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# Northwestern Margin of the East Siberian Sea: Structure, Sedimentary Basin Development and Hydrocarbon Possibilities

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THEME 9: Hydrocarbon Potential of the Eurasian Margins: Geological and Tectonic Factors

The East Siberian Sea is often cited as one of the least studied parts of the world. Structural history and tectonic zonation in the area have been based mainly on regional gravity and magnetic surveys, along with geological data from adjacent islands and surrounding continents (VINOGRADOV et al. 1974, 1976; KOS'KO et al. 1984, 1990, FUJITA & COOK 1990). Based on different ages of onshore fold belts, most researchers are of the opinion that there are several different zones of continental basement. These zones are exposed on the De Long Islands of the New Siberian Archipelago. The western De Long High and the Vil'kitskiy Depression are interpreted to have Precambrian basement and metamorphosed and folded rocks with northwest and north trending structures. Folded Paleozoic structures of the Henrietta fold belt (Henrietta Island) are noted in the basement east of the De Long High (VINOGRADOV et al. 1974, 1976). Two main structural complexes are distinguished in the sedimentary cover: an upper basin complex that includes Aptian to Cenozoic deposits, and an intermediate and lower complex of Upper Proterozoic to Lower Cretaceous rocks. The lower complex may either be folded or undeformed (KOS'KO et al 1984, 1990).

In 1991, a multi-disciplinary 600 km long geophysical line was recorded by Polar Expedition (PMGRE) of „Sevmorgeologia", from the south of the De Long High to just in front of the southern edge of the Makarov Basin. Seismic reflection and refraction profiles, deep seismic sounding, gravity and magnetic surveys were carried out from ice floes along this line (GRAMBERG et al. 1993). In the western and northwestern parts of the East Siberian continental margin, some multichannel seismic reflection data were recorded in 1989 by LARGE (DRACHEV et al. 1995) and BGR in co-operation with SMNG (1993-1994) (ROESER et al. 1995). This article is based on the geological interpretation of a regional 2D seismic survey (Figs. 1, 2) carried out by MAGE in 1990 from the R/V „Professor Kurentsov". About 1000 km of seismic reflection lines were completed on the north western continental margin of the East Siberian Sea. Seismic reflection profiling was based on a standard technique with a 24- or 48-fold CDP overlap. Seismic shots were generated by a linear airgun array and the receivers were in a seismic streamer of 2400 m active length with a 300 m offset.

Multichannel seismic reflection data along lines 90800, 90800-1, 90801 show the geological structure of the East Siberian Sea continental margin between 77-80 °N latitude and 156-164 °E longitude, where it faces the Makarov Basin of the Arctic Ocean (Figs 1, 2). This area was not covered by LARGE and BGR-SMNG seismic surveys. This northwestern part of the East Siberian margin may be regarded as a passive-transform margin (SAVOSTIN et al. 1984, ZONENSHAIN et al. 1990) bordering a Late Mesozoic - Early Cenozoic Makarov Basin (TAYLOR et al. 1981). Continental basement is everywhere covered by sediments. The De Long High and Vil'kitsky Depression can be distinguished as major features on the shelf and continental slope (Fig. 2). They were already recognized in the earlier regional gravity surveys (KOS'KO et al. 1984, 1990). In the multichannel seismic reflection data, the De Long High and Vil'kitskiy Depression clearly show up at the top of the basement, bounded by major faults (Fig. 2). The total thickness of the sedimentary cover varies from a few metres to 8-9 km, increasing generally northward from the De Long High to the rise of the continental slope. At least 10 sedimentary units can be identified and correlated in the seismic data. Seismic velocities change from 1.7 km/s in the upper unit to 4.0-4.8 km/s in lower ones. An isopach map of the sedimentary cover was compiled on the basis of seismic reflection data (Fig. 2).

No deep boreholes have been drilled on the East Siberian continental margin. Because of this situation, sedimentary seismic reflectors, unconformities, and the seismic sequences were defined by an analysis of the geology on adjacent islands and coastal regions (VOL'NOV 1975, GRINENKO et al. 1989, ALEKSEEV et al. 1992). The global Cenozoic sea level curve was also taken into consideration (Fig. 3). Using these data, regional seismo-geological successions and units were identified and their thickness and internal structure interpreted (Figs. 4, 5, 6).

The sedimentary cover of the northwestern East Siberian margin is interpreted to consist of Lower Cretaceous (Aptian) to Cenozoic terrigenous deposits, which overlie eroded Late Cimmerian folded basement (Figs. 4, 5, 6). Only locally can isolated relics of older, Mesozoic or Paleozoic, sedimentary basins be recognized in the structure of the folded basement. The bulk of Lower Cretaceous (Aptian) to Upper Cretaceous (Santonian) sediments was deposited on the continental slope, where their total thickness reaches 2.5-4.5 km (Figs. 5, 6). Cretaceous strata and sedimentary strata in general are very

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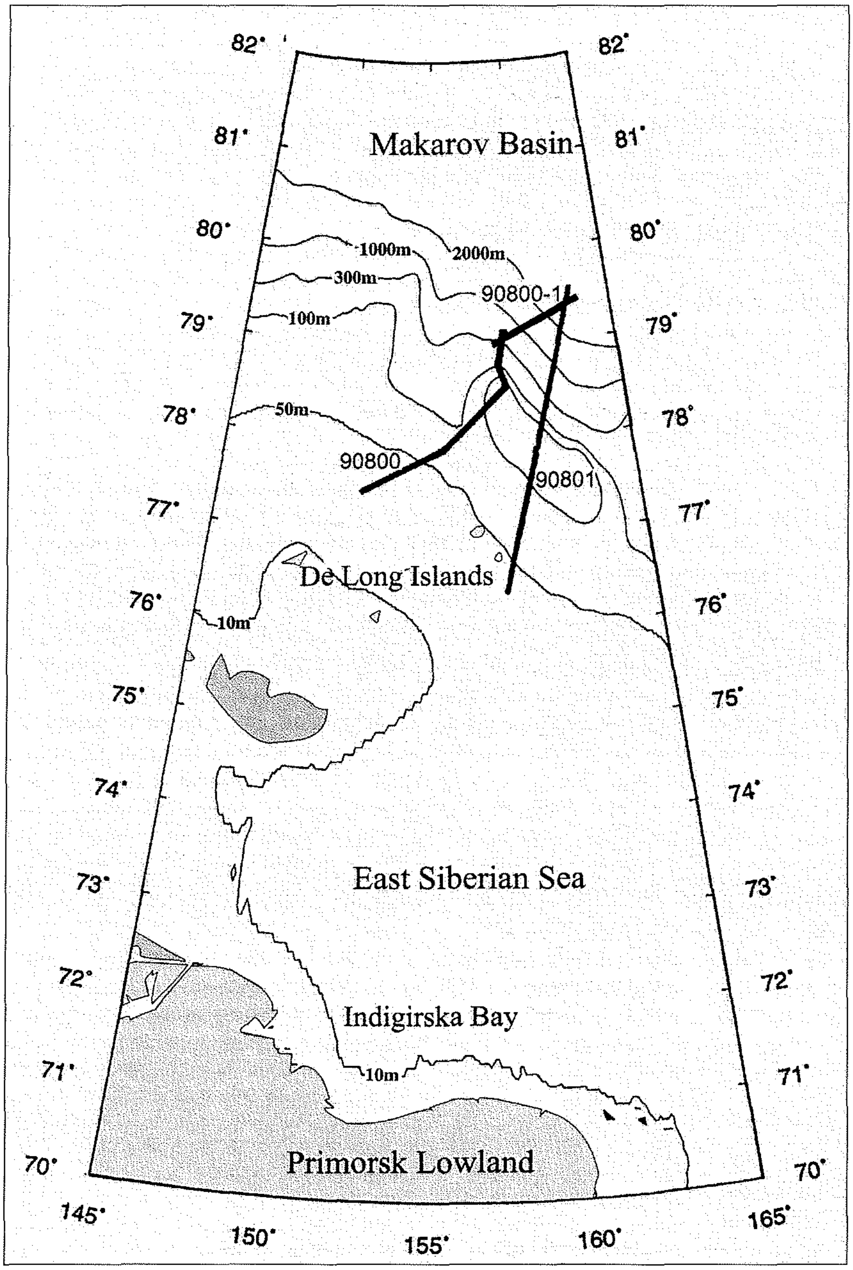


**Fig. 1:** Bathymetric chart of the north western East Siberian Sea and the adjacent Makarov Basin with locations of the MAGE seismic lines 90800, 90800-1 and 90801. Bathymetric contours are given in metres.

thin southwest of the De Long High (Fig. 2). The Cretaceous on the northern De Long High and in the Vil'kitskiy Depression have distinct seismic characteristics: extended or intermittent dynamically expressive reflections with specific rugged relief are marked on the seismic sections. At places, a group of bright, high-amplitude reflectors in the base of the sedimentary section shield reflectors from the top of the folded basement. Seismic velocities in the Cretaceous succession show a wide range of values from less than 2 km/s to 4.8 km/s. Typical values are 2.6-3.9 km/s. Anomalous low velocities of 2.0-2.1 km/s were detected within the De Long High, where the thickness of Cretaceous deposits is less than 300-500 m. Anomalous high seismic velocities of approximately 4.5-4.6 km/s and exceptionnaly 4.7-4.8 km/s were recorded within the base of the thick sedimentary cover of the northern Vil'kitskiy Depression and continental slope. The variations of seismic velocities and seismic reflection characteristics may be caused by three principal factors: lithologic composition of the sediments, thickness of the beds and proportion of magmatic formations.

The geology of the New Siberian islands and adjacent coastal regions of Arctic Asia (VOL'NOV 1975, GRINENKO et al. 1989; ALEKSEEV et al. 1992), along with seismic reflection data, suggests that the Cretaceous strata on the De Long High are mainly strata of continental facies, and possibly coal-bearing. However, in the Vil'kitskiy Depression and on the continental slope the Cretaceous is likely to consist of marine sediments (sandstones, clays, siltstones). All over the study area, the Cretaceous succession may include different proportions of magmatic rocks. In the Vil'kitsky Depression, there are recognizable clinoforms suggesting the presence of a classic progradating deltaic sequence. Higher up in the section in the northern margin of the Vil'kitskiy Depression and on the continental slope, Upper Cretaceous (Campanian) to Lower Paleocene sediments have seismic velocities of 3.9-4.1 km/s.

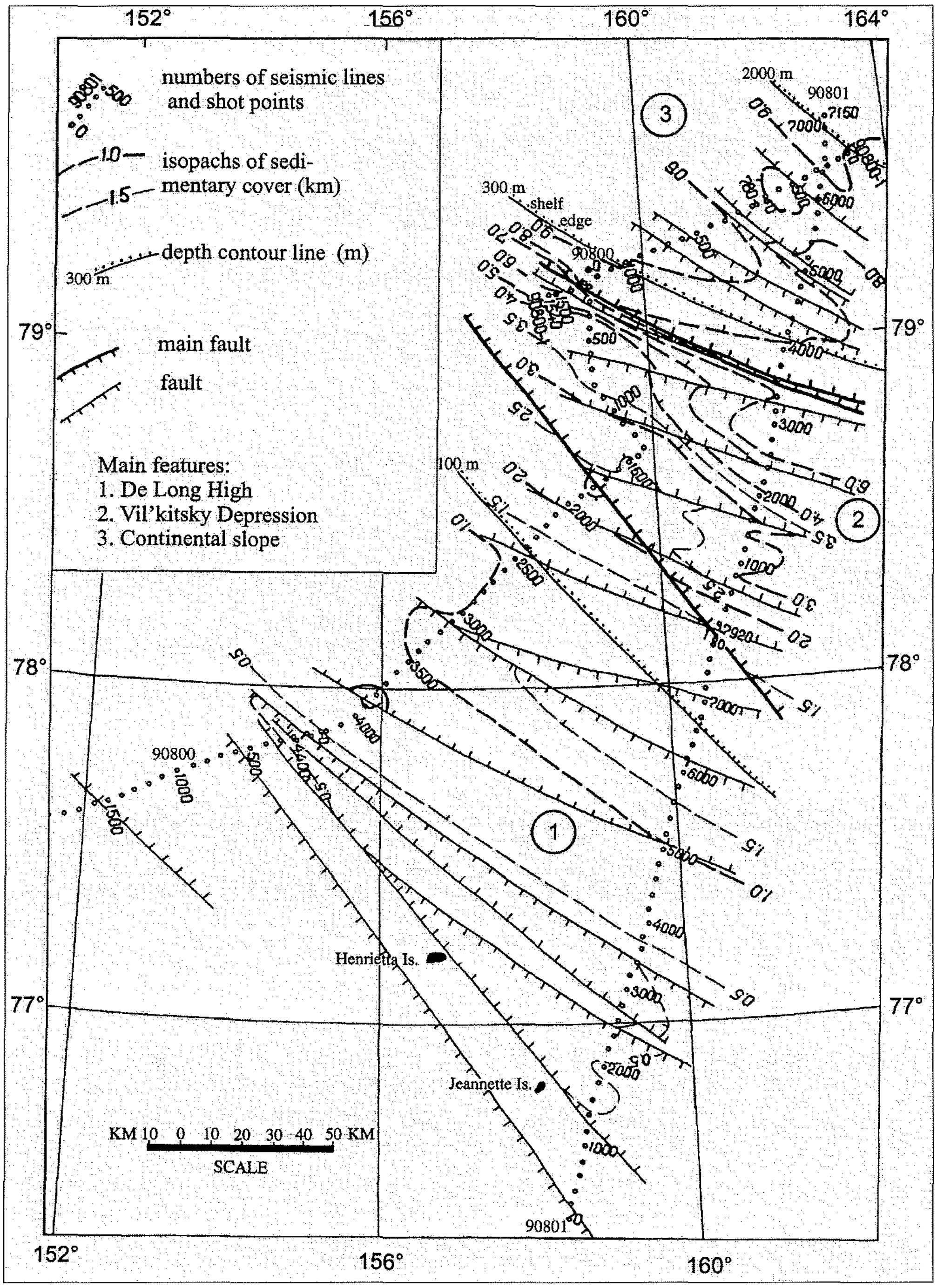


**Fig. 2:** Isopach map for the sedimentary cover of the northwestern continental margin of the East Siberian Sea. The prongs on the tectonic faults show which side is down-thrown.

They are identified as a separate unit (Figs. 5, 6). Seismic stratigraphic analysis and the position of this unit on the continental slope in the interval between 6 km and 7 km suggest a marine origin.

Both along the northern margin of the Vil'kitskiy Depression and on the continental slope, several units can be identified as Cenozoic (Figs. 4, 5, 6). In ascending order these units are:

- Upper Paleocene, 0.3-0.6 km thick, with seismic velocities of 3.9-4.1 km/s;
- Eocene, 0.7-1.2 km thick, with seismic velocities of 3.5-3.9 km/s;
- Oligocene, 0.3-0.8 km thick, with seismic velocities of 3.5-3.9 km/s;
- Upper Oligocene - Lower Miocene, 0.7-1,3 km thick, with seismic velocities of 3.0- 3.3km/s;
- Miocene, 0.3-1.2 km thick, with seismic velocities of 3.0-3.1 km/s;
- Upper Miocene, 0.7-2.2 km thick, with seismic velocities of 2.6-2.8 km/s;
- Pliocene, 0.2-0.9 km thick, with seismic velocities of 1.9-2.25 km/s;
- Pleistocene, 0.3-0.7 km thick, with seismic velocities of 1.7-2.0 km/s.

There is a distinct clinoform structure in part of the Cenozoic succession, particularly in Paleogene and Lower Miocene strata in the Vil'kitskiy Depression (Figs. 4, 6). Typical clinoform

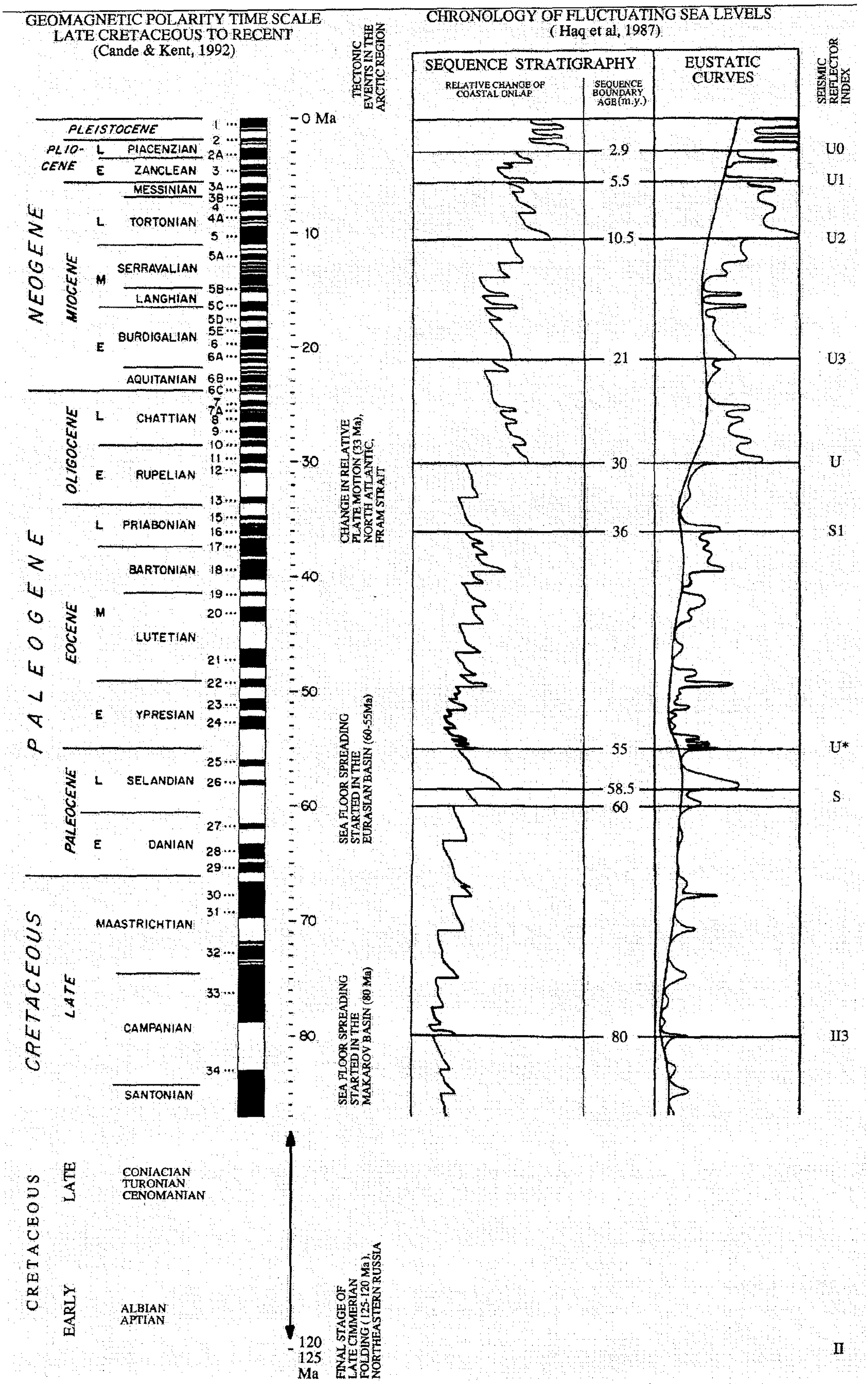


**Fig. 3:** Seismic stratigraphy correlation chart for the northwestern continental margin of the East Siberian Sea.

reflections indicate a progradating sedimentation. The general sedimentary setting of the Tertiary cover in the Vil'kitskiy Depression and on the continental slope resembles a classical progradating deltaic sequence. It is known, that progradating

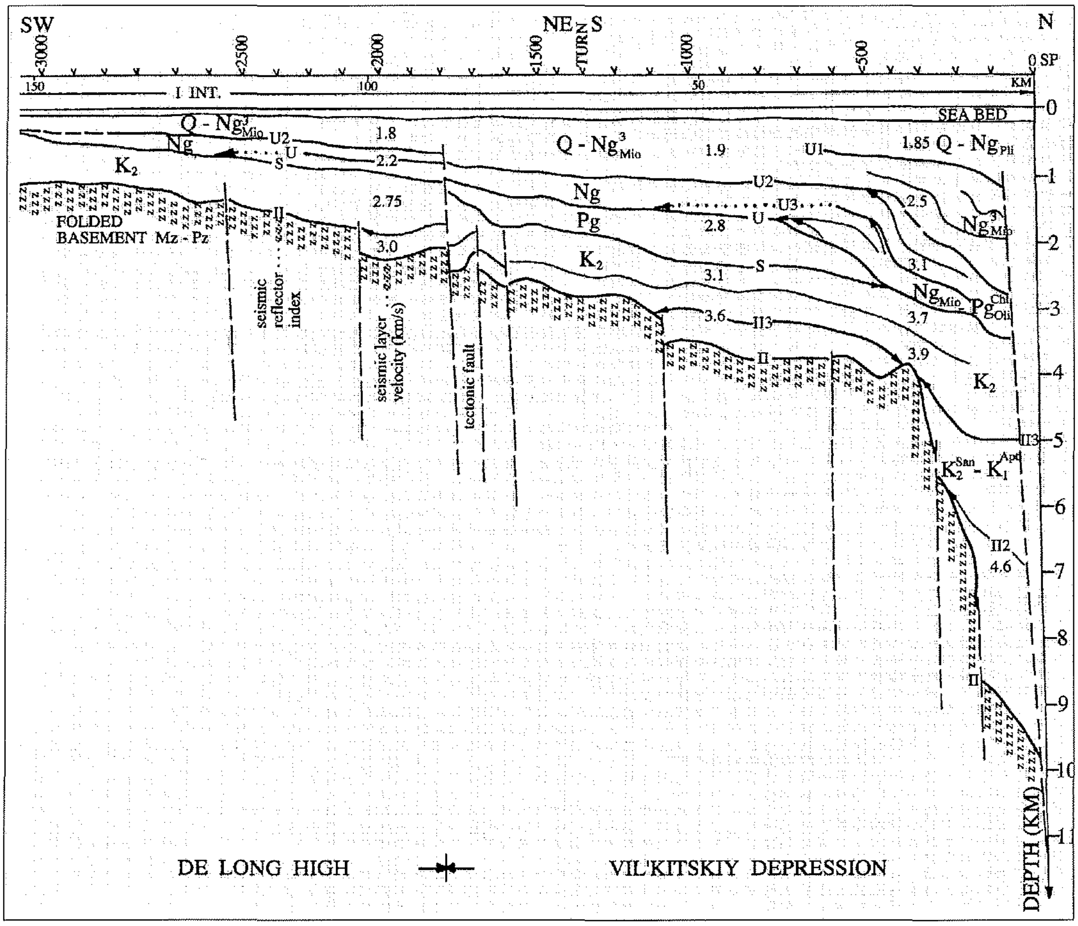


**Fig. 4:** Fragment of the seismic line 90800. Depth section. SP: shot points and their numbers. The horizontal km scale shows the shooting direction and total length of the seismic line. I INT: part of the seismic line with shot point sequence. Vertical depth scale is given in kilometres.

stratigraphic sequences develop in conditions dominated by the action of rivers and associated turbidity flows (BERG 1982). The sedimentary cover of the East Siberian continental slope is deposited in a water depth of about 1000 m. The succession here includes the Upper Cretaceous and includes a distinct set of almost parallel, high-amplitude seismic reflectors of large extension. Such reflections can be produced by the rhythmic alternation of turbidite sandstones and claystones.

In the southern part of the Vil'kitskiy Depression and at the northeastern margin of the De Long High, only three Cenozoic sedimentary units are recognized (Figs 4, 6). These units, in ascending order, are:

- Paleogene, 200-600 m thick, with seismic velocities of 2.2-2.6 km/s;
- Miocene, 100-400 m thick, with seismic velocities of 2.2-2.45 km/s;
- Upper Miocene to Pleistocene, 200-800 m thick, with seismic velocities of 1.75-1.85 km/s.
- South of 77.5 °N and west of 158 °E on the De Long High, all three units disappear sequentially, until none is left in the section. Geological data on Tertiary deposits on the New Siberian Islands and the surrounding mainland (VOL'NOV 1975, GRINENKO et al. 1989, ALEKSEEV et al. 1992), along with the seismic character of the Cenozoic succession described above, suggest that Tertiary rocks on the De Long High would be basically of coastal facies with occasional intercalations of continental facies. One could probably expect claystones, aleurites and sandstones interstratified with pebble conglomerates and brown coal horizons. In the northern part of the Vil'kitskiy Depression and on the continental slope, the Cenozoic cover consists of marine sandy-argillaceous turbidites.

These data indicate that the basin development on the present northwestern margin of the East Siberian Sea started with rifting off of continental crust in the post-Neocomian Cretaceous time, accompanied by the formation of the Makarov Basin. Rift structures propagated into Eurasia. Continental basement on this margin is interpreted to consist of Paleozoic and Mesozoic rocks folded in late Cimmerian time. There are two main stages of outer margin evolution: continental rifting and synoceanic. The formation of a synrift terrigeneous sequence occured from the Aptian to late Cretaceous (Santonian) time. The growth of the synoceanic turbidity sequence, which consists of submarine fans, started in late Cretaceous (Campanian) time. Submarine fan deposits formed a gigantic progradational sedimentary prism on the northwestern margin of the East Siberian Sea. Seismic stratigraphic analysis clearly indicates an influx of sediments from southern sources. Modern morphology of the northern shelf and outer margin is a result of continental-terrace progradation and gravity-driven slope processes.

Because of the paucity of geological and geophysical studies in the East Siberian Sea, only a general hydrocarbon zonation is suggested. The East Siberian shelf may be the oil and gas-

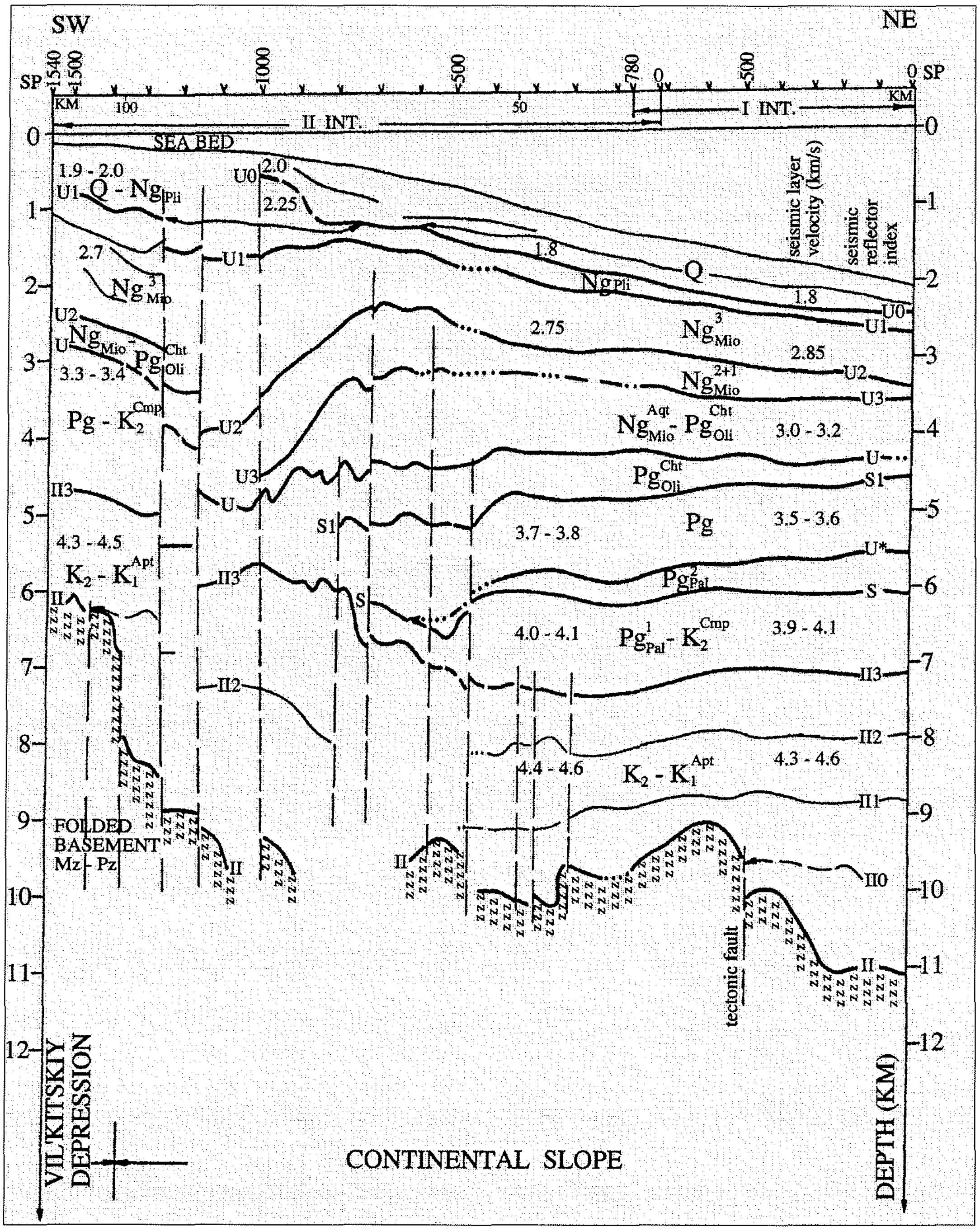


**Fig. 5:** Seismic line 90800-1. Depth section. SP: shot points and their numbers. The horizontal km-scale shows the shooting direction and total length of the seismic line. I INT, II INT: parts of the seismic line with shot point sequences. Vertical depth scale is given in kilometres.

bearing area (OGA) of the Laptev - East Siberian Shelf oil and gas-bearing basin (OGB). The outer margin of the East Siberian Sea may be considered as the East Siberian Outer Margin OGB.

In the north western part of the East Siberian Shelf OGA, the most prospective structure is the Vil'kitskiy Depression. Here Lower Cretaceous (Aptian) to Cenozoic terrigeneous strata are 2-8 km thick. Seismic stratigraphic analysis indicates that these strata are marine sand- and claystones. In contrast, the Upper Cretaceous to Cenozoic formed a progradating deltaic sequence in the northern part of the Vil'kitskiy Depression. The hydrocarbon potential of sandstone-claystone deltaic sequences is well known and the progradational clinoforms in the northern part of the shelf indicate a high hydrocarbon potential. Very likely stratigraphic and structural traps exist in this succession.

On the De-Long High the thickness of the sedimentary cover is less than 1-1.5 km, but over the high it varies from a few metres to several hundreds of metres. This structure is considered to have no potential for oil and gas. The East Siberian Outer Margin OGB zone corresponds tectonically with the continental slope of the passive-transform margin of the East Siberian Sea. The total thickness of the sedimentary cover is 7-9 km. Two structural sequences can be distinguished in ascending order:

- a synrift succession, which consists of Lower Cretaceous

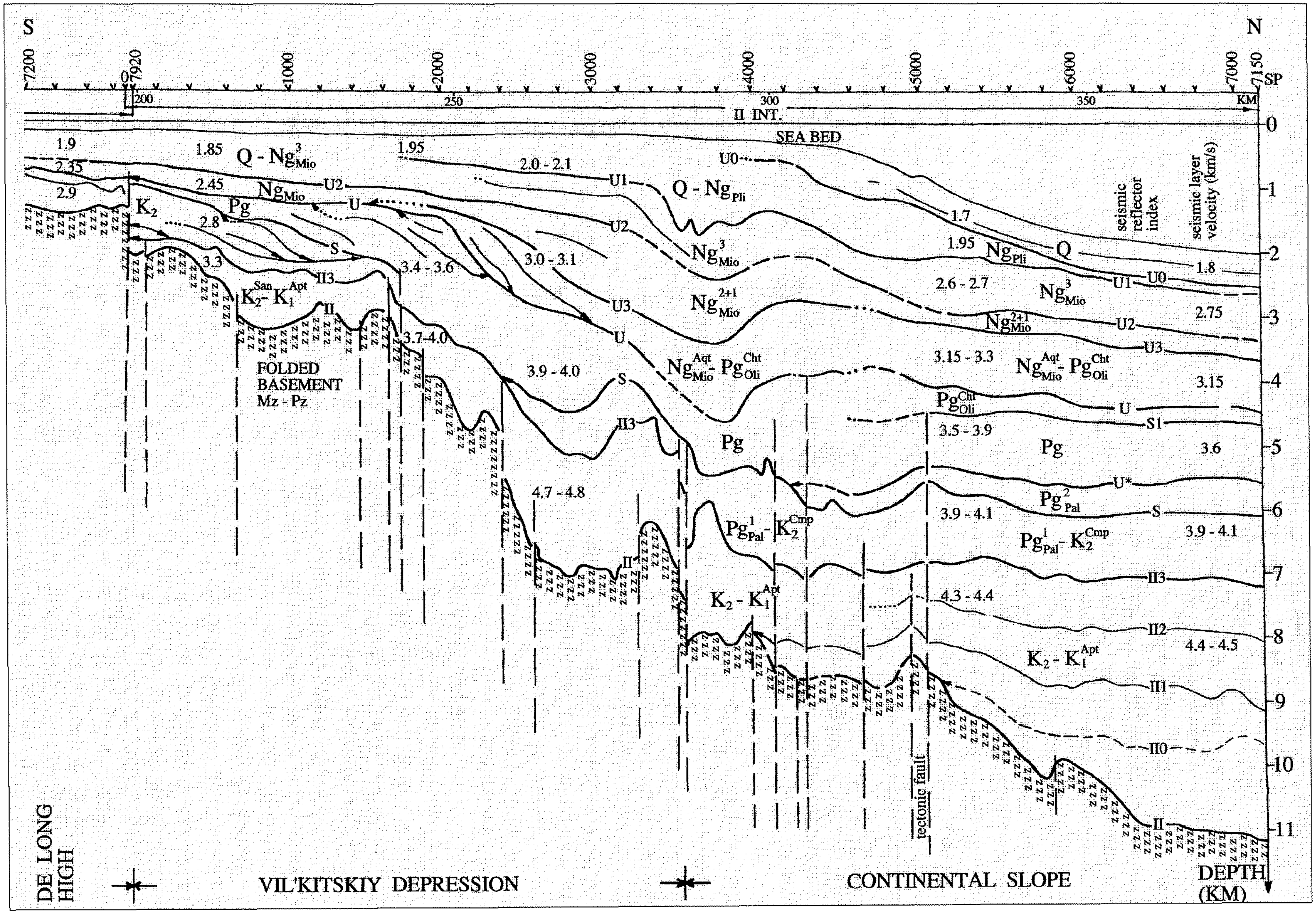


**Fig. 6:** Fragment of the seismic line 90801. Depth section. SP: shot points and their numbers. The horizontal km-scale shows the shooting direction and total length of the seismic line. II INT: part of the seismic line with shot point sequence. Vertical depth scale is given in kilometres.

(Aptian) to Upper Cretaceous (Santonian) deposits, and

- a synoceanic sequence, which consists of Upper Cretaceous (Campanian) to Cenozoic sediments.

The entire continental slope succession consists of rhythmically alternating turbidite sandstones and claystones. The synrift sediment succession is 2-4 km thick. Synrift strata are well known for their high oil and gas potential. The thickness of the synoceanic sequence varies from 4 to 6 km. Active subsidence of the East-Siberian outer margin in late Cretaceous(?) - Cenozoic time favoured considerable changes in the supply of organic source material interstratified with the thick sandstone-argillite succession. This should create favourable circumstances for hydrocarbon generation, migration and accumulation within the East-Siberian Outer Margin OGB. There should be favourable stratigraphic traps in the outer margin Cenozoic sequence.

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