Structure and seismostratigraphy of the East Siberian Sea shelf along the Indigirka Bay–Jannetta Island Seismic profile

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GEOLOGY

Structure and Seismostratigraphy of the East Siberian Sea Shelf along the Indigirka Bay–Jannetta Island Seismic Profile

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According to concepts elaborated in the 1970s by the Research Institute of Geology of the Arctic Regions (NIIGA), which is now the All-Russia Research Institute of Geology and Mineral Resources of the World Ocean (VNIIOkeanologiya), the results of aeromagnetic, gravimetric, and geological surveys within the East Siberian Sea region suggest that structural elements of the western segment of the shelf are represented by basements of different ages along the De Longa Rise and in the Novaya Sibir and Blagoveshchensk sedimentary basins [1–3]. Based on the works of NIIGA geologists, Fujita and Newberry proposed that these basins may be underlain by oceanic crust and may represent relics of the Southern Anyui paleoocean [4].

The first multichannel common-depth-point (CDP) seismic reflection profiles in the western segment of the shelf were studied at the Laboratory of Regional Geodynamics (LARGE) Geophysical Company in September 1989, using an airgun source of 5.9 l and a 1200-m-long 48-channel seismic streamer (Fig. 1, inset). The field data were processed at the GECO Company in Norway.

The 550-km-long LARGE-89001 profile originates 110 km away from the Indigirka Bay coast and ends 20 km east of Jannetta Island in the De Longa Archipelago. Interpretation of this profile yielded a substantially new concept that is different from the existing ones. This segment of the shelf includes a large sedimentary basin that is bounded on the north by the De Longa Rise. We have named this structure the East Siberian Basin (ESB). The previously recognized Novaya Sibir and Blagoveshchensk basins, as well as the linear Anzhu Rise between the basins, are not expressed on the profile and supposedly do not exist.

The two-phase low-frequency reflecting horizon A represents the acoustic basement roof and is traced to depths of 0.5–3.5 s TWT* (Figs. 1–3). Regional reflectors revealed in the wave field above this horizon divide the sedimentary cover into six seismic complexes. The uppermost seismic complex (VS-6) makes up a continuous cover. Seismic complexes VS-5, VS-4, VS-3, and VS-2 are complete within depressions and are reduced or cut by an unconformity in the VS-6 floor on the uplifts. The seismic complex VS-1 is locally developed in the floor of the cover in the northern sector of the profile.

The southern sector of the profile (shotpoints, SP 1–1200) crosses a small depression in Indigirka Bay. The sedimentary cover (VS-6 and, probably, VS-4 or VS-3) in this area has an acoustic thickness of 1.0–1.5 s. The short and sinuous reflections suggest dynamic sedimentation conditions in the Indigirka River unloading area. Magnetic anomalies of the Southern Anyui–Lyakhov Suture extend into this shelf area. Therefore, the Late Mesozoic age of the basement here is certain.

The central section of the profile (SP 1200–9000) is about 340 km long and crosses the ESB area. The southern limb of this basin (SP 1200–5700) characterizes the gentle northward plunge of the basement surface to a depth of 2.3 s (about 3 km). The deep Blagoveshchensk Basin, previously distinguished in this area, has not been confirmed by the LARGE profile.

A continuous succession of seismic complexes of the ESB cover with acoustic thickness up to 3.5 s (about 5 km) has been revealed within a graben in the center of the basin (Fig. 2).

The VS-2 seismic complex is represented by a series of discontinuous (but sufficiently contrasting) subhorizontal reflections that are governed by strike-slip faults in the lower section of the graben. This suggests that the VS-2 complex is a synrift structure that marks the first extensional phase of the ESB basement.

The VS-3 complex is distinguished in the lower section of the cover in the southern ESB limb. It represents a packet of parallel high-intensity reflections concordant to the roof (horizon II) or cut by horizon IV. The VS-4 complex, which overlies the lower horizons of the cover or the acoustic basement, is almost ubiquitous in the ESB area. Its upper section it is dominated by extended reflections that form a fan diverging to the basin center. The VS-4 sequence probably accumulated

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* TWT, the two way travel time, is omitted hereafter.

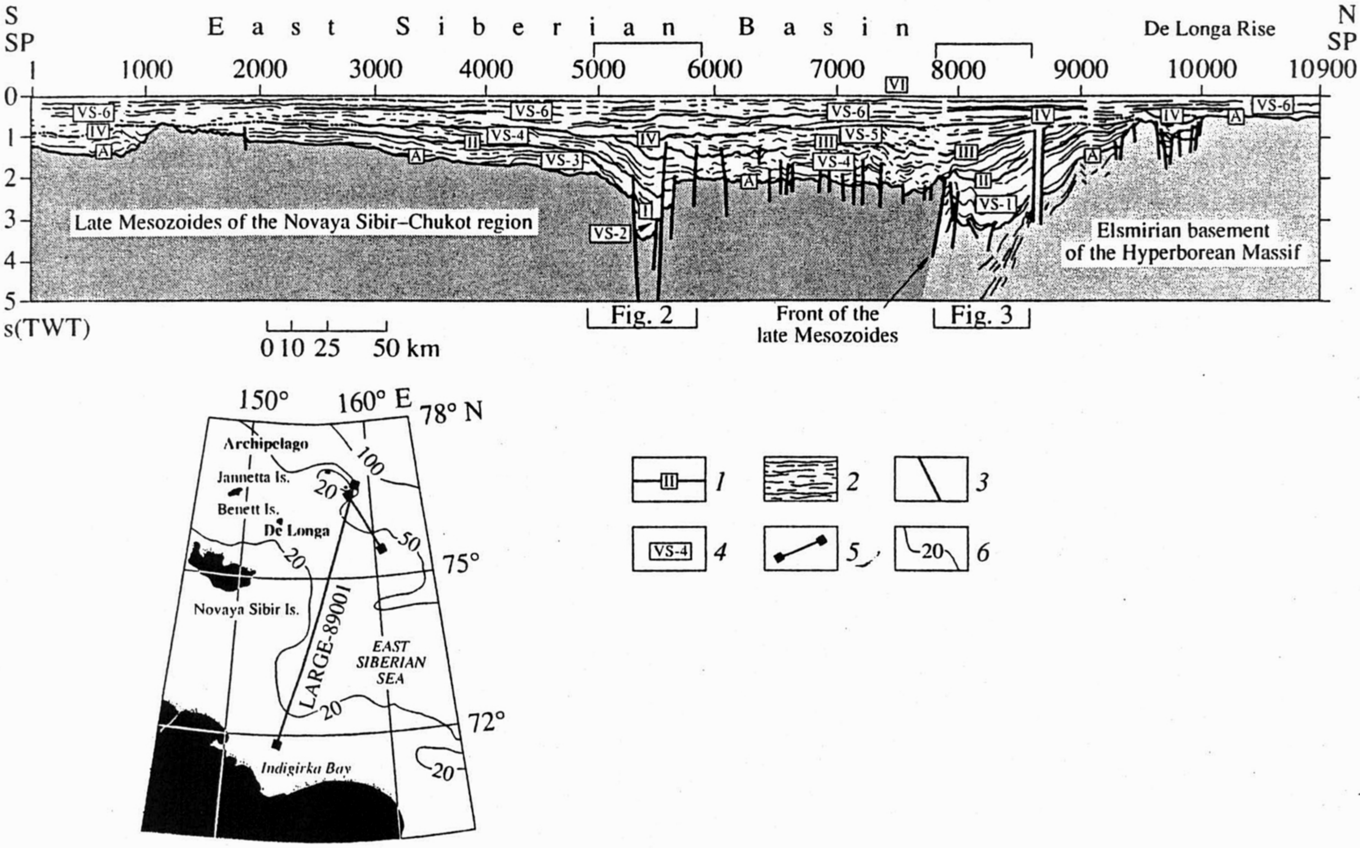

Fig. 1. Seismogeological cross section along the LARGE-89001 profile illustrating the structure and seismostratigraphy of the western sector of the East Siberian Sea shelf (location of the cross section is shown on the inset). The staples mark fragments presented in Figs. 2 and 3. (*1*) Seismic boundaries and their indexes; (*2*) reflections within seismic complexes; (*3*) faults; (*4*) indexes of the seismic complexes; (*5*) LARGE seismic profiles in 1989; (*6*) isobaths, m. (SP) shotpoint.

due to sedimentary material supply both from the northern and southern areas. In the central segment of the basin, the VS-4 wave field becomes heterogeneous, being characterized by numerous short, intense reflections inclined in different directions. Here, intricate facies relationships are possible in the area of interaction of the two countersedimentation flows.

The VS-5 complex has been distinguished in the central, most subsided ESB segment. It is underlain by the VS-4 complex and overlain by the VS-6 complex. This seismic complex is characterized by a moderate to weak reflectivity and by discontinuous but well expressed subhorizontal reflectors overlapping horizon III in the seismic complex floor, which suggests that this horizon is a transgressive unconformity. It is likely that the VS-5 sequence is dominated by marine facies.

The VS-6 complex discordantly overlaps the preceding seismic complexes and acoustic basement. Horizon IV in the VS-4 floor represents one of the most pronounced erosion surfaces. Against the background of low-intensity reflections, individual short and extended subhorizontal reflectors with higher contrast are distinguished. The VS-6 thickness varies from 0.5 to 1.1 s in the central ESB segment. It is noteworthy that faults disrupting the cover in the graben walls do not reach the VS-6 floor. As is suggested by seismostratigraphic indicators, sediments corresponding to the VS-6 complex accumulated during a general subsidence of the whole basin and domination of a marine sedimentary environment. It can therefore be supposed that the ESB continental crustal extension had been completed by the time of formation of this seismic complex.

The age of the seismic complexes cannot be solved unambiguously because of the lack of borehole data on the East Siberian Sea shelf. However, the age can be preliminarily estimated by a correlation of the seismic horizons with regional unconformities known in the Circum-Arctic region. These unconformities exist between the Lower and Upper Cretaceous, at the Maastrichtian and Upper Paleocene levels, and at the Eocene–Oligocene boundary. We correlate them with the VS-2 floor, horizon II, horizon III, and horizon IV, respectively. Cenomanian–Turonian deposits on Novaya Sibir Island can be considered as probable analogs of the VS-2; and the Eocene Anzhu Formation and the Oligocene–Lower Miocene Nerpich'e Sequence on Faddeevskii Island, as analogs of the VS-5 and VS-6,

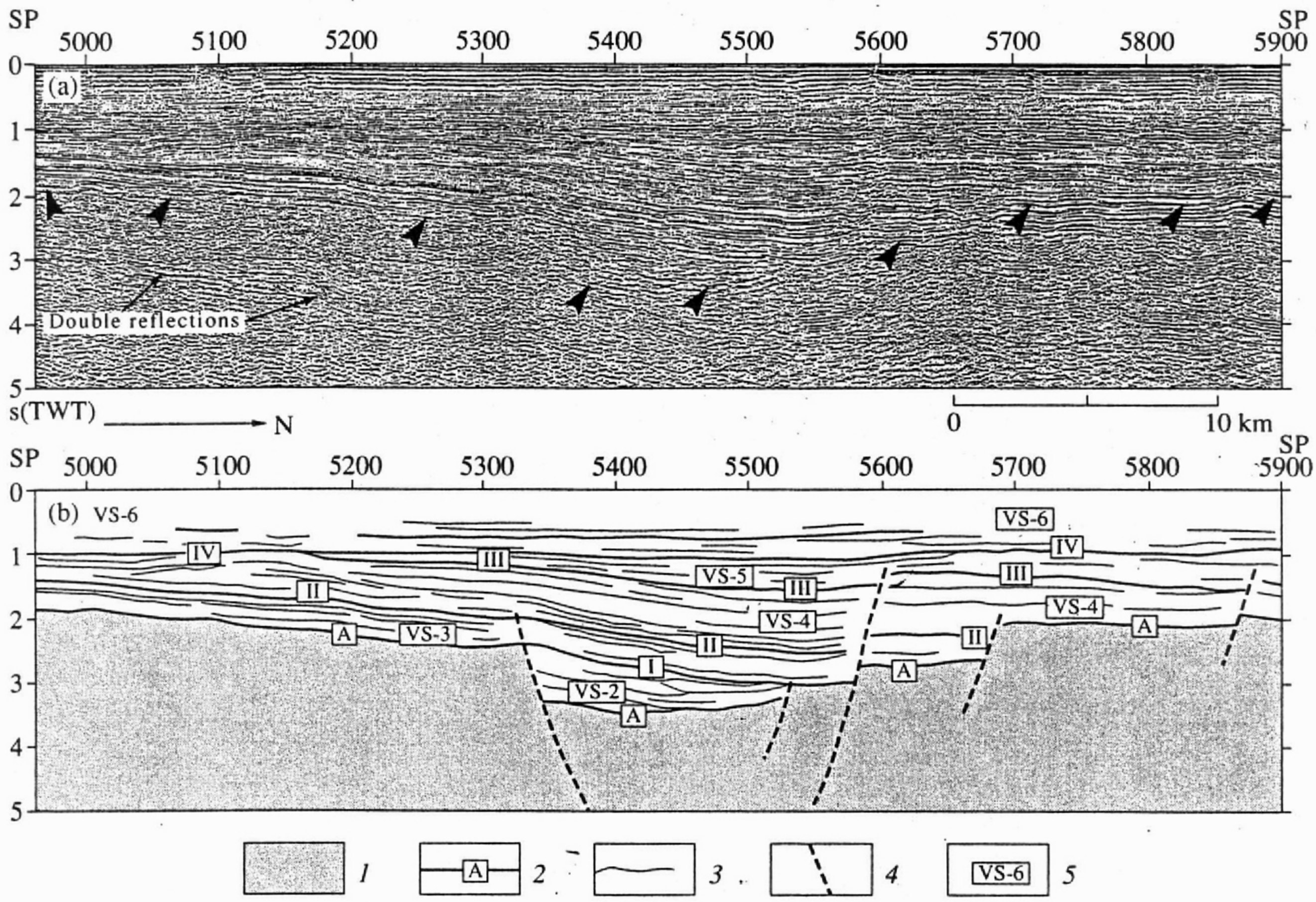

Fig. 2. Fragment of the LARGE 89001 profile showing the structure and principal seismostratigraphic divisions of the sedimentary fill of the central East Siberian Basin (location of the fragment is shown in Fig. 1). (a) Migrated time section and (b) its interpretation. The black arrows in (a) indicate horizon A. (*1*) Lower Mesozoic folded basement; (*2*) seismic boundaries and their indexes; (*3*) reflections within the seismic complexes; (*4*) normal faults; (*5*) indexes of the seismic complexes.

respectively. The upper section of the VS-6 possibly includes marine sediments of the Kanarchak Sequence (Upper Pliocene–Lower Pleistocene).

The seismic complex distinguished between SP 7900 and SP 9500 beneath horizon II is conventionally identified as VS-1 (Fig. 3). Southward, it thickens and its wave field changes from almost transparent to moderately contrasting and multiphase. In the latter case, one can see the domination of nearly parallel high-amplitude reflections, which gently incline to the north, where the VS-1 complex is reduced and underlain by horizon A.

South of SP 8200, the VS-1 complex is underlain by the acoustic basement. North of this shotpoint, we observe a fan-shaped packet of discontinuous reflections diverging and plunging southward to a depth of 5 s or deeper. It is obvious that this wave packet characterizes a sedimentary sequence older than the VS-1, which is not distinguished in other sectors of the profile.

The structural position of the VS-1 is specific. To the south, it is terminated by a salient of the central ESB basement where horizon A is 1.2 s higher compared to the position on the De Longa Rise side. Approaching this salient from the north, the wave packet is not traced beneath horizon A and the VS-1 reflections become sinuous. The edge reflections of the antiforms are irregular, suggesting the fracture-related (most likely, reverse-thrust) character of the boundaries. In the SP 8000 area, a 2.5-km-wide anticlinal bend is bounded by fan-shaped diverging upthrusts. Such a geometry of the reflections may be the result of compressive or transpressive dislocations. The antiform at SP 8000 is typical for transpression zones; such a structure is known in the literature as a positive flower structure for its resemblance to an upward-bent flower.

We consider the VS-1 dislocations as an expression of the transpression–overthrust front of late Mesozoides at their boundary with the rigid Hyperborean Massif, which consists of the probably Early Paleozoic core of the Chukot–North Alaskan microcontinent. Eastward, this zone may extend to the Chukot Sea and is exposed in the Brooks Orogen front in northern Alaska [5], where the upper section of the Lower Brooks Formation has a structural position analogous to that of VS-1. Therefore, the VS-1 sequence could have accu-

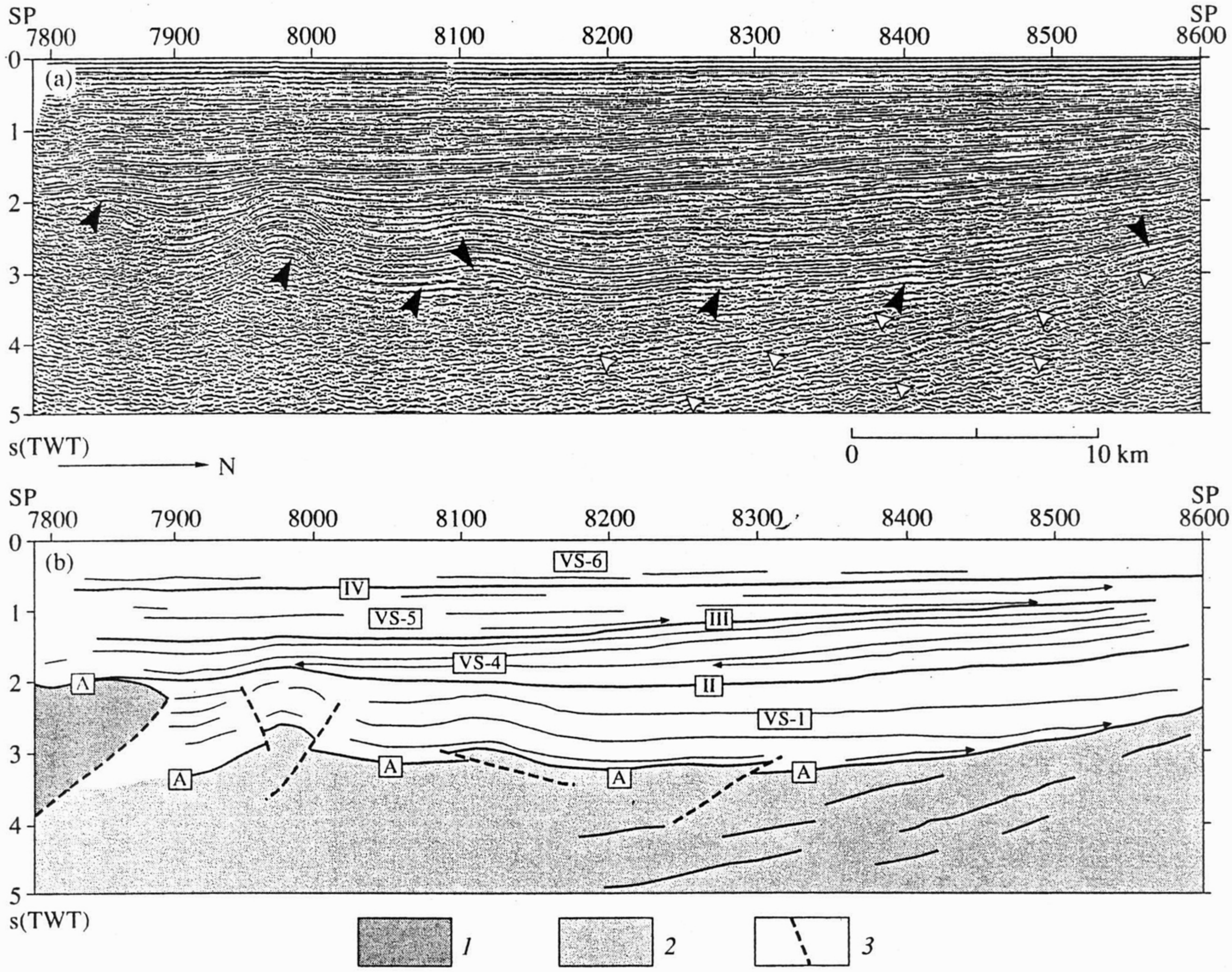

Fig. 3. Fragment of the LARGE 89001 profile showing the structure and principal seismostratigraphic divisions of the sedimentary cover on the northern slope of the East Siberian Basin (location of the fragment is shown in Fig. 1). (a) Migrated time section and (b) its interpretation. The black arrows in (a) indicate horizon A; the white arrows point to the seismic reflections forming a fan-shaped packet beneath the horizon A. (*1*) Epi-Elsmirian Hyperborean Massif; (*2*) Late Mesozoic folded basement; (*3*) upthrusts and overthrusts with a possible strike-slip component. Other symbols are the same as in Fig. 2.

mulated in the Albian, contemporaneously with the final deformations, while the reflection packet beneath the VS-1 may characterize a more ancient (possibly epi-Elsmirian) cover of the massif.

The profile termination (SP 9000–10900) crosses the southern edge of the De Longa Rise expressed in the gravity and magnetic fields. It consists of the high elevation of the basement of the Hyperborean Massif covered by Early Cretaceous and Late Cenozoic subaerial subalkalic and alkaline basalts and by terrigenous sediments. The gravitational data show a series of small grabens and horsts that complicate the internal segments of the rise. One of such grabens, 17 km wide and about 2 km deep, has been crossed by the LARGE profile.

Thus, the LARGE-89001 seismic profile has made it possible for the first time to confidently characterize the structure and seismostratigraphy of the western segment of the East Siberian Sea shelf. The synonymous sedimentary basin probably originated in the Late Cretaceous on the heterogeneous basement composed of the late Mesozoides, which extend from the continental region, and the Hyperborean Massif, which was not subject to the Late Mesozoic dislocations. The ESB formation was possibly related to destructive processes that led to the separation of the North American and Eurasian plates in the Arctic Ocean region. However, ESB basement extension was not significant, and the basin was formed due to a large-scale subsidence of the lithosphere. Beginning in the terminal Cretaceous(?) to the initial Oligocene(?), the basin was wide and in places uncompensated depression that was filled with sediments supplied both from the De Longa Rise and from a continental region.

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