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Eurasian Basin – Laptev Sea Geodynamic System: Tectonic and Structural Evolution

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THEME 3: Plate Boundary Problems in the Laptev Sea area.

The mid-ocean Gakkel Ridge is the Cenozoic spreading centre in the Eurasian Basin of the Arctic Ocean and reaches the Laptev Sea continental margin (KARASIK 1968, 1980, VOGT et al. 1979). A fundamental question, which goes beyond regional interest, is the study of the tectonics of the Laptev shelf in the Cenozoic. The Laptev shelf is a unique area to investigate in detail the penetration of an oceanic rift into a continent and to study the initial rifting stage of the continental crust. The above reason gives a high scientific value to research performed in the region.

On the base of gravity, magnetic, bathymetric and neotectonic data analysis, the Ust' Lena rift trough was considered to be the pivotal structure of the Laptev shelf, which is tectonically related to the Gakkel Ridge (VINOGRADOV 1984). Later, on the basis of the same data, the Omoloi graben was recognized as the structural continuation of the mid-oceanic rift on the shelf (KIM 1986). However, the shallow character of the Laptev Sea and very gentle topography of the sea bed is evidence for the existence of a peculiar geodynamic regime and makes the study of rifting practically impossible without the investigation of the internal structure of the sedimentary cover.

Multichannel seismic reflection data, acquired by Marine Arctic Geological Expedition (MAGE) from Murmansk in 1986 to 1990, clarify the geological structure of the southeastern termination of the Eurasian Basin and the Laptev Sea passive-transform continental margin (Fig. 1). Seismic reflection profiling was based on standard techniques with a 12- and 24-fold CDP coverage. The exploration work was conducted by the Research Vessels "Geolog Dmitriy Nalivkin", "Geofizik" and "Professor Kurentsov". Seismic shots were generated by single airguns or a linear airgun array with a total volume of 8-16 litres. Seismic streamers with an active length of 1200 m in 1986 to 1988 and 2400 m in 1990 were used as receivers. As a result of four expeditions during five years, approximately 7000 km of seismic reflection lines were completed 8-16 litres. Seismic streamers with an active length of 1200 m in 1986 to 1988 and 2400 m in 1990 were used as receivers. As a result of four expeditions during five years, approximately 7000 km of seismic reflection lines were completed within the Laptev Sea and adjoining area of the Arctic Ocean (Fig. 1). It is necessary to note, that within the Laptev Sea continental margin a number of multichannel seismic reflection data were obtained also by LARGE in 1989 (DRACHEV et al 1995, 1998) and BGR in co-operation with SMNG in 1993-1997 (ROESER et al 1995, HINZ et al, 1998). This article summarizes the geological model for the Eurasian Basin - Laptev Sea geodynamic system based on the opinion of MAGE specialists (IVANOVA et al, 1989, SEKRETOV 1993, 1998).

At 77.5 °N between 128-131 °E, the mid-oceanic Gakkel Ridge reaches the Laptev Sea continental margin and ends. The development of the present Laptev Sea deep margin started from continental rifting along an axis between Eurasia and the Lomonosov Ridge in Late Cretaceous time and continued due to the opening of the Eurasian Basin and sea-floor spreading since 56 Ma. Owing to the major change in relative motions of the North American and Eurasian lithosphere plates close to 33 Ma. the oceanic crust at the southeastern termination of the Eurasian Basin, near the Laptev Sea continental slope, was almost completely formed from 56 Ma to 33 Ma (SEKRETOV 1998). South of 78 °N the tectonic evolution of the Gakkel Ridge oceanic rift ceased approximately from 33 Ma till 3-1 Ma and no sea-floor spreading occurred in the Eurasian Basin during the last 33 Ma The rifting within the modern Laptev Sea continental slope occurred generally in Late Cretaceous to Early Paleocene time, excluding the most southern segment, which was formed in Late Paleocene to Eocene time as a result of the Gakkel Ridge oceanic rift propagating into Eurasia (SEKRETOV 1998).

The investigations have shown that the mid-oceanic Gakkel Ridge extended onto the Laptev shelf as a Cenozoic continental rift zone (IVANOVA et al. 1989, GRAMBERG et al. 1990, SEKRETOV 1993). Spreading in the oceanic crust of the Eurasian Basin changes as a result of extension of the continental crust on the shelf. A system of buried Cenozoic structures is recognized in the central and eastern Laptev Sea shelf (Figs. 1, 2, 3). They are linear, sediment-filled grabens with a complex structure, asymmetric cross profile and adjoining marginal and inner uplifts. From seismic profiling and gravimetric surveys, the following structures have been delineated: Ust' Lena, Omoloi, Ust' Yana, Chondon, Shiroston and Belkov-Svyatonos grabens, and the Trofimov, Minin, Intensivnoye, Omoloi, Buor-Khaya, Ust-Yana, Berelekh, Stolbovoi and East Laptev horst-like and anticlinal uplifts and highs. Geophysical data show that the rift axes are offset by strike-slip faults, which form a system of NE-trending and sublatitudinal faults (Fig. 1). Cenozoic buried volcanoes as one of the principal diagnostic features of rifting, have been found within the Omoloi graben, (Fig. 3B). Rifting is reflected in the morphology of the sedimentary cover. According to seismic stratigraphic analysis, subsidence associated with crustal extension occurred in the eastern Laptev shelf as early as the

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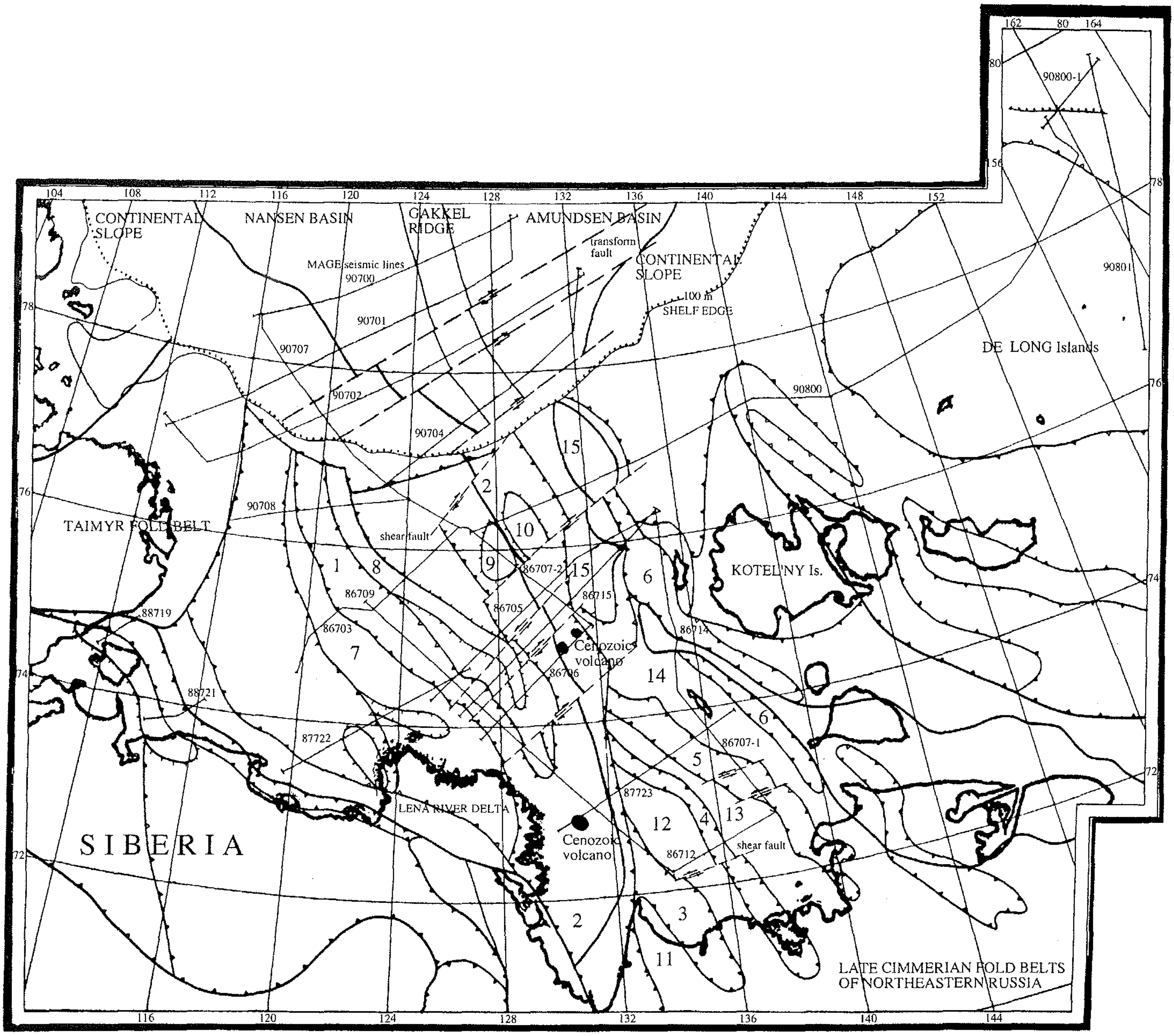

Fig. 1. Structural map of the southeastern termination of the Eurasian Basin and the Laptev Sea rift system (SEKRETOV 1993, simplified). Structural elements of the Laptev Sea rift system: Grabens: 1 = Ust' Lena, 2 = Omoloi, 3 = Ust' Yana, 4 = Chondon, 5 = Shiroston, 6 = Bel'kov-Svyatonos; Highs and horsts: 7 = Trofimov, 8 = Minin, 9 = Intensivnoye, 10 = Omoloi, 11 = Buor-Khaya, 12 = Ust' Yana, 13 = Berelekh, 14 = Stolbovoi, 15 = East Laptev.

end of Late Mesozoic time (Figs. 2B, 3B). The Upper Cretaceous sedimentary sequence was formed as a result of the differentiated subsidence of the Late Cimmerian folded basement. In the Paleogene, tectonic motions were suddenly activated (Figs. 2, 3). The vertical amplitude of block motions along the faults varied from several hundred meters to 2 km. In most cases, the faults fade out in the Paleogene sedimentary sequence. Key seismic reflector "I", correlated with the Early Paleocene (Danian) erosional surface, exposes the rugged block topography with a system of pronounced steps on seismic reflection profiles. In contrast, the overlying reflector "L", identified as a Late Oligocene to Early Miocene erosional surface, has a completely different structure (Figs. 2, 3). Its top exposes no faults with vertical displacements. The Paleogene regional system of rift-grabens was compensated by the synrift sedimentation and the adjacent horst-like and anticlinal uplifts and highs were buried under the Miocene-Pleistocene deposits, which form a layered sediment sequence and apparently correspond to the general post-rift subsidence.

The setting of the Cenozoic continental rifting on basement of different age predetermined the tectonic features as expressed in the strike, geometry and structure of grabens. The pattern of evolution inherited from the ancient structural plan can be found for practically all rift structures. The Belkov-Svyatonos, Shiroston, Chondon and Ust' Yana grabens have inherited the northwestern strike and some tectonic elements of the structural depressions in the Late Cimmerian folded basement. The northwestern strike of the Cenozoic Ust' Lena graben, superimposed on Riphean and Paleozoic rifts seems to be inherited

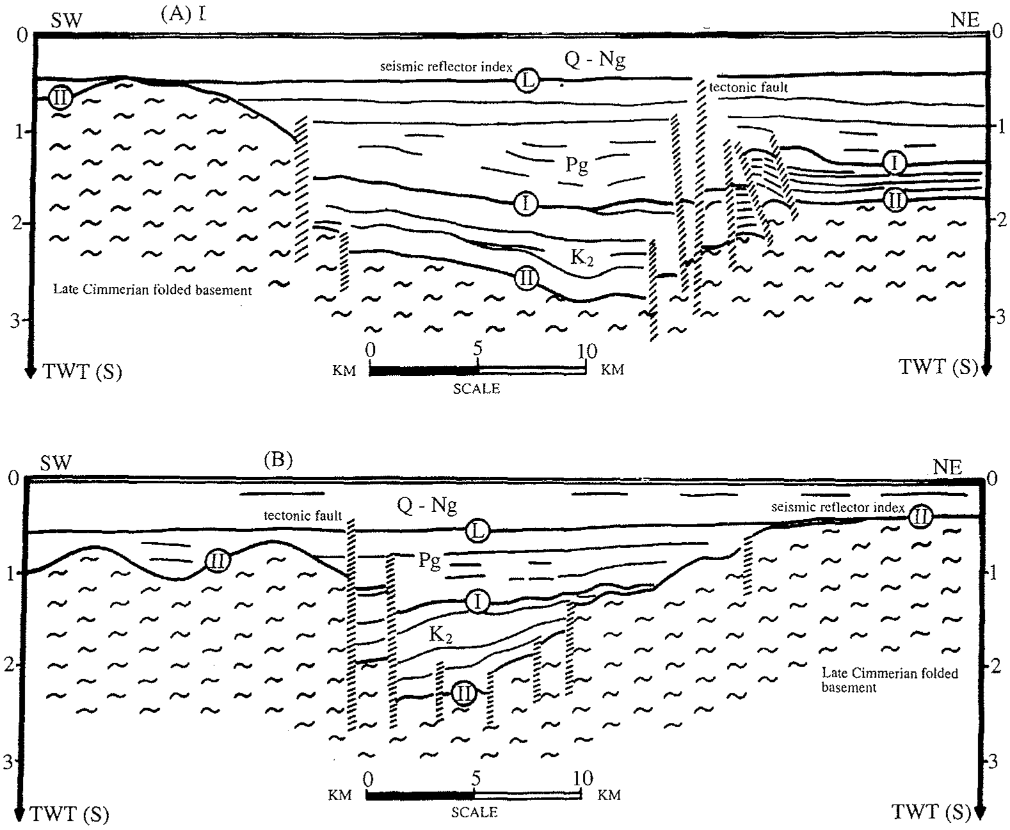

Fig. 2: Fragments of seismic lines 86715 (A) and 86712 (B). Line drawings across Bel'kov-Svyatonos graben (A) and Chondon graben (B). Two-way travel time (TWT) scale is given in seconds.

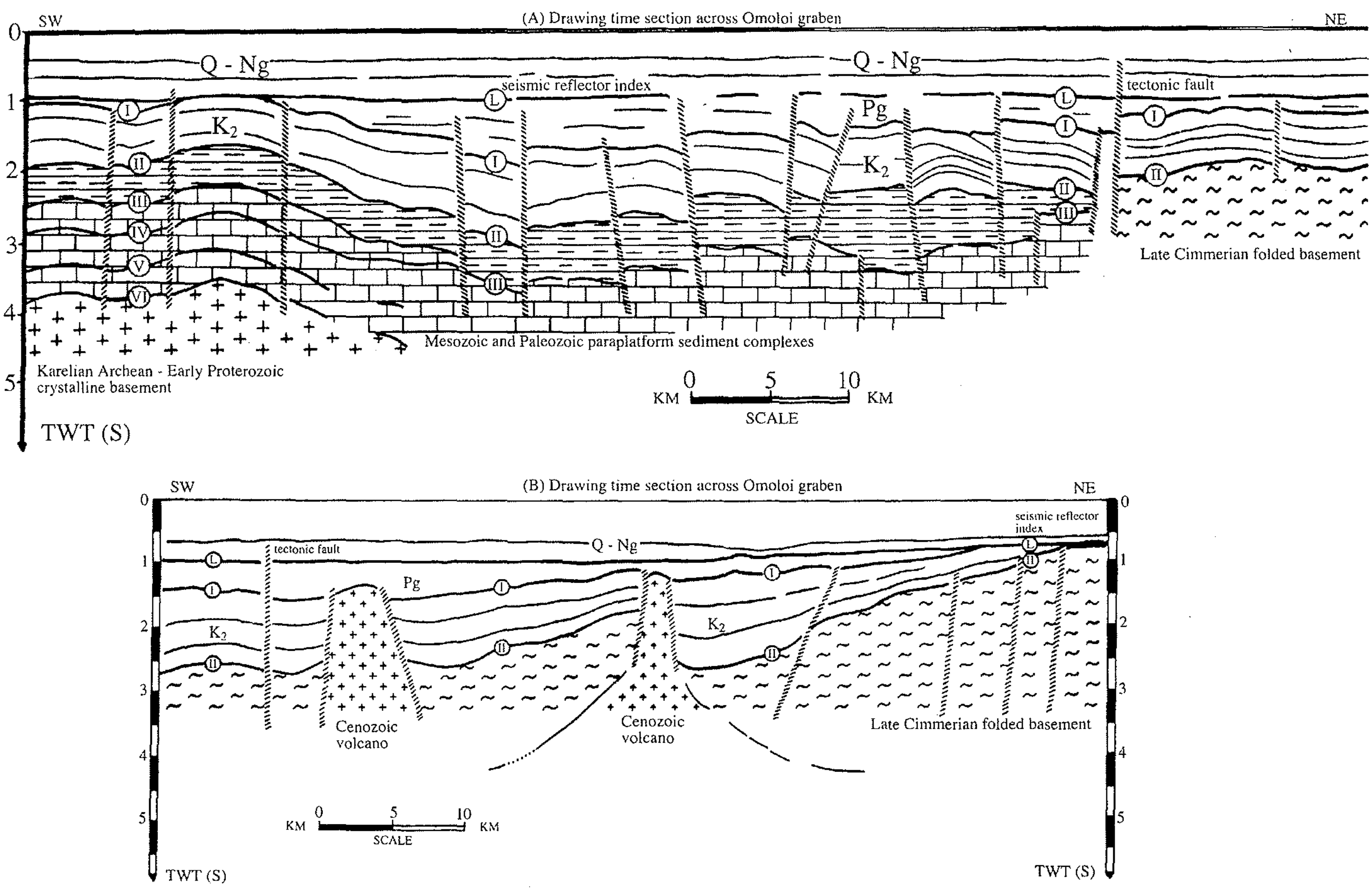

Fig. 3: Fragments of seismic lines 86715 (A) and 86706 (B). Line drawings across Omoloi graben. Two-way travel time (TWT) scale is given in seconds.

from tectonic fault zones in the Karelian crystalline basement similar to those observed on the land within the Anabar shield and Olenek high of the Siberian platform. The confinement of the Omoloi graben to the suture zone between the Laptev massif of the Siberian platform and the offshore extension of Late Cimmerian fold belts predetermined its submeridional strike (Fig. 1).

The assemblage of tectonic elements formed mainly in the Paleogene, i.e. grabens and uplifts, on the Laptev shelf, can be considered as a single system, the Laptev Sea continental rift system. The Omoloi graben forms the axial principal graben judging by its length and position among other rift structures, but also its apparent volcanic activity (Figs. 1, 3). The Gakkel Ridge spreading centre and the Laptev Sea continental rift system are tectonically linked by a transform fault at the ocean/continent crustal boundary.

The Cenozoic continental rift process on the Laptev shelf is structurally characterized by a complicated deformational system, including normal faults and strike-slip faults associated with the graben formation corresponding to an extensional regime, but also reverse faults, transpressional overthrusts and gentle folding of the Upper Cretaceous and Paleogene deposits indicating the influence of horizontal compression (Figs. 2, 3). It does not seem possible to derive the chronological sequence of geodynamic events solely from the analysis of seismic profiles. However, the model for the opening of the Eurasian Basin and the interaction of the North American and Eurasian plates proposed by KARASIK et al. (1983) and SAVOSTIN et al. (1984) may explain the structures observed on the Laptev Sea shelf. According to their model, extension dominated the Laptev Sea in the Paleocene and the Eocene when the pole of rotation between North America and Eurasia was to the south, on the Eurasian continent. In the Oligocene, the pole migrated to the north and the region to the south of the New Siberian Islands was placed into compression. This would explain the lack of evidence for rifting within the Laptev shelf in the Miocene to Pliocene and the presence of isolated reverse and thrust faults. Moreover, the seismic reflection data from the southeastern end of the Eurasian Basin propose the absence of rifting within the Laptev shelf in the Late Oligocene to Pliocene time (SEKRETOV 1998).

The present-day seismicity of the region is evidence for the recent mobility of the Eurasian Basin - Laptev Sea geodynamic system (FUJITA et al. 1990, AVETISOV 1996). Thus, tectonic and structural evolution of the Eurasian Basin - Laptev Sea geodynamic system cannot be considered simply within the concept of propagating rift. Most probably there are several lithospheric microplates in the continental area of interaction between the Eurasian and North American plates and modern boundaries between them are marked by belts of seismicity (ZONENSHAIN et al. 1990). The character of interaction between microplates changed during various periods of the Cenozoic with the changes in relative motions of the two major lithosphere plates. The region is of special interest for further theoretical investigations of rifting and plate tectonics.

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