UDC 551.33

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ARCTIC BASIN TECTONICS

Abstract: *This article presences assessment about the tectonic structure of the Arctic shelf and the Arctic Basin water area followed by the determination of structural delineations of geological formations. Evaluation of gravitational Eurasia's basin anomalies and numerical seismic data of Arctic basin. There is presented structure of sedimentary layer and modern morphological shape of Arctic basin.*

Key words: *Cup rock, hydrogen accumulation, permeable rock, limestone, sandstone, shale, geological assessment, layer structure, hydrocarbon migration, restricted basin.*

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ТЕКТОНИКА АРКТИЧЕСКОГО БАССЕЙНА

Аннотация: *В данной статье представлена оценка тектонического строения арктического шельфа и акватории Арктического бассейна с последующим определением структурных разграничений геологических формаций. Дана оценка гравитационных аномалий бассейна Евразии и численных сейсмических данных Арктического бассейна. Представлена структура осадочного слоя и современный морфологический облик Арктического бассейна.*

Ключевые слова: *Покрышка коллектора, скопление углеводородов, проницаемая порода, известняк, песчаник, сланец, геологический анализ, структура породы, миграция углеводородов, ограниченный бассейн.*

INTRODUCTION

The Arctic Ocean is a unique polar area in the world basin. This area is much smaller compared with other oceans, connecting to the World Ocean only by narrow straits - the Fram Strait in the west (with the Atlantic Ocean) and the Bering Strait in the east (with the Pacific Ocean). The Arctic Ocean differs from other oceans in a much smaller average depth (~2.5 times), the largest area of the adjacent shelf and deep water areas with continental crust, as well as in a much more thicker sedimentary cover. It should also be noted that the Arctic Ocean is also the youngest ocean on the planet.

Below (Figure 1) is a map of the main morphostructures of the Arctic Basin, where 1 is the province of Central Arctic uplifts; 2 is the bathymetric terraces of the Makarov Basin.

Considering the diversity of the existing tectonic models of the Arctic Ocean from the Arctic Geodynamic System (or Arctic Geodepression) by Pogrebitsky Yu.E. (1976) to the ultra-mobile model by Lawver L.A. (2002), it should be noted that they have one common fundamental element - the split of Arctic Eurasia with subsequent development of the spreading Eurasian sub-basin in the Cenozoic.

It should be noted that all disintegrated supercontinents (Pangea, Gondwana, and Eurasia) are characterized not only by the typical for the oceanic crust bilateral symmetry along the oceanic floor level relative to the divergent axis (the observed symmetry breaking is local), but also elements of symmetry between the continents that have moved apart along the hypsometric level of the lithospheric surface (South America and Africa, North America and Western Europe - representing the elevated above sea level shoulders of the Atlantic Ocean rift).

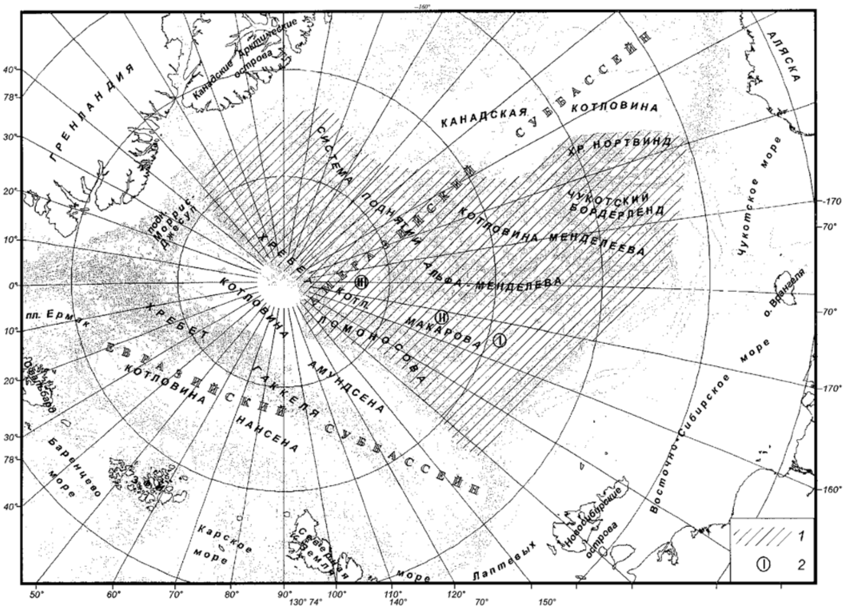

Figure 1 - Carat of the main morphostructures of the Arctic Basin

On the other hand, a review of the existing tectonic reconstructions of the subbasin, which reveal the mechanisms of its oceanic floor expansion on the basis of interpretation of the linear magnetic anomalies, reveals their extreme instability (chaotic wandering of the opening/rotation poles over significant distances, irregular scatter of the paired anomalies when trying to align them with the opening axes, etc.). As a result, none of the series of known paleomagnetic reconstructions of the Amerasian sub-basin fully satisfies neither the magnetometric data on the water area nor the geological data on the coastal and island framing.

METHODS

In 1997 the Russian Federation ratified the "1982 United Nations (hereinafter UN) Convention on the Law of the Sea" and subsequently prepared a Submission (Application) on the Outer Limit of the Continental Shelf (OLCS) of Russia in the Arctic Ocean (VNIIOkeangeologiya - the leading organisation on this issue). In 2001 the Russian application was submitted to the UN Commission on the Limits of the Continental Shelf. The work of the Commission's experts resulted in a number of comments and recommendations regarding the Russian Application, failure to comply with which jeopardizes international recognition of the Russian ILCS in the Arctic. Particular attention was paid by the experts to the analysis of geological and geophysical data, which provided information on the regional features of the structure and evolution of the Arctic Ocean lithosphere and, ultimately, developed the concept of the Russian application, which is based on attribution of parts of the largest rises the Amerasian subbasin (Lomonosov Ridge and Mendeleev Rise) to components the continental margin of north-east Eurasia. "Regional features of the sedimentary cover of the Amerasian subbasin and possibilities of their paleotectonic interpretation" was presented at the international conference "Morphology and geological nature of deep-water of the waters and submarine notions of the Arctic Basin: Controversial Scientific Issues in the Context of Article 76 of the UN Convention on the Law of the Sea" in St. Petersburg, 2003; "Paleotectonic Interpretation of Seismic Data in the Deep Arctic" was presented at the 4th International Conference on Arctic Continental Margins (1CAM IV) in Halifax (Canada), 2003; report on geological-geophysical survey results in the zone of junction of the Mendeleev Rise with the adjacent shelf was made at the American Geophysical Union Conference (AGU 2006 Fall Meeting) in San Diego (USA), 2006; report "Geological and Geophysical Model of the Earth's crust in junction zone of the Mendeleev Rise with shelf of the East Siberian and Chukchi Seas" was presented at the 33rd International Geological Congress (33rd IGC) in Oslo (Norway), 2008.

The Deep Arctic Basin or Arctic (Arctic) Ocean has traditionally been subdivided into the Eurasian and Amerasian sub-basins (Figure 2).

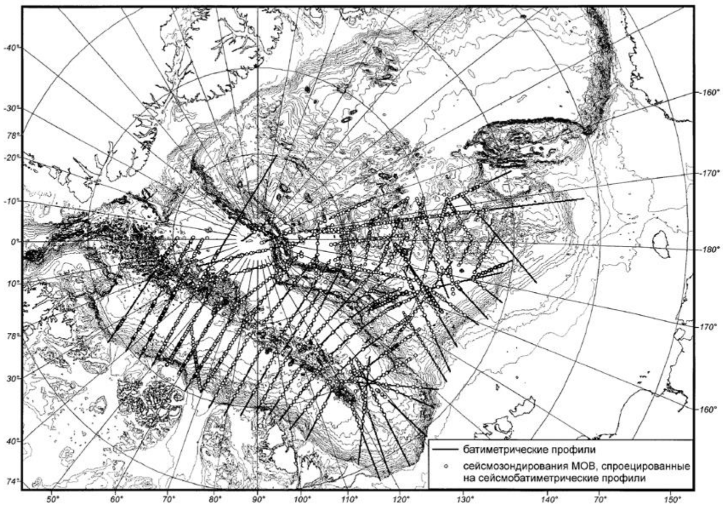

Figure 2 - Area network of point soundings of the North Expedition MOU

The polar branch of the Mid-Atlantic Ridge, the Gakkel Ridge, ends in the Eurasian sub-basin.

The latter is axial in the Eurasian sub-basin and is morphologically pronounced up to the continental slope of the Laptev Sea shelf. The Central Arctic uplift province on the seafloor map has the appearance of irregularly elevated trapezoid (in early publications, it was sometimes referred to as a trans-Arctic bridge), the larger base which is cut off by the continental shelf slope of the East Siberian and Chukchi Seas, and the smaller, on the American side, by the continental uplifts of Greenland and the Canadian Arctic Islands (Figure 2).

Trans-Arctic 1989-92 and ARCTICA 2000 deep seismic surveys. Airborne observations of the Transarctic 1989-92 GSS were carried out by PMGRE (with participation of VNIIOkeangeologiya) during four field seasons from 1989 to 1992. As a result, two regional profiles were worked out. One, submeridional, with a length of about 1,500 km, ran from the shelf of the De Long Islands in the East Siberian Sea through the Makarov Basin to the near-pole part of the Arctic Ocean.

The other, sublatitudinal, about 300 km long, crossed the Lomonosov Ridge, flanking the Amundsen and Makarov Basins (Figure 3).

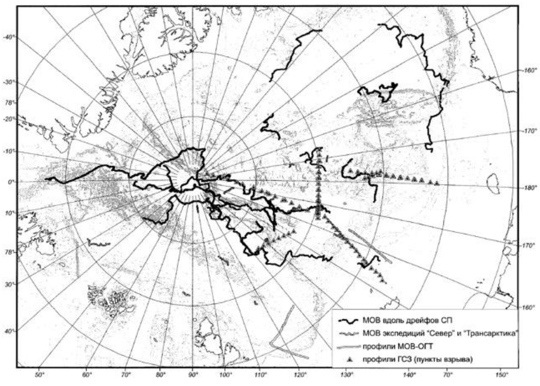

Figure 3 - Russian seismic survey of the Arctic Ocean

RESULTS AND DISCUSSION

In 2008, the seismic database holds the following volume of digital seismic data in SEG-Y format:14,913 phys.n./seismograms or 13,787 km profiles on drifts of the North Pole ice stations (Figure 3);

2,021 MOB seismograms of area observations of "North" expeditions (digitized from total volume of 17 426 probes) from which 78 seismo-bathymetric profiles were created with total volume of 25 736 km (Figure 2);

1,332 phys.n./seismograms or 616 km of MOB baseline profiles of the "North" expeditions (Figure 2);

3,064 PE/seismograms or 3,560 km of GSS profiles (Figure 3).

The continuous reflector distributed within the basin serves in seismic stratigraphy as the main stratigraphic recorder in the region under study. If the surface equivalent to this reflector is characterized by features of unconformity according to the seismic-stratigraphic type of underlying bedding, it acquires paramount importance as a stratigraphic reference. The importance of this seismostratigraphic type of unconformity in deep-water basins is due to the experimentally established fact in numerous areas of the World Ocean, which is formulated as follows: "Subsidence is a diagnostic sign of a major relative sea level lowering and is most commonly found in areas of continental margins and deep basins" (Sheriff et al. 1982). Other words, "Following a major sea level lowering to some globally low level, a major interregional unconformity usually develops" (Sheriff et al., 1982).

A classification of seismofacial unit types has been developed and based on worldwide experience in seismofacial analysis (Sheriff et al., 1982). Of the large set of seismofacial types, we shall distinguish three the most significant types:

The first type of seismofacies is displayed on seismic records by clearly defined continuity and high reflector amplitudes, with a parallel or slightly divergent inner pattern of the multiphase packet. It is characteristic of typically shallow marine clastic sediments and is often formed by surf events.

The second type of seismofacies is characterized by an alternating set of low-amplitude record sections separated by relatively high-amplitude parallel two- to three-phase reflectors. This type is usually observed when relatively thin strata deposited in high-energy and low-energy depositional environments and represented by turbidite sandstones and clays, respectively, are interbedded.

The third type of seismofacies is characterized by a pattern of chaotic filling with low-amplitude reflectors. This type usually displays structures of post-sedimentary landsliding of sediments, complexes of filling of relief depressions due to slope collapse and zones of intense disturbances or complex dislocations.

The Canadian Geological Survey's MOU-OGT seismic survey of the Beaufort Shelf (Enachescu, 1990) identified a number of seismic stratigraphic unconformities, stratified by drilling data in the vicinity of the seismic survey area. Four major stratigraphic unconformities were identified:

late Miocene (correlated with sea level lowering at the Tc and Td supercycle boundary of the Weyl curve);

late Oligocene (correlated with lowering of the sea level at the boundary of supercycle Tb and Tc of the Weyl curve);

Early Paleocene (correlated with declining sea level at the boundary of supercycle Kb and Ta of the Weyl curve);

at the end of the Early Cretaceous (correlated with the sea level drop at the boundary of supercycles Ka and Kb of the Weyl curve).

Thus, the data from geological and drill-surveyed seismic surveys along the periphery of the Amerasian subbasin are well correlated, at least since the mid-Cretaceous, with the global supercycle of eustatic sea-level fluctuations according to the Weyl model. Consequently, there is a strong rationale for using eustatic minima to control for correlation between major unconformities in the Upper Cretaceous-Cenozoic sedimentary cover and major tectonic events in the Arctic Ocean. Apparently, the existing deviations of Arctic regional supercycles from eustatic ones (under the influence of Arctic-specific geotectonic phenomena) are of importance only in low-promising attempts at detailed stratification of the section by higher-order cycles.

Another serious evidence not in favor of the rift nature of the Moma trenches is the establishment of fold dislocations within the seismotectonic zone of the Chersonese, as well as thrusts and faults in the Cenozoic formations, including within the Moma trenches themselves.

The analysis of the stress state of the Earth's crust in the Arctic-Asian seismic belt reveals an inversion of the tectonic stress field within the belt, related to the change of tensile conditions in the Gakkel Ridge zone (faults) to extension with a horizontal component of motion on the Laptev Sea shelf (faults and fault-slips), further to the combination of stretching and compression in the zone from the Laptev Sea coast to the Yana River basin and then to the manifestation of transpressional compression conditions (compression with sliding) in the Chersky mountain system (Imaev et al. , 2000).

Thus, we have two groups of seemingly contradictory facts pointing to both compression and extension within the Chersky zone.

Thus, within a single interplate boundary, traceable from the Fram Strait to the Shelikhov Bay of the Sea of Okhotsk and separating the Eurasian lithospheric plate from the North American plate, there is a consistent change in the geodynamic regimes:

stretching in the divergent zone of the Gakkel Ridge; a mixed tectonic stress field on the coast of the Laptev Sea and in the Yana River basin (intermediate zone); left-sliding caused by north-eastern compression resulting from oblique plate convergence (the Chersky mountain system).

The Eurasian lithospheric plate, slowly shifting eastward, interacting with the faster giant plate, the North American plate, splits into small blocks in the borderland. The latter are experiencing complex movements (turning, crawling against each other, etc.), reminiscent of the collision of small ice blocks during river ice drift (Imaev et al., 2000). According to G.P. Avetisov (2000), focal solutions for the southern boundary of the Laptev Sea microplate gave a close to normal-discharge mechanism. However, along with the predominant discharge component, horizontal slip, corresponding to the lefttlateral strikeeslip rotation, i.e. clockwise rotation of the microplate, is established here.

The seismic passivity of the junction zone between the megablock of the Amerasian subbasin and a part of the North American lithospheric plate, geographically corresponding to the northeast Eurasia, indicates that this junction was static during the opening of the Eurasian subbasin, i.e. in the Cenozoic.

Consequently, if the hypothetical Charlie Fault (or Northern Transfer) does exist, it is not as an active transform, but as an ancient (at least pre-Cenozoic) tectonic disturbance.

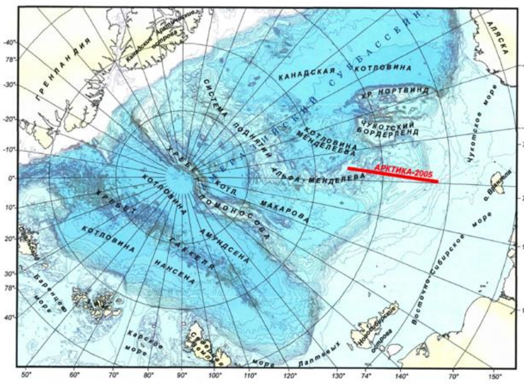

Figure 4 - Location of the ARKTIKA-2005 GZS profile

As can be seen from the new map of the acoustic basement surface relief (Fig. 5), the North Chukchi Superdeep Trough (more than 14 km depth) of northwestern strike extends at the junction of the East Siberian and Chukchi Seas shelf, which, crossing the continental slope of the East Siberian Sea at an acute angle, has its deepwater extension in the Vilkitsky Trough in the southern part of the Makarov Basin (more than 8 km depth).

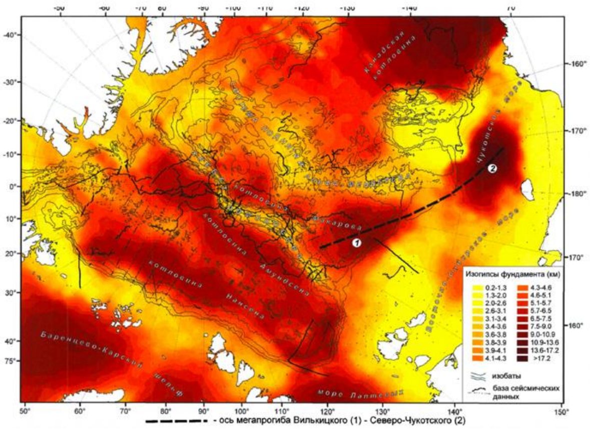

Figure 5 - 2D relief of the Arctic Basin acoustic basement surface (Poselov L.G., Pavlenkin A.D., 2006)

Thus, as a result of the analysis of the maps obtained (Figure 4, 5), the main structural element of the basement and sedimentary cover in the junction zone of the megablock of the Amerasian subbasin with the adjacent shelf of northeastern Eurasia can be identified as the Vilkitsky - North Chukotsky megaprofault. The southern ends of the Mendeleev Rise and the Chukchi Borderland are structurally elevated fragments of the northern flank of the North Chukchi Trough; the deep continuation of this northern flank is the uplift separating the Makarov - Makarov I and Makarov II basin terraces. The southern flank of the Wilkitskii-North Chukchi megaproject is represented by the northern slope of the De Long Massif, which transitions across the shelf edge into the northern slope of the Wrangel Rise. The connection between the regional break in sedimentation and the penetration of the Norwegian-Grenland rift system into the young Eurasian subbasin is convincingly confirmed by comparing the sedimentary cover structure of the subbasin with the configuration of the anomalous magnetic field.

CONCLUSION

Based on the presented information on the tectonic model of the Arctic Ocean, namely on the assumed geodynamic synchronisms of the main tectonic events of its history (synchronisms in the continental setting of the ocean), promising directions of geological research in the mainland part of the Arctic-Asian seismic belt can be determined.

The most effective direction of research appears to be the search for seismostratigraphic markers in the reflected wave field, their referencing to major tectonic events, reconstruction of sedimentation conditions and subsequent probabilistic estimation of geological age and sedimentary characteristics of sedimentary complexes.

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