the Lomonosov Ridge relief. Also noteworthy is the regular interval (500-600 m) in bathymetric highs in the central part of the Arctic ocean. Some new essential details have also emerged in sub-polar part of the Canada Basin.

CONCLUSION

A new digital model of the Arctic Ocean bottom relief has been developed in VNIIOkeangeologia and tested in comparison with both earlier digital compilations and modern manual products. It has also been successfully applied in lithospheric studies based on joint analysis of bathymetry and potential fields (MASCHENKOV et al. 1999). The model may be regarded as the first step in creating a comprehensive integration of digital Arctic Ocean bathymetry currently undertaken by the Arctic earth science community under IOC-IASC-IHO project (MACNAB & GRIKUROV 1997) for the purposes of improved cartographic imaging and resource management in the High Arctic.

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