CENOZOIC HISTORY OF SEDIMENTARY BASINS ALONG THE WESTERN MARGIN OF THE BERING SEA AND PETROLEUM-RESOURCE POTENTIAL

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ABSTRACT

Sedimentary basins on the Western margin of the Bering Sea and the surrounding region generally exhibit structural features associated with extension and compression of the lithosphere. The most active period of structural transformation occurred in the Oligocene and Early Miocene when differential vertical movement created the Khatyrka borderland and associated systems of deltas and underwater fans on the narrow shelf and steep continental slope. The Anadyr-Laguny and Navarin basins are post-riftogenic structures filled with molasse. There are two main hydrocarbon-generating complexes of Late Cretaceous and Oligocene age within Anadyr Basin and only one Late Eocene-Oligocene complex within Khatyrka Basin.

INTRODUCTION

The dynamics of sedimentary basin development in transitional zones depends on the combination of stretching, spreading, and compressive stresses of the lithosphere. Anadyr-Laguny, Navarin, Khatyrka, and Olutorsko-Komandorsky basins (Fig.1) developed differently. These developmental characteristics determine the oil and gas potential of the basins. The conditions for oil and gas potential are very different, for example, between Anadyr and Khatyrka basins.

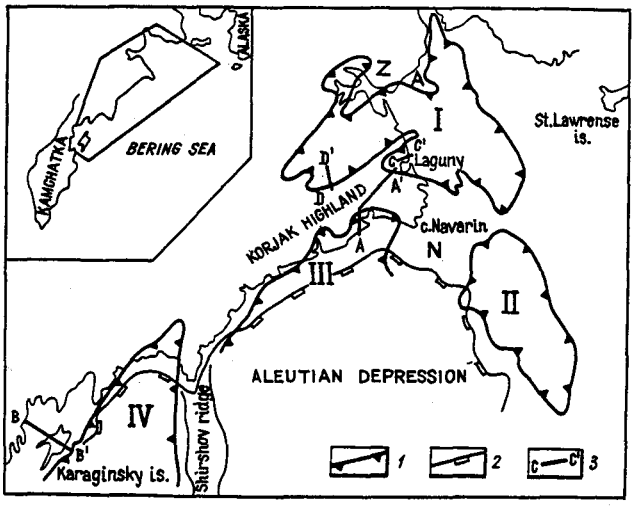

Fig.1. Sketch map of basins in the northwestern part of the Bering Sea. 1 - border of basins; 2 - shelf break; 3 - profile lines. I-Anadyr-Laguny Basin, II-Navarin Basin, III-Khatyrka Basin, and IV-Olutorsko-Komadorsky Basin.

STRUCTURE

Volcanic belts and riftogenic troughs determined the environments within the boundaries of Anadyr-Laguny and Navarin basins during the Cretaceous and Early Tertiary. Volcano-sedimentary formations, including continental coal-bearing beds, accumulated during the initial stages of basin formation. The second important

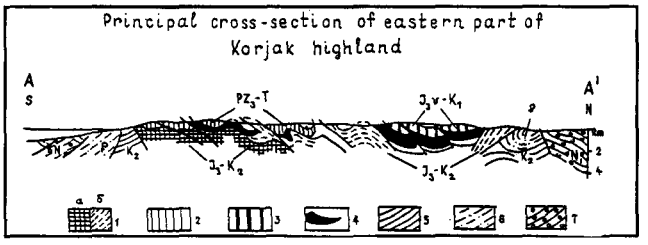

Fig.2. Principal cross-section of the eastern part of Koryak highland. 1 - autochthon of the Koryak folded system: (a) siliceous-volcanic in southern zone and (b) terrigenous tuff in the northern zone; 2 - Al'katvaam overthrust (PZ_3-T); 3 - Majnizky overthrust; 4 - serpentinites; 5 - Upper Cretaceous terrigenous deposits; 6 - Paleogene deposits; 7 - recent superimposed trough. (After Kazimirov, 1985, with author's permission).

stage is characterized by compression, allochthon overthrust, and molasse accumulation. The overthrusting was directed both to the north and the south, away from the central part of Koryak Range, as shown on profile A-A' in Fig.2 (Kazimirov, 1985). In contrast, another style of structural development connected with differential processes in the oceanic crust near continental margins characterizes the Olutorsko-East Kamchatka region and Khatyrka Basin. The deep-water early Cenozoic province was transformed into continental margin structure by overthrusting of ophiolitic plates and fragments of oceanic crust onto deposits of the continental slope and rise (Fig.3) and as a result of compensation for spreading in deep-sea depressions, e.g., Aleutian, Komandore and others (Bogdanov et. al, 1982; Alekseev, 1987). All of the processes mentioned above resulted in sharp vertical and horizontal heterogeneity in the distribution of geodynamic strains and transformation of rocks of adjacent structural-formational zones within the active margins.

Khatyrka and Olutorsko-Komandorsky basins formed as near-continental basins connected with spreading processes in the marginal part of the ocean. Some spreading centers were separated by fracture zones in deep-water depressions. These fracture zones were parallel to the paleo-Bering margin. Several fracture zones now exist in the Komandorsky depression, where continental slope and abyssal plain sediments dominated (Fig.4). Evolution of the North Aleutian deep-water depression correlates with the geologic history of the Shirshov and Navarin ridges. Two rock complexes, an oceanic and island-arc, were distinguished on the Shirshov Ridge. The oceanic complex comprises amphibolites and gabbro-dolerites, which are overlain by deep-sea chert and basalt lavas. The island-arc complex is represented by volcano-sedimentary and volcanic rocks of andesite composition with an absolute age of 27.8 to 1.1 ma (Late Oligocene). The separation of Khatyrka Basin began at that time. Navarin Ridge was a more stabilized structure and formed the dividing element between Khatyrka, Anadyr, and Navarin basins.

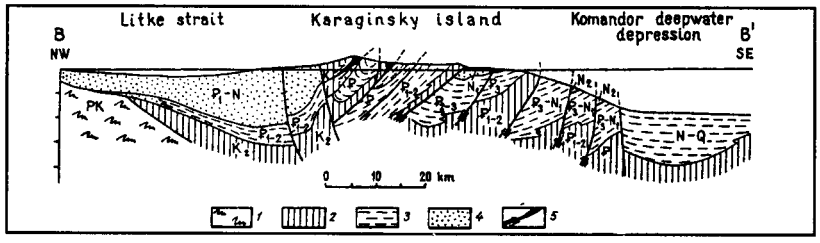

Fig.3. Profile B - B'. Cross-section of Litke Strait, Karaginsky Island and continental slope. 1 - intensive folded pre-Cretaceous beds; 2 - terrigenous tuff deposits; 3 - pelitic deposits; 4 - molasse; 5 - bodies of hyperbasites and direction of movement.

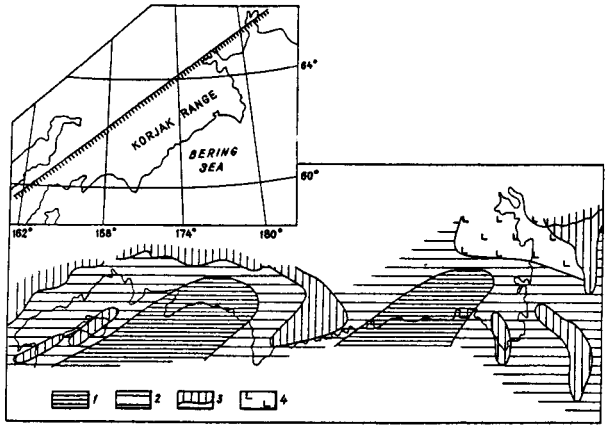

Fig.4. Paleogeographical scheme of the Late Eocene and Early Oligocene. 1 - deep-water areas; 2 - shelf; 3 - subaerial volcanic structures; 4 - areas with a presumed absence of sediments.

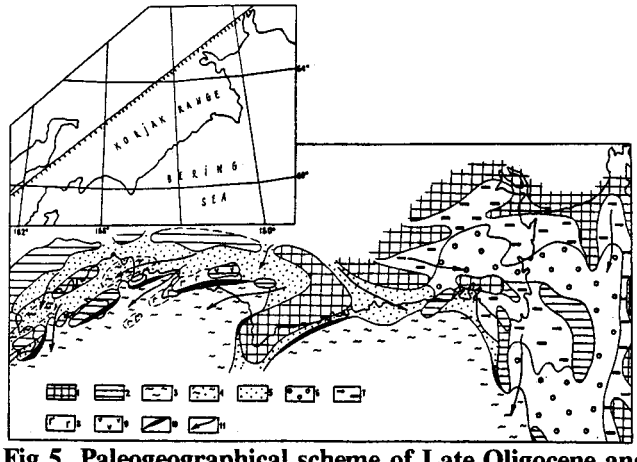

Fig.5. Paleogeographical scheme of Late Oligocene and Early Miocene. 1 - highland; 2 - islands and subsea highs, 3 - rise of continental slope and subabyssal zone; 4 - shelf depressions; 5 - shelf zones with active sediment accumulation; 6 - planed shelf; 7 - periodically submerged coastal areas; 8 - underwater volcanic ridge; 9 - volcanic island; 10 - erosional escarpments on the continental slope; 11 - sediment transport.

SEDIMENTATION

Until the end of the Eocene, deep-water sedimentation conditions existed in Khatyrka Basin as shown in Fig.4. Conditions began to change at the end of the Eocene. The most active period of transformation processes occurred in Oligocene-early Miocene time, when the Khatyrka borderland was created. Differential vertical movements caused step-line subsidence along the flanks of deep-water depressions and the formation of thick proluvian-alluvian cones onshore and offshore (Gladenkov et al., 1985).

An interesting sedimentary feature that formed in the basins of the borderland is fans. River transport, erosion, and deposition of deltas and underwater fans on the narrow shelf and steep continental slope played an important role during the Oligocene and Neogene (Figs.5 and 6). Paleodeltas and fans are the exploration objectives for discovering new oil and gas resources. The bedding type and ripple marks indicate shallow-water conditions during deposition of the upper part of cones. We propose that the deposits formed in narrow valley openings to submarine slopes. Moreover, sedimentation was accompanied by slumping and sliding on submarine slopes.

There are several structural zones in the Kamchatka and Chukotka margin where this type of sedimentation took place, resulting in large lens-shaped bodies. Each body is divided into several parts or cycles, and each

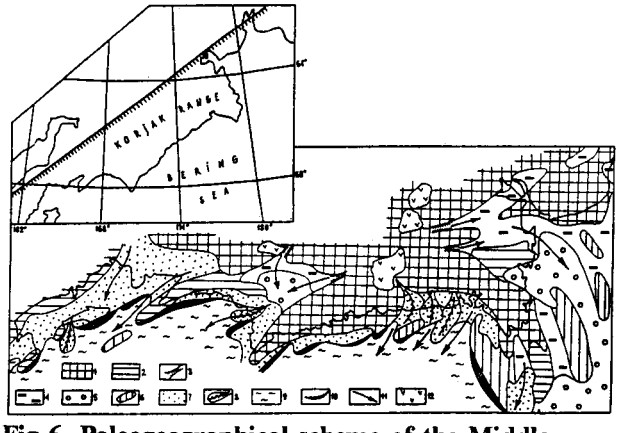

Fig.6. Paleogeographical scheme of the Middle Miocene. 1 - highland; 2 - nearshore lowland; 3 - river valley; 4 - periodically submerged coastal areas; 5 - shoal water areas; 6 - subsea highs; 7 - areas of shelf with contrasting relief; 8 - underwater fans; 9 - rise of continental slope and abyssal zone; 10 - escarpments on the continental slope; 11 - direction of sediment transport; 12 - volcanic structure.

cycle begins with a conglomerate that is "inlaid" in the previous layers by displacement. Each cycle has its own depocenter. For example, the Oligocene Mallen Suite, in its depocenter located in the western part of the Khatyrka Basin, reaches 8-9 km in thickness. The thickness of upper Miocene-Pliocene sediments in a depocenter, located in the eastern part of Khatyrka Basin, reaches 6 km. This construction of sedimentary bodies is common on the borderland. The layers of each cycle have different dip directions (Burlin and Ivanov, 1987).

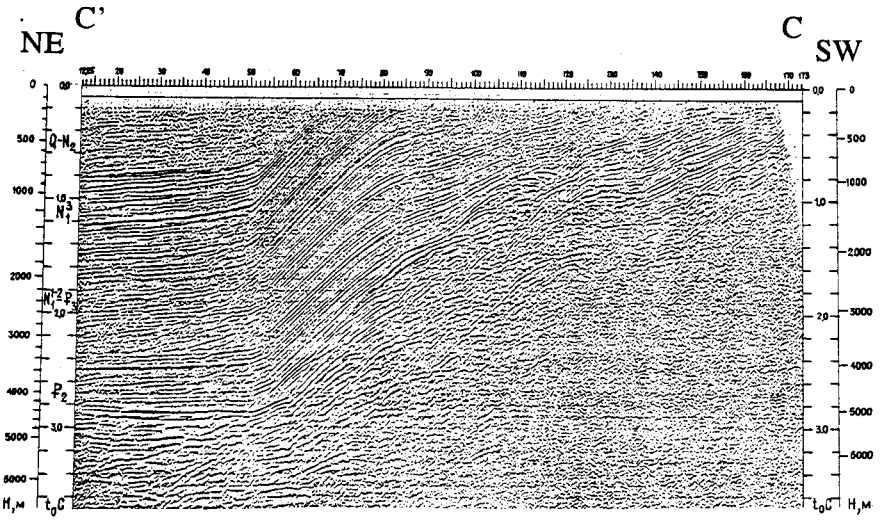

Fig.7. Reflection seismic profile C - C' of Laguny trough.

The development of Anadyr, Navarin and Laguny basins is different from the Khatyrka Basin. Riftogenesis and volcanism occurred in the Cretaceous and Early Tertiary. The fold systems were formed at the end of the Paleocene. They were then peneplained and overlapped by Upper Paleogene and Neogene sediments. As a result, the areas of Anadyr and nearby basins can be considered as young platform or plates.

The sedimentary bodies of these basins consist of the lower (tafrogenic) and an upper (platy) complex. The lower complex is represented by subcontinental molasse, associated with andesite-basalt and basalt volcanics. Generally, these strata fill large graben-like troughs that developed in the low part of basins. When the young Bering platform stabilized, an epicontinental shallow-marine basin formed and near-coastal to lagoon-continental environments were established. In the early Miocene, deltaic and near-coastal formations, containing complicated lens-bodies reflecting dynamic processes of coast and shelf sedimentation, were established along the boundaries of Anadyr and Navarin basins. In the Laguny Basin, a progradational shelf was growing (Fig.7). We refer to these types of basins as post-riftogenic, but active neotectonic movements, including uplift and lateral, have generated synorogenic deposits of molasse. Peripheral parts of these basins are overthrust by rock from the surrounding fold structures (Fig.8).

PETROLEUM POTENTIAL

All of these characteristics determine the oil and gas potential of the basins. The conditions for oil-gas potential are very different in Anadyr and Khatyrka basins. There are two main hydrocarbon-generating complexes in Anadyr Basin, the lower (Cretaceous-Paleogene)--predominantly an oil-generating group--and the upper (Miocene)--a gas-generating group. Khatyrka and Olutorsko-Komandorsky basins exhibit only one phase of hydrocarbon generation in the Late Miocene and Pliocene.

The features of oil occurrence in Anadyr Basin is very specific and is reflected in the composition of oil and the type of oil pools. These pools were generated during (or as the result of) processes of intrusion of high-temperature fluids containing chlorite alkaline solutions and hydrocarbons, into the beds. Zones of high permeability are determined by the riftogenic nature of the basin. The solutions going through these zones affect the level of catagenesis. The migration pathways of hydrothermal solutions are the same as for hydrocarbons. Upward-moving solutions intensify hydrocarbon generation from organic matter. Filling of hydrocarbon traps occurred in multiple phases that were connected with leaching of feldspars and secondary zeolitization. Oil included in zeolite is frequently observed. One example

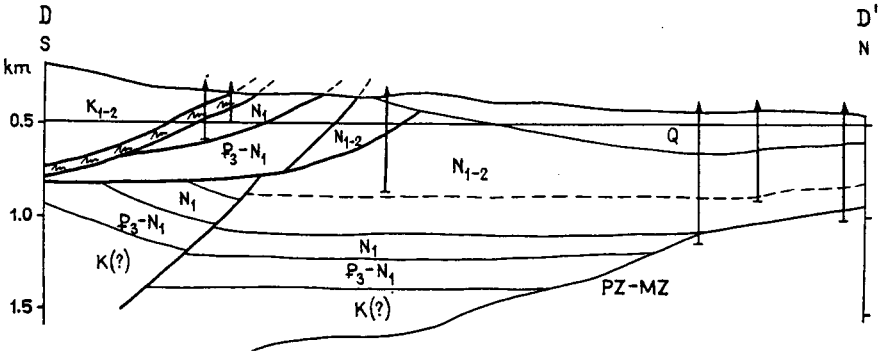

Fig.8. Profile D - D'. Cross-section of the southern part of Anadyr basin.

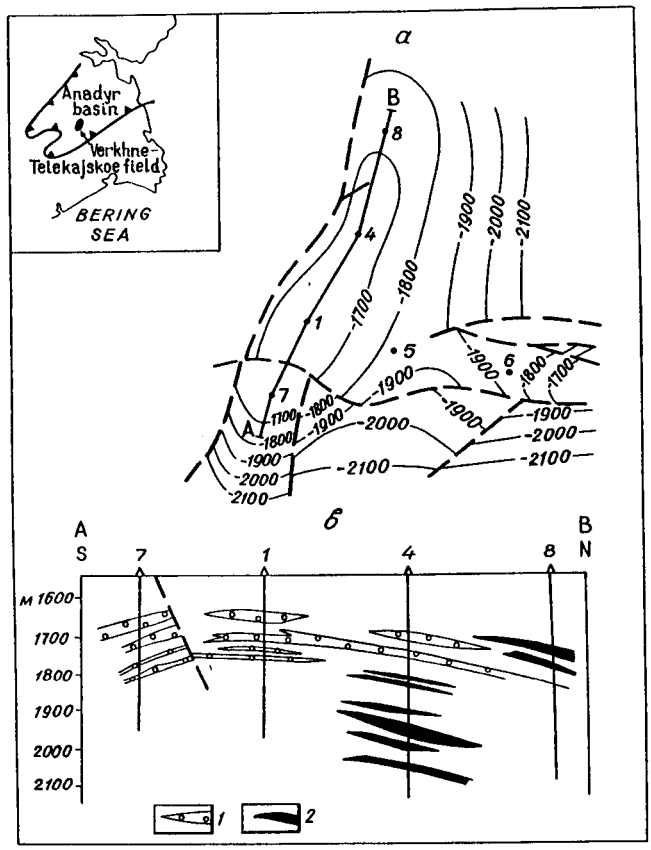

Fig.9. Verkhne - Telekayskoe oil-gas field. a. Structural map of upper part of Sobolkovskaya suit; b. Cross-section along line A - B, 1 - gas and condensate, 2 - oil.

of an oil field of this type is the Verkhne-Telekayskoye oil-gas-condensate field (Fig.9), located in the southern part of Anadyr Basin. All oil pools are confined to the Sobolkovskaya suite of the Lower Miocene and exhibit lens-shaped pools (Agapitov et al., 1991). It is possible that they are not lenses but zones of irregular configuration caused by secondary alteration of rocks. Additionally, oil from the Verkhne-Telekayskoye field contains a very large quantity of paraffins: up to 27 percent. The reason for the high amount of paraffin is the profound transformation of source rocks and the humic organic matter they contain in subcontinental Paleocene deposits under the influence of high heat flows. This is typical for basins of the Pacific belt.

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