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Joint Compilation of Russian and US Navy Aeromagnetic Data in the Central Arctic Seas

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THEME 1: Magnetic Provinces around the Eurasian Basin: Interplay with Tectonism

Summary: A reliable and well adjusted digital magnetic anomaly data base is crucial for production of accurate magnetic anomaly maps and its geological interpretation. Widely used magnetic anomaly grids and maps compiled for the Arctic ocean (VERHOEF et al. 1996) in the large part of the central Arctic seas covered mostly by historical Russian and in some areas by historical US aeromagnetic surveys are presented by inadequately accurate data. To create a more accurate digital magnetic anomaly data base in the Arctic region teams at VNIIOkeangeologia and at the US Naval Research Laboratory have been assembled to combine and reprocess both historical and recently collected anomaly magnetic profile data in the central Arctic seas. The new magnetic anomaly map based on results of the compilation is more accurate and provides additional information for geological mapping and tectonic interpretation.

INTRODUCTION

Magnetic anomaly maps in the Arctic ocean have been the subject of regional compilation for many years. A magnetic anomaly map of the Arctic ocean showing black and white strips of positive and negative magnetic anomalies compiled by A.M. Karasik (KARASIK 1980) and a residual magnetic anomaly chart compiled at NRL (KOVACS et al. 1985) are well known and were widely used for geological interpretation. The significance of these maps for better understanding of tectonic and evolution of the Arctic ocean is difficult to overrate. For instance, analysis of magnetic field anomalies allowed researchers to reveal in the Arctic ocean two basins, Eurasia and Amerasia, divided by the Lomonosov Ridge and characterized by a complex geological structure and evolution. After aeromagnetic surveying the origin and general features of the Eurasia Basin and Lomonosov Ridge became much clearer. At the same time, however, in contrast to the simple two plate spreading system of the neighboring Eurasia Basin and the Gakkel Ridge, there remain several unresolved problems connected with the origin and evolution of the Amerasia Basin.

In the early 1990s it was realized that any real success in interpretation of the Arctic magnetic anomalies may be achieved only after a joint digital compilation of all available aeromagnetic data that have been collected by different countries in the region. The first available computer readable magnetic anomaly data base of the entire Arctic ocean for the geoscientific community was created at the Geological Survey of Canada-Atlantic (VERHOEF et al. 1996). The appearance and wide distribution of this significant new magnetic data set in digital form, presented as grids and maps, resulted in the development of various new ideas connected mostly with the origin and details of the evolution of the Amerasia Basin. At the same time this compiled data set in the central Arctic Seas is based mainly on results of historical US Navy and Russian aeromagnetic surveys. The Russian part of the data was extracted from previously digitized hand contoured maps, originally prepared at a small scale of 1 : 5 000 000. The real patterns and the level of magnetic anomalies on this map are quite problematic. These problems could only be resolved after total reprocessing of all Russian data from raw magnetic anomaly profile maps. A good opportunity to create a more accurate digital compilation of magnetic anomaly data in the central Arctic ocean presented itself in 1996. At that moment a large amount of more accurate digital aeromagnetic information in the central Arctic Seas was being collected by NRL. All Russian historical initial magnetic anomaly profile data sets partly overlapped by the recent US surveys were digitized and involved in the coherent data base. Thus the joint work for adjusting of all historical and modern US and Russian raw anomaly magnetic profiles data was initiated by teams at NRL and VNIIOkeangeologia. In this paper we present both the results of reprocessing and analysis of existing Russian data sets and the results of the new joint US/RF magnetic anomaly data compilation.

The first attempt to adjust the navigation and to level historical Russian and US Navy profiles was undertaken in 1993 in order to provide a unified high quality data set for use in the magnetic anomaly compilation in the Arctic ocean project initiated by GSC-Atlantic (MACNAB et al. 1991). Preliminary comparison of the digitized contour magnetic data contributed to the project by the scientists of VNIIOkeangeologia with the data contributed by scientists from the US Naval Research Laboratory (NRL) have shown many problems in both historical data sets overlapping each other in the Amerasia Basin. The data sets require special handling for meaningful comparison and adjustment (MACNAB et al. 1992). The analysis of initial magnetic anomaly profile data showed that leveling and diurnal correction of the individual profiles of the US Navy data was poor, although its absolute navigation is good; while for the

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Russian data the leveling and diurnal correction are supposedly much better, but the absolute navigation is poor. Taking into account that the strengths and weaknesses of the two data sets are complimentary, an opportunity for fruitful scientific collaboration in adjustment and interpretation of the resulting joint data set was recognized by scientists of VNIIOkeangeologia and NRL.

DESCRIPTION OF THE DATA

Russian aeromagnetic data in the Central Arctic were acquired between 1961 and 1992 during surveys flown with variable line spacing and orientation (Fig. 1). Most of these tracks are oriented almost perpendicular to the main geological structures of the Gakkel, Lomonosov, Alpha-Mendeleev Ridges and the adjacent basins. The surveys have been carried out by VNIIOkeangeologia and the Polar Marine Geosurvey Expedition (PMGE). Different models of fluxgate, proton precession and quantum (optically pumped) magnetometers were used. Base stations were established on islands, on coastal areas and on ice to monitor diurnal variations and to provide observations for regional adjustments. The very first surveys were navigated by both visual positioning and by a photo positioning technique. The errors of navigation in this case varied from a few km to a few tens of km. Later several modifications of radiogeodetic systems (RYM and POISK) were applied for navigation, yielding positions with standard deviation of 1-9 km at a survey altitude of 600 m. The modern (1989-1992) surveys over the De Long Islands - North Pole Geotransect were flown at an altitude of 100 m and navigated by a satellite system. The standard deviation of positioning over the Geotransect area ranges between 45-65 m. Original information is stored in VNIIOkeangeologia in analogous records and magnetic anomaly profiles maps in different geographical projections at scales ranging between 1 : 5 000 000 (trackline spacing 50 km) and 1 : 500 000 (trackline spacing 5 km). The total length of Russian aeromagnetic profiles in the central Arctic ocean is more than 550 thousand line km.

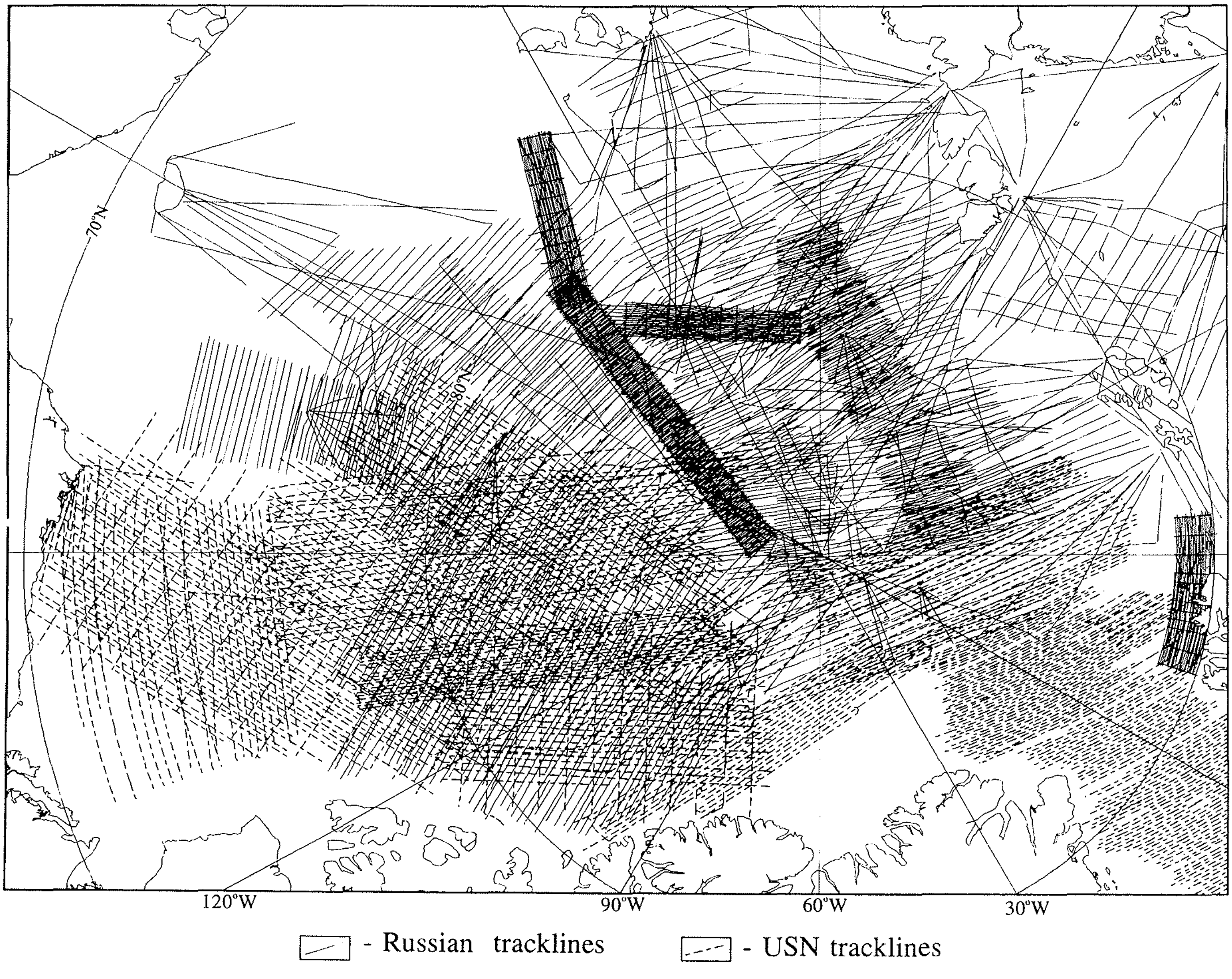

Fig.1: Russian and US Navy aeromagnetic tracklines in the central Arctic seas.

US data in the region were collected between 1972 and 1998 and approximately doubles the aeromagnetic coverage in the region. The south part of the Eurasia Basin and the largest part of Amerasia Basin are covered by a regular net of profiles (Fig. 1). Historical data sets collected in the 1970s had better absolute navigation than Russian surveys but had problems with the leveling and diurnal correction. The recent data acquired from 1992 to present have high quality and excellent navigation based on long-baseline GPS intereferometry (rms error = 0.1 m). The surveys cover the Canada Basin, Alpha-Mendeleev Ridge and Chukchi Cap by tracks with a line spacing of 10-30 km and cross tracks every 75-90 km.Survey altitude was about 600 m altitude. The surveys were laid out to tie one into another to form a continuous net of profiles. The new data sets are oriented oblique to the historical US and Russian aeromagnetics, allowing the adjustment of those historical magnetics to the modern data.

DATA PROCESSING

The adjusting software procedure consists of several steps. The preliminary adjusting was proceeded using the digitized Russian contour data used at GSC-Atlantic. These data were divided into coherent survey blocks and cross-correlated with band-pass filtered USN data, which had a power spectrum similar to the gridded Russian contour data, to provide initial navigation correction vectors. At that point, the initial vector correction was applied to the original Russian profile data, also divided into a few coherent blocks of profiles flown in short periods of time for each survey. These blocks later were gridded and cross-correlated with high-pass filtered USN data to provide the final vectors of navigation corrections. These vectors were then applied to the original Russian profile data. Next, the US data were leveled and adjusted to the Russian data using a cross-correlation procedure to form the final combined data set which was later involved in the GSC-Atlantic compilation. The results of the preliminary combination of a few historical Russian and US data sets in the Amerasia Basin were presented a few years ago (Kovacs & Glebovsky 1993). It was shown that the usage of combined data sets significantly improves the regional magnetic anomaly map in the most complex areas of the Central Arctic.

In 1996 a new joint project funded by CRDF (Civilian Research and Development Foundation) was arranged in collaboration between NRL and VNIIOkeangeologia, in order to improve the magnetic anomaly data set for the entire Arctic Ocean and to compile a high quality regional computer-derived magnetic anomaly map for integrated geophysical analysis and tectonic interpretation. At the beginning of the project a large part of the Amerasia Basin was covered by US low-level, high quality aeromagnetics (Fig. 1), providing an opportunity to adjust the major part of historical Russian surveys in the region (to date the recent NRL study area is about 2 000 000 km^2). The raw US Navy data were leveled at NRL and handed to the Russian collaborators. To adjust the Russian magnetic anomaly data sets the cross-correlation procedure has been applied for each historical survey. The initial assumption about relatively accurate local navigation for the old Russian data was refuted after detailed crossover analysis. Individual analysis of every Russian digitized profile compared with the more accurate recent NRL data (considered as the reference data set) shows that individual profiles must have different navigational correction. Thus the processing of Russian historical data was complicated by additional steps for more precise adjustment. It includes: initial leveling and cross-correlation analysis of the gridded magnetic anomaly profile data sets with final grid of the recent NRL data in the overlapping area; large scale (1 : 1 000 000) plotting; initial determination of the best position for each profile; discarding or initial shifting, using software developed by M. Korneva; and final computer correction of navigation and adjusting, using software developed by GSC-Atlantic (Verhoef & Usov 1995).

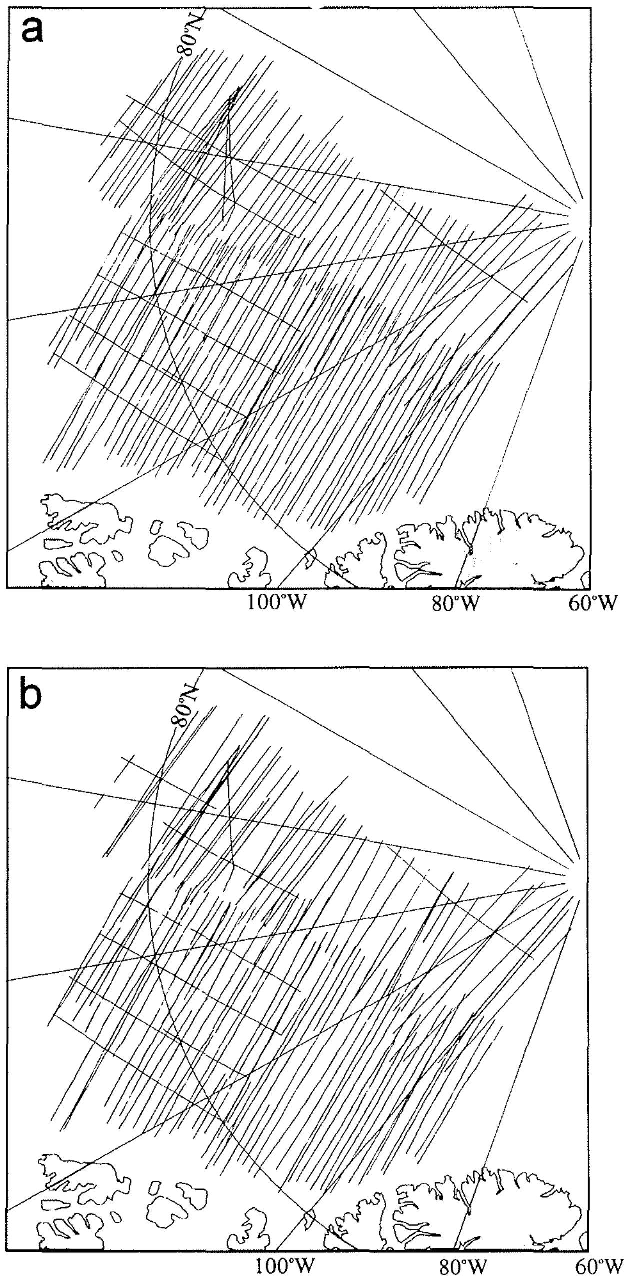

Fig.2: Russian tracklines before (a) and after (b) navigational corrections.

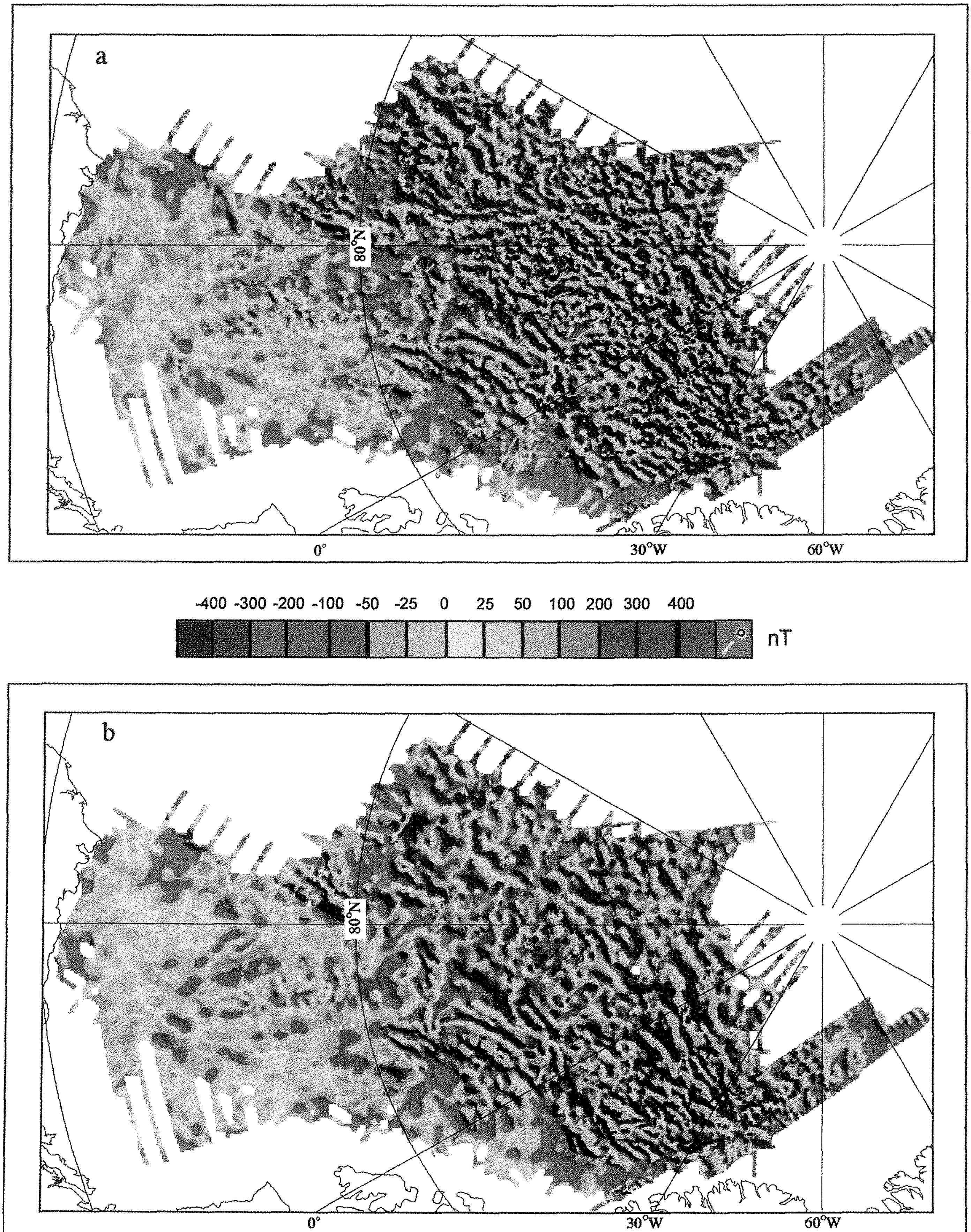

Fig.3: Magnetic anomalies in the Amerasia Basin. (a) based on results of adjusting of the USN and Russian aeromagnetics; (b) extracted from 5 x 5 km grid (GSC, Open file 3125a, VERHOEF et al. 1996).

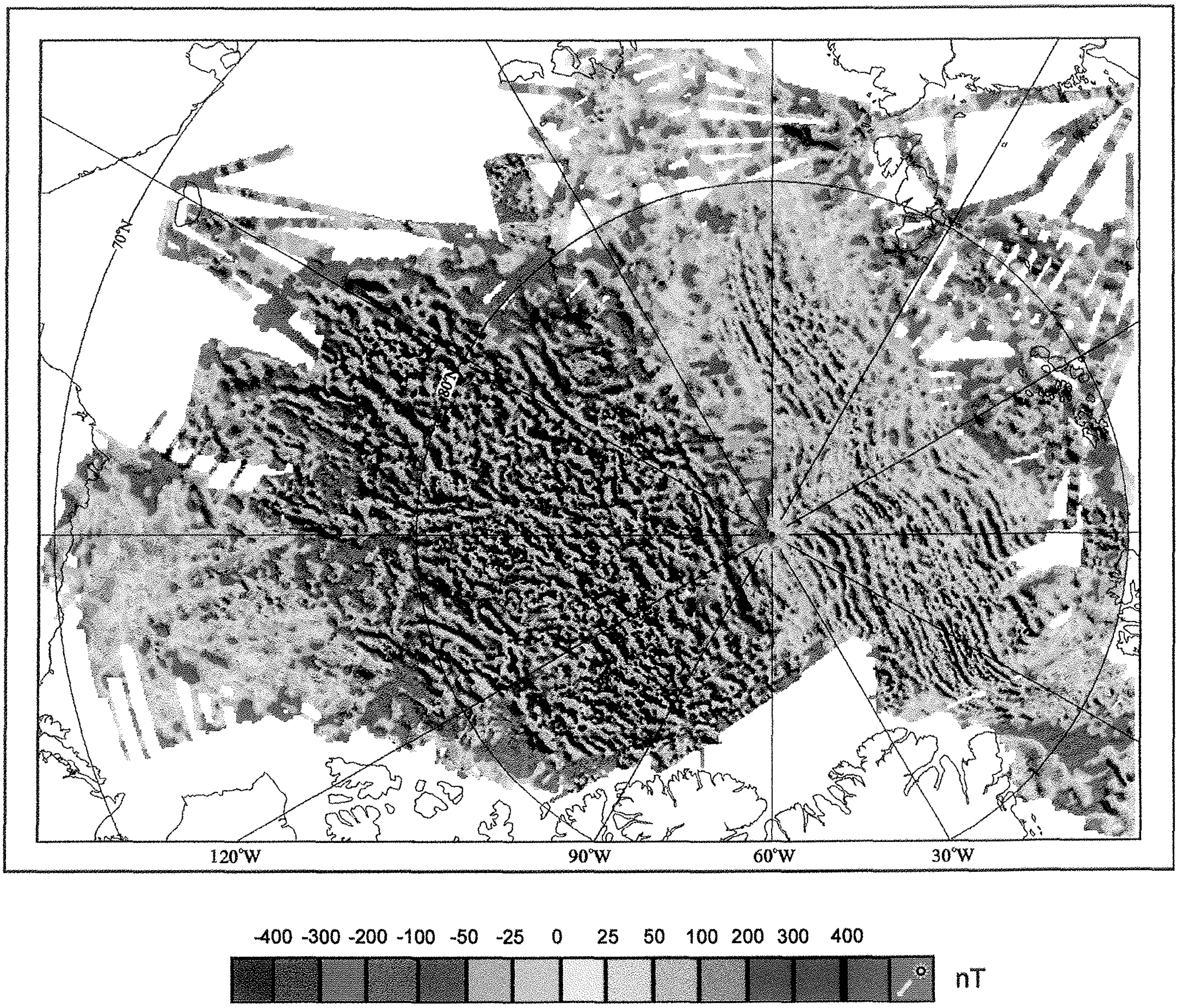

Fig.4: Magnetic anomalies in the central Arctic seas (USN / Russian joint 5 x 5 km grid).

The results of navigational correction for a few Russian historical data sets are shown on Figure 2. About 10 % of the data was discarded. Each newly adjusted data set was then used as reference field to combine and adjust historical surveys which have no overlap with NRL investigations. The final combined NRL/RF data set then was converted to a Transverse Mercator grid with cells 5 x 5 km by means of a minimum curvature algorithm (SMITH & WESSEL 1990) and plotted.

NEWLY COMPILED MAPS.

Combining and adjusting the NRL and Russian magnetic anomalies is still in progress. The new NRL aeromagnetic studies of the Chukchi Cap in 1997 are included in the grid, while the 1998 study of the Gakkel Ridge was used for navigation adjustment. The resulting shaded relief magnetic anomaly maps in the Amerasia Basin (Fig. 3) and the Central Arctic ocean (Fig. 4) are much more detailed in the area covered by recent NRL and historical Russian surveys in comparison to the magnetic anomaly map distributed by GSC (VERHOEF et al. 1996). The maps portray more accurately major tectonic elements and boundaries in the central Arctic Seas and may allow some major problems of geological structure and evolution of the Amerasia and Eurasia Basins to be resolved. Areas of possible seafloor spreading, magnetic lineations and transform faults in the Makarov Basin have become better defined in these maps. The signature of magnetic lineations in the Eurasia Basin, especially those close to the Gakkel Ridge/Laptev sea shelf junction is defined more accurately. We hope that the new digital compilation of NRL and Russian magnetic anomaly profiles will form the basis for future interpretation and analysis, and for the design of new shipborne and airborne studies in the region.

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