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GEOLOGY

Specific Features of the Seismoacoustic Structure of Cenozoic Deposits in the White Sea

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We studied the Cenozoic sedimentary cover on the basis of data of continuous seismic profiling (CSP) carried out in 2003–2004 in the White Sea in the course of comprehensive geophysical investigations by the Marine Arctic Geological Expedition (MAGE) (Fig. 1). Judging from the wave pattern, bedding, and availability of unconformable surfaces, the deposits are subdivided into separate seismoacoustic complexes (SC).

The Cenozoic section includes seismoacoustic complexes apparently overlying rocks of the basement and sedimentary cover. The upper sedimentary cover of the White Sea basin incorporates three major SCs (III–I) that differ in acoustic characteristics and positions in the section.

SC III was distinguished in the neck of the White Sea near the Zimnii and Terskii shores (Kerets Cape) (Fig. 2). This is a nonuniform (in terms of acoustics) sequence with poorly expressed bedding. Its top and base are distinguished with certainty. Sediments of SC III overlie Upper Proterozoic rocks with angular and stratigraphic unconformities. The sheet mode of occurrence and the stratified structure of the seismoacoustic complex count in favor of its marine genesis. It is most likely that sediments of this complex belong to the Mikulino Interglacial.

SC II is widely developed in the neck of the White Sea along the Terskii shore and slopes of the Kandalaksha graben, as well as in the southern part of the sea. Within the Dvina Bay, the seismoacoustic complex is retained as relicts near the Zimnii shore and is widespread on the rugged topography of the seafloor in the central part of the bay. Dissected, hummocky surfaces are typical of the seismoacoustic complex (Figs. 2, 3). Boundaries of the top are distinct, and the base is generally clear. SC II occurs on the flat or slightly dissected surface of bedrocks and SC III. The internal wave pattern is characterized by a chaotic pattern of in-phase axes. Fragments of differently oriented boundaries are rare. Such a wave pattern indicates that the seismoacoustic complex is composed of unsorted sediments overlying large objects that diffract waves. Based on these characteristics, the seismoacoustic complex was assigned to glacial deposits. Sediments of this complex make up ridges mapped along the Terskii Shore in the White Sea neck and basin. These ridges are likely to be peripheral and lateral moraines. The central part of the sea incorporates individual isometric irregular ridges (Fig. 3). The top of the morainic ridge shows a boundary that probably separates glacial deposits of different ages. The seismic record pattern suggests that the moraine formed at least during two stages. The moraine can be subdivided into the upper and lower parts. The lower moraine is denser than the upper moraine and hosts sediments. This is indicated by a positive gravity anomaly. The thickness of SC II reaches 115 m in ridge crests. We believe that SC II is composed of the Valdai Glaciation sediments. However, one cannot rule out the preservation of older morainic deposits in the region.

In the Kandalaksha Gulf, a large morainic ridge is distinguished near the southwestern slope of the Kandalaksha graben. The ridge top is highly dissected and overlapped by SC I deposits. Based on the wave pattern, the ridge includes several seismic boundaries that are likely to separate deposits of different ages. It seems plausible that deposits of the Moscow Glaciation, as well as Mikulino and Leningrad interglacials, could be retained at the ridge base. Short fragments of reflecting horizons are tracked in the upper part of these bodies. In-phase axes of these bodies are often curved, indicating the landslide-type mechanism of their formation. The heterogeneous inner structure indicates the multistage formation of these bodies.

SC I comprises all deposits of the uppermost part of the Cenozoic section. It is subdivided into four (SC I_1,

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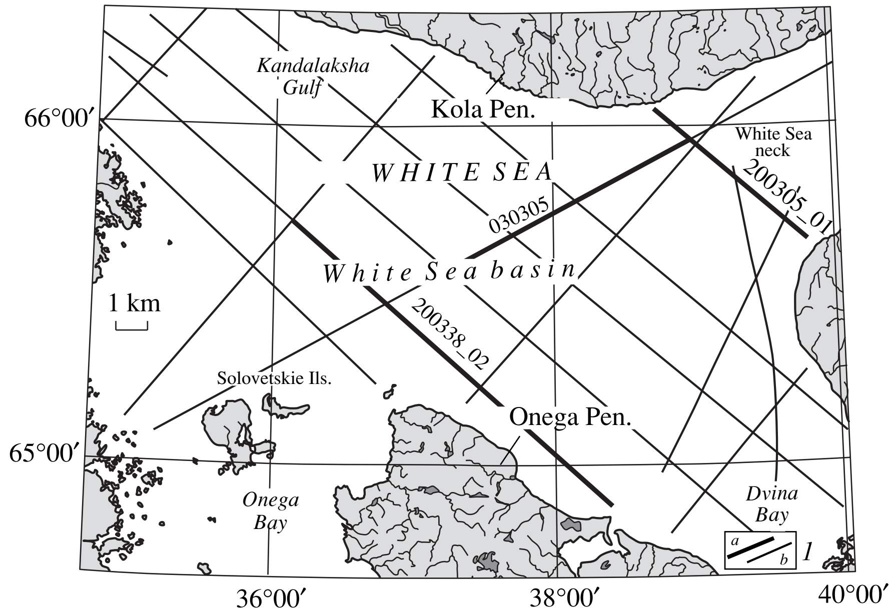

Fig. 1. Layout of seismoacoustic profiles in the White Sea. (*1*) Seismoacoustic profiles: (a) mentioned in the text, (b) others.

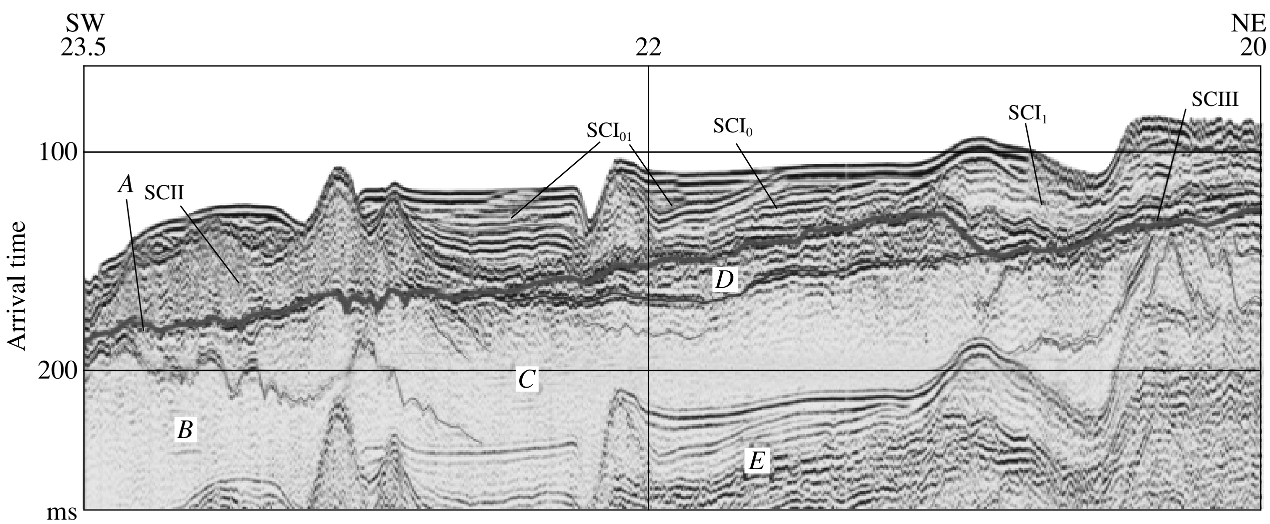

Fig. 2. A fragment of CSP time section 030305. (*A*) The base of Quaternary deposits; (*B*) Riphean SC; (*C*) Upper Riphean SC; (*D*) Vendian SC; (*E*) multiple wave.

SC I_0, SC I_{11}, and SC I_{01}) subcomplexes with different wave patterns (Fig. 2).

SC I_1 is identified on profiles in the northern part of the basin and neck, as well as on profiles in the funnel of the White Sea (Figs. 2, 4). This is an acoustically uniform complex with vague inner boundaries that make up the obscure subhorizontal (often, wavy) bedding. SC I_1 is characterized by a well-defined top and base, as well as by smooth and gentle slopes. Sediments of this seismoacoustic complex form a blanket and fill up incisions in some places. The SC I_1 top is complicated by a microrelief in the form of fine to very coarse sandy ripples.

SC I_0 is characterized by distinct extended inner boundaries that make up the subhorizontal bedding (Figs. 2, 3). At the base, reflectors of the seismoacoustic complex envelop underlying structures of the paleorelief. The surface of the seismoacoustic complex is even. Prominent inner boundaries indicate a sharp differentiation of SC I_0 sediments with respect to acoustic properties as a result of the alternation of beds of different lithological compositions. SC I_0 occurs as a blanket cover that fills up and smoothes irregularities in the relief of underlying rocks.

SC I_{11} is distinguished by a characteristic pattern of the seismoacoustic record. This is an acoustically uni-

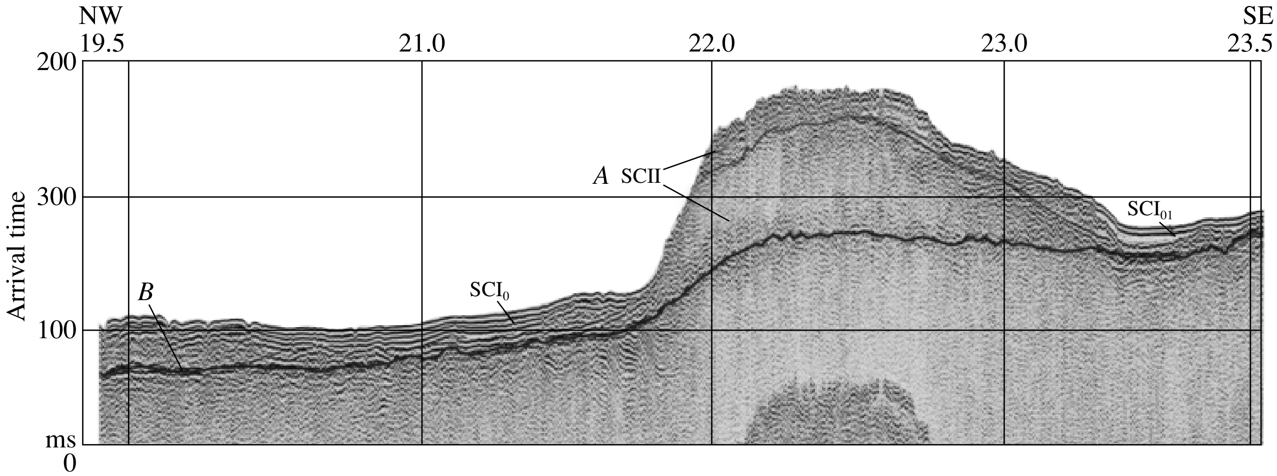

Fig. 3. A fragment of CSP section 200338_02. (*A*) Glacial deposits of different ages; (*B*) the base of Quaternary deposits.

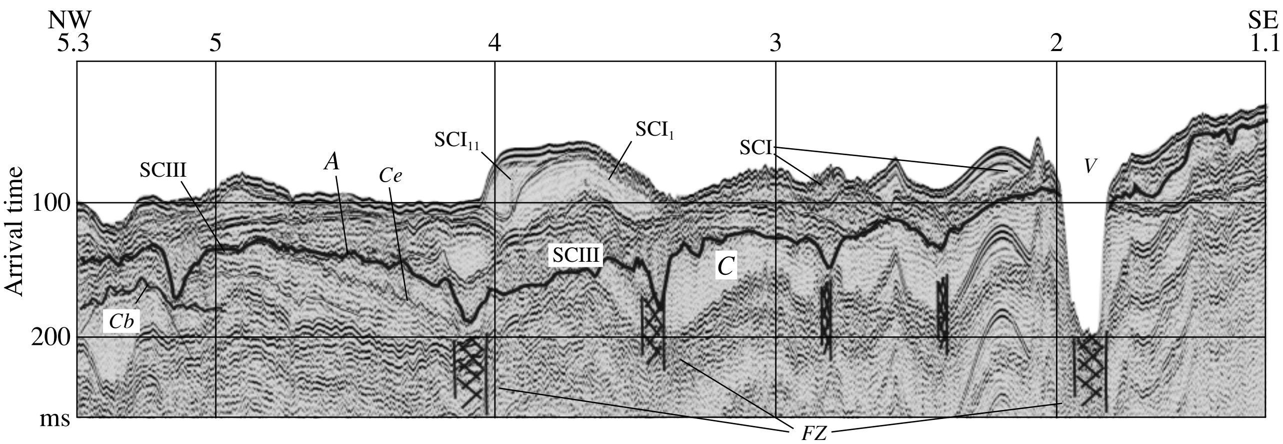

Fig. 4. A fragment of CSP section 200305_01. (*A*) The base of Quaternary deposits; (*Cb*) the base of Vendian deposits; (*Ce*) erosional surface in Vendian deposits; (*C*) Vendian SC: (*V*) present-day incision; (*FZ*) fractured zones.

form transparent seismoacoustic complex that is distinguished from SC I_1 and SC I_0 by the presence of oblique bedding (Fig. 4). The seismoacoustic complex is recognized in the northern part of the White Sea basin. Boundaries of the top and base are clearly defined. The seismoacoustic complex makes up a steep (northwestern) slope of a large sand bar. In the bottom topography, the bar extends northward along the axis of the White Sea neck. The seismoacoustic complex makes up a lens on sediments of SC I_1. Such deposits are formed under the influence of contour currents.

Sediments of SC I_{01} (?) overlie SC I_0 (with an angular unconformity at the base) and, probably, SC II as well (Fig. 2). This complex is characterized by short and less intense (relative to SC I_0) reflections. The top is even. Reflections form unconformities with underlying rocks at the base. The seismoacoustic complex is rather widespread in the White Sea basin.

Based on the wave pattern and position in the section, we assigned SC I to Pleistocene–Holocene marine deposits.

The thickness of Quaternary deposits in the studied area varies from 3 to 150 m (average 30 m). The Quaternary deposits are the thinnest near the Zimnii and Letnii shores of the White Sea. The maximum thickness is recorded in ancient and recent hollows, as well as positive landforms of the bottom (hills and ridges) located north of the Solovetskie Islands and along the Terskii shore. These large hills and ridges, which are clearly defined in the bottom topography, represent a marginal moraine formed during the melting of a glacier in the Last Glaciation [1].

Large (probably, landslide-type) bodies of the type described above are observed along the southwestern slope of the Kandalaksha graben. They are traced for 60 km along the graben slope [2]. The thickness of Quaternary deposits in these bodies is 90–120 m. The thickening of Quaternary deposits in the White Sea neck is related to large sand bar.

A series of incised structures is distinguished within Dvina Bay. The largest incision extends from the Zimnii shore to south. The thickness of sediments in the structure reaches 80 km. Smaller incisions are developed along the Letnii shore. Incisions are absent in hollows of the pre-Quaternary relief.

Thus, Cenozoic deposits are composed of three major SCs that correspond to middle–late Quaternary marine sediments, Valdaian glacial deposits, Holocene–Pleistocene marine sediments, and Holocene marine sediments. Principal geomorphologic bodies have been revealed at the base of Quaternary deposits.

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