ISSN 1028-334X, Doklady Earth Sciences, 2008, Vol. 419, No. 2, pp. 205–209. © Pleiades Publishing, Ltd., 2008.
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GEOLOGY

Prognostic Map of the Sedimentary Cover Thickness for the East Siberian Sea Based on Satellite Altimetry Data

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Presented by Academician V.E. Khain January 18, 2007

Received January 19, 2007

DOI: 10.1134/S1028334X08020037

Due to its geographic position and climatic conditions, the East Siberian Sea shelf is the least studied passive continental margin of Russia. The shelf area makes up about 10^6 km^2, and its seismic study involves only individual profiles with a total length of a few thousand kilometers. Therefore, the observation system does not even correspond to the regional scale. As a direct correlation of seismic data to drilling is unavailable for the region, its interpretation is based on indirect information and wave field characteristics used in seismostratigraphy [2, 6–8].

The high hydrocarbon potential of the region requires new approaches to the reliable assessment of the sedimentary cover thickness (SCV) for the whole region and compilation of a tectonic map. This work elucidates an approach to solution of the problem in a semiquantitative form (with a low appraised accuracy) based on remote methods.

Such information involves satellite altimetry data recalculated into the free-air gravity anomaly for the polar region [9]. The coverage accuracy makes up 7.5 mGal, which is sufficient for solving regional problems. The free-air anomaly recalculated into the Bouguer anomaly using topographic data of the International Bathymetric Chart of the Arctic Ocean (IBCAO) is presented in Fig. 1. The Bouguer anomaly virtually does not differ from the free-air anomaly for the shelf area, but its high values suggest the proximity of the dense mantle substrate to the ocean and continental slope beyond the shelf. Taking into account the weak (compared to the deep-water part of the profile) effect, the behavior of the Bouguer anomaly on the shelf generally reflects the topography of the most contrasting and closest density boundary of the crust. Such an interface represents the top of the acoustic basement. The correlation of values of the gravity anomaly and the basement top depth is used for the quantitative prediction of the interface position in the absence of direct seismic data. Such a prediction involves, as a rule, construction of the model implying the relationship between the basement depth H (or SCT) and the anomaly ΔG representing a simple linear dependence. The dependence is calculated by the correlation of real structural data with the anomalous field for regions located in the neighborhood or presumably exhibiting a similar structure. Later, in the case of direct seismic observations, the model can be corrected or the necessity for its use may vanish. The Bouguer anomaly pattern of the water area exhibits depressions separated by bulkheads and linear dislocations (Fig. 1). The structure of this field was transformed into the map of prognostic isopachs of the sedimentary cover. In the south, such a transformation is constrained by the coastline, because the satellite altimetry provides us with information about the gravity field on water areas; in the north, by the shelf edge, the area beyond which is characterized by quite another relationship between the field, relief, and sedimentary cover; and in the west and east, by the New Siberian Islands and Wrangel Island, respectively.

The Laptev Sea, which has been much studied in terms of seismic observations on the regional scale and for which maps of the SCT have been published, is one of the regions nearest to the water area under investigation [4]. Figure 2 shows the correlation of the SCT and the Bouguer anomaly. It is evident that a vast area of the main part of the shelf located in a weak gravity field (<50 mGal) exhibits a stable linear correlation with the SCT and can be approximated by the linear relationship

$$H = -582\Delta G + 3492,$$

where H is the thickness of sediments, m, and ΔG is the Bouguer anomaly, mGal. The accuracy of the approximation is poor. Therefore, we speak only about a semiquantitative appraisal, which allows us to assess the character and order of the value under study. The correlation at higher values of the Bouguer anomaly (>50 mGal) is uncertain because of differences in the geometry and density properties of the crust in the region beyond the

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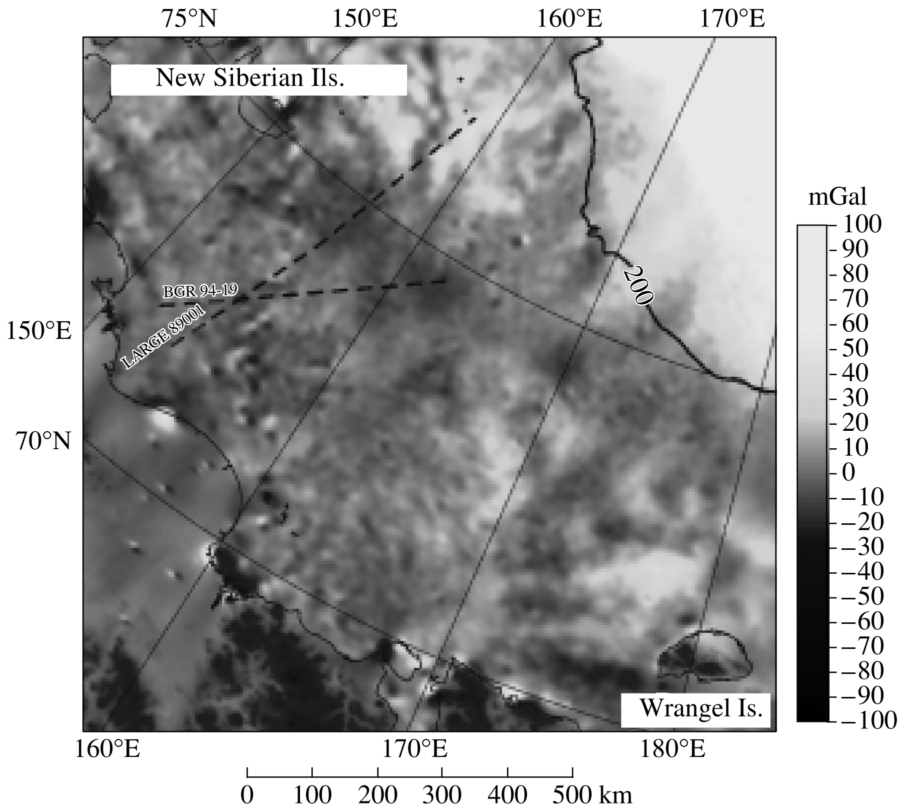

Fig. 1. The Bouguer anomaly for the East Siberian Sea calculated after [9], positions of profiles LARGE 89001 [2] and BGR94-19 [7], and isobath 200 m marking the shelf edge.

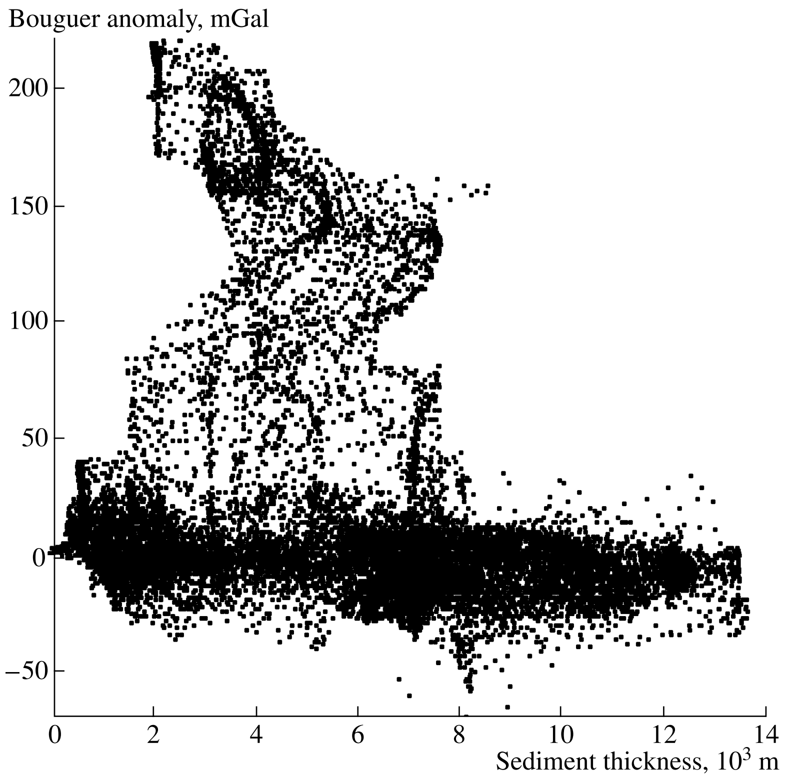

Fig. 2. Correlation of the Bouguer anomaly and the sedimentary cover thickness for the Laptev Sea based on data from [4].

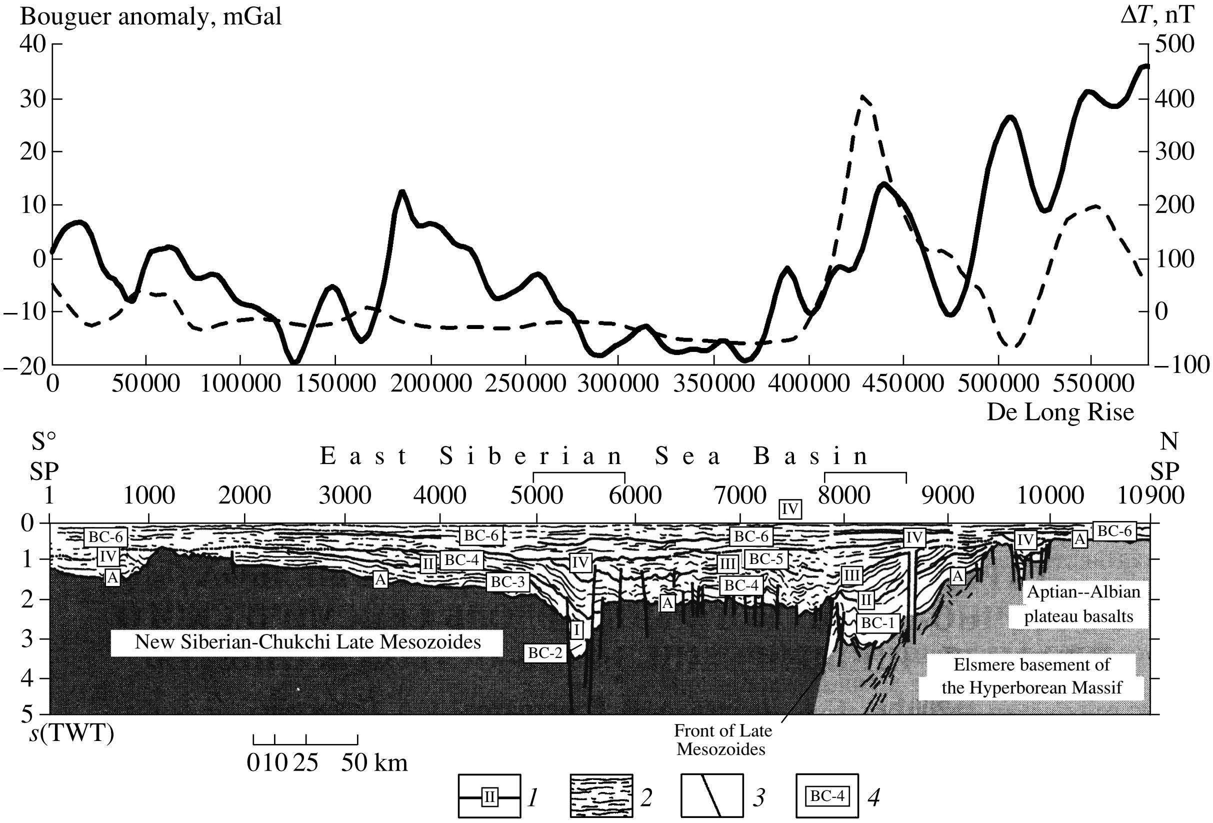

Fig. 3. Seismogeological section along profile LARGE 89001 modified after [2], the Bouguer anomaly calculated after [9] (firm line), and the anomalous magnetic field after [11] (dotted line). (*1*) Seismic boundaries and their indexes; (*2*) reflection within seismic complexes; (*3*) faults; (*4*) indexes of seismic complexes.

shelf edge, for which no prediction isopach map will be compiled.

For the East Siberian Sea, the model obtained by the correlation presented in Fig. 2 should be corrected by comparing remote measurements with rare real data along individual profiles. The dotted lines in Fig. 1 show the positions of western profiles LARGE 89001 [2] and BGR94-19 [7], with which the necessary comparison has been carried out. Figure 3 shows the seismogeological section along the profile LARGE 89001 and its comparison with data of the Bouguer anomaly and the anomalous magnetic field [11]. A similar comparison for the profile BGR94-19 is given in [7] (Fig. 3). It is evident from these comparisons that the Bouguer anomaly satisfactorily correlates with the acoustic basement depth, although there are two distinctions. First, when comparing the anomalies with the basement, the alternating difference was established in the southern part of the profile LARGE 89001 (Fig. 3), which might be related to the essential heterogeneity of the New Siberian–Chukchi Late Mesozoides, the lithology of which varied from ophiolites to terrigenous flysch sequences [5]. In this case, the calculation of the parameters of the total SCT by the Bouguer anomaly may be more objective than the determination of its base by the intense correlatable reflector on the seismic profile. In terms of physical properties, flysch sequences in Mesozoides should belong to the sedimentary cover. Second, the northern part of the profile located in front of the De Long Rise exposure onto the slope in the depression area with the SCT equal to 3.5 s (~5 km) includes the Bouguer anomaly maximum, which coincides with an intense anomaly in the magnetic field (>400 nT) (Fig. 3) and unambiguously indicates the presence of massive magmatic bodies in this part of the profile. The De Long Rise incorporates Neogene–Quaternary olivine basalts and alkaline ultrabasic rocks [3] with a greater density relative to sediments. These rocks introduce interference in the calculation algorithm for parameters of the sedimentary cover by the Bouguer anomaly. This means that areas of intense magnetic anomalies should be marked on the map as zones where the algorithm can be invalid. The analysis of the profile BGR94-19 [7] passing through a local depocenter (maximal sediment thickness of ~6 km), which spatially coincides with the position of the local minimum of the Bouguer anomaly (Fig. 1), confirms the above-mentioned relationship between the potential field and parameters of the sedimentary cover. The reflection horizon ESS-1 was considered as the sedimentary cover base for the profile BGR94-19.

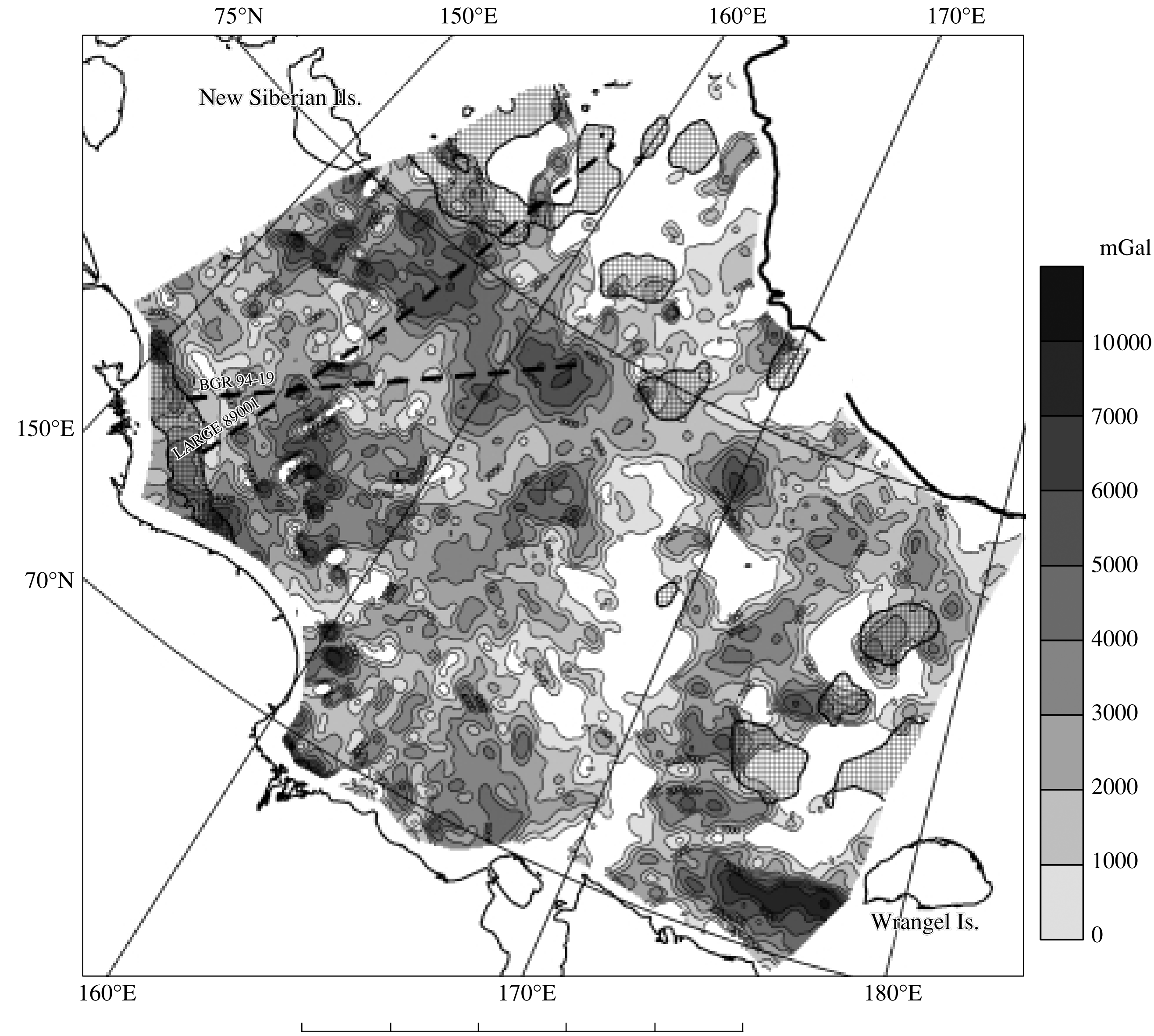

Fig. 4. Prognostic map of the sedimentary cover thickness for the East Siberian Sea, positions of profiles LARGE 89001 [2] and BGR94-19 [7], isobath 200 m marking the shelf edge, and zones of intense (>100 nT) magnetic anomalies (hatched areas).

The comparison of anomaly graphs (Fig. 3) with values of the sediment thickness on profiles allows us to calibrate the linear model for the gravity dependence of the sediment thickness obtained based on data for the Laptev Sea and to display it as

$$H = -240\Delta G + 1480,$$

where H is the thickness of sediments, m, and ΔG is the Bouguer anomaly, mGal. The dependence was used for compiling the prognostic map of the SCT for the East Siberian Sea (Fig. 4) after calculation of the spatial low-frequency filtration of the result for wavelengths exceeding 15 km.

The distribution of the SCT obtained shows that the cover is located in grabenlike basement depressions, which separate block segments of the sea area described in [1]. The basic sediment mass is concentrated in the western part of the Novosibirsk–Alaska Trough [10], which is referred to as the Vilíkitskii Trough, and in its branches (Fig. 4). It is crosscut by numerous NE- and NW-trending linear zones. Areas with signs of magmatism established by magnetic data are shown by hatching. The areas are, as a rule, confined to the periphery of the basement protrusions or intersections of linear zones. The greatest thickness is expected to be in the depression southwest of Wrangel Island, which is similar in its Bouguer anomaly configuration to the southern Chukchi Sea basin but occupies a smaller area. Nevertheless, the maximal prognostic thickness in the depression reaches 10 km. The combination of three depressions located northwest of Wrangel Island is interesting. According to magnetic data, the thickness of sediments with zones of magmatic manifestation exceeds 4 km. They make an arc around the island. The southern extension of the arc is the above-mentioned depression in the Long Strait. The comparison of the prognostic map of the sediment thickness (with the structural scheme for the regional surface of the Lower Cretaceous unconformity) based on individual seismic profiles in the central part of the water area [6] shows a satisfactory coincidence of the map configuration in profile sites. In this case, generalization of the adduced contour lines should be taken into account.

Thus, calculation of the prognostic thickness of the sedimentary cover for the East Siberian Sea based on satellite altimetry data allowed us to outline the distribution of the desired parameter, which is consistent with real seismic data even on rare isolated profiles. The map is an appraisal version. It shows the semiquantitative order of values and spatial distribution of the SCT, as well as the relationship of the cover with tectonic structures of the basement and manifestations of magmatism. The map may be used for the calculations of resource assessments of the water area, the study of the regional tectonics and heterogeneity of the acoustic basement, and the choice of the most promising lines of investigations in the region. The compilation principle of such maps can also be used for drawing the SCT map for passive margins of the Arctic Ocean.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research (project nos. 06-05-65223 and 05-05-65198) and the Division of Earth Sciences of the Presidium of the Russian Academy of Sciences (program 14).

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