ISSN 1028-334X, Doklady Earth Sciences, 2007, Vol. 413, No. 2, pp. 167–169. © Pleiades Publishing, Ltd., 2007.
Original Russian Text © O.G. Epshtein, Yu.A. Lavrushin, 2007, published in Doklady Akademii Nauk, 2007, Vol. 412, No. 5, pp. 668–671.

GEOLOGY

Upper Weichselian Submarine Fluvioglacial Deposits of Ice-Contact Fans in the Southeastern Barents Sea

O. G. Epshtein and Yu. A. Lavrushin

Presented by Academician Yu.G. Leonov, February 22, 2006

Received March 9, 2006

DOI: 10.1134/S1028334X07020043

Fluvioglacial deposits are widespread in areas of recent and old glaciation. They are represented by different-type sediments accumulated in on-land and basin environments [6]. Submarine deposits of ice-contact fans are the most specific ones among them. They represent a significant element of glaciomarine deposits and are comprehensively studied in uplifted (in terms of glacial isostasy) modern continental areas [4, 5, and others] and in some fjords [7, 9, 10]. We revealed such ice-contact fans in offshore areas on the glacial shelf of the Barents Sea.

Upper Weichselian submarine fluvioglacial deposits of the Barents Sea, which make up ice-contact fans, were penetrated by a number of marine geotechnical boreholes. According to drilling data, the fans are composed of sand (more rarely silt) with a total thickness of 15–20 m. We carried out comprehensive study of the material obtained during high-resolution continuous seismic profiling (CSP) and revealed that these deposits are characterized by progradation clinoform bedding and are widespread in the southeastern Barents Sea shelf. They form two vast (30–40 × 120–170 km) zones. The first zone is located on the bottom at the northern slope of the Goose Trench, whereas the second zone is located east of Kolguev Island (the Goose and Kolguev zones, respectively) (Fig. 1, map). Bedded deposits of ice-contact fans mainly composed of sands make up the lower part of the seismic stratigraphic unit (SSU) II related to deglaciation of the shelf 14–10 ka ago [8]. Sediments of SSU IIb overlie with hiatus (mainly onlap mode) the upper Weichselian moraine (SSU III) and are conformably overlain by thin parallel-bedded glaciosuspensites of SSU IIa. The moraine underlying the deposits of ice-contact fans exhibits a chaotic (unstratified) type of seismic acoustic record, a subhorizontal exaration base, and a ridge–sinkhole top. Glaciosuspensites on fluvioglacial sediments are mainly represented by brown clay. They originated in a desalinated ice-contact sea basin due to the accumulation of melting products from the Novaya Zemlya ice sheet [1–3]. In the southeastern Barents Sea, they usually make up almost the entire SSU II section (the thickness varies from 5–7 to 75–100 m) [2].

The most extensively studied *Kolguev zone* of ice-contact fans is located in a relatively shallow-water zone (seawater depth <90 m). Geotechnical boreholes have penetrated sediments of fans in this zone. In addition to regional CSP profiles, a network of detailed profiles has been established in a large area of this zone (Fig. 1, map, and fragments A, B). The present boundaries of the zone are represented in many cases by areas where the top of the upper Weichselian moraine with fan deposits lies at the altitude of –70 to –75 m. At a lower depth, the moraine top with traces of abrasion is overlain by sediments of the Holocene transgression (SSU I). Within the zone, sand-rich deposits form a continuous, mainly oblique-bedded (in places, horizontally bedded) cover, the thickness of which irregularly varies from a few meters to 20–25 m. The floor of the discussed sediments (the moraine top) lies at the interval of negative absolute altitudes (from 75–80 to 150–160 m) and exhibits a rugged glacial topography, which was eroded in places by subglacial meltwater. This is demonstrated by leveled areas of the moraine top 1–2 km long and small trough-shaped hollows. The top of silty–sandy deposits is also uneven: in sediments with an oblique pattern of seismic reflections, the top has a more complicated structure than the floor topography. In horizontally bedded deposits, the top is nearly conformal to the floor line.

Obliquely bedded clinoform bodies, which make up downlap structures in the deposits, extend for hundreds of meters. After each interval of 1–3 km along the lateral direction, the dip of these planes changes to the opposite direction. In areas of the unilateral dip, oblique surfaces often form a typical sigmoid pattern of the lateral stacking of sediments (Fig. 1A). In addition

Geological Institute, Russian Academy of Sciences, Pyzhevskii per. 7, Moscow, 109117 Russia; e-mail: pacordus@mtu-net.ru

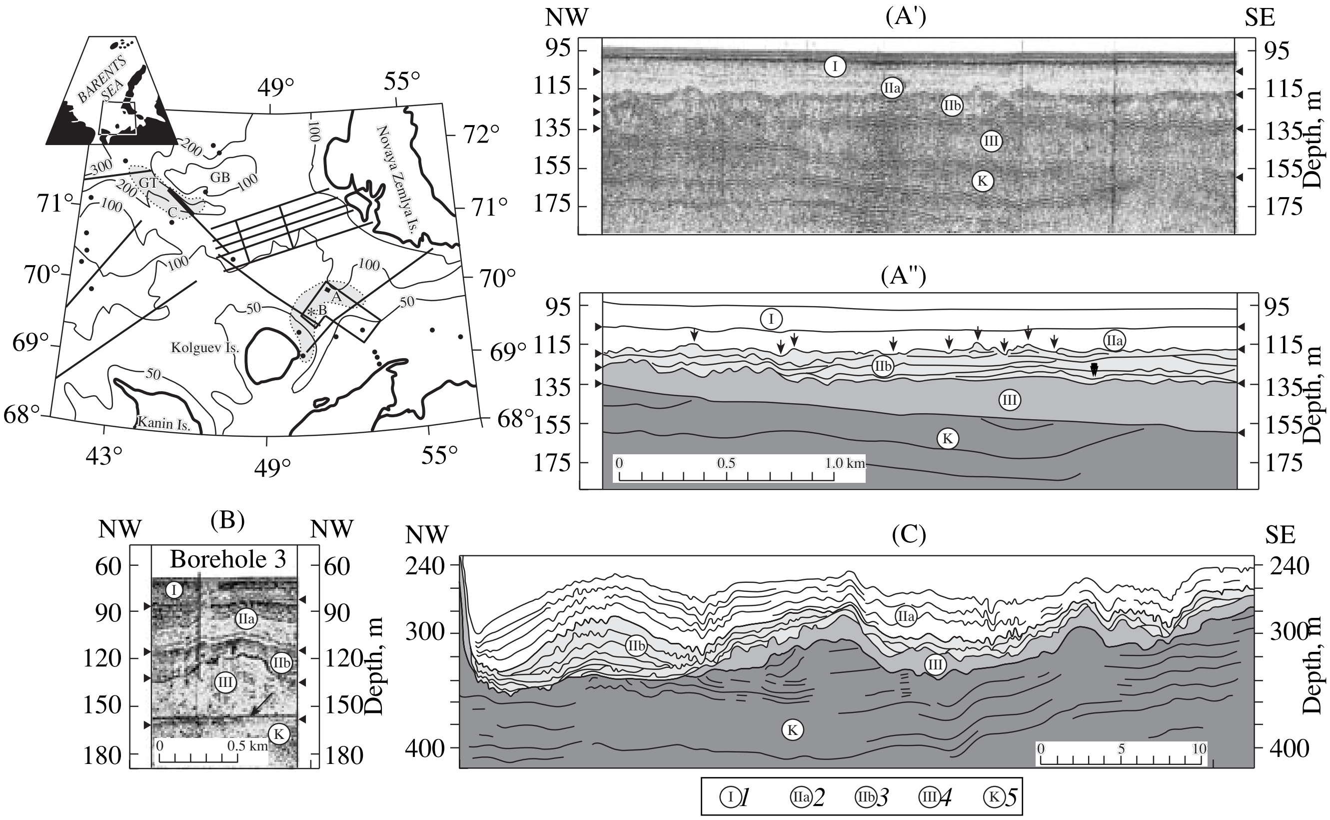

Fig. 1. Schematic map of the southeastern Barents Sea with zones of upper Weichselian submarine fluvioglacial deposits of ice-contact fans (outlined by a dotted line and colored in gray) and fragments of seismoacoustic and seismic geological profiles (A–C). Legend for the map. Straight lines denote the studied regional CSP lines; the right-angled polygon is the detailed CSP study area; and points are individual geotechnical boreholes, which penetrated the whole Quaternary section (asterisk denotes borehole 3 shown in fragment B). (GB) Goose Bank; (GT) Goose Trench. (A–C) CSP areas (bold lines) depicted on fragments of the figure (the area of profile B is not shown in the map, because it spatially coincides with the position of borehole 3). Isobaths are given in meters. Fragment A consists of two parts: A' represents the seismoacoustic profile, and A" is the result of its geological interpretation. Fragments A–B show seismostratigraphic units of the section: (*1*) Holocene marine sediments (SSU I); (*2*) late glacial glaciosuspensites (SSU IIa); (*3*) late glacial sandy–clayey accumulations of ice-contact fans (SSU IIb); (*4*) upper Weichselian moraine (SSU III); (*5*) Cretaceous deposits. Fragment C does not show Holocene sediments, because they are of small thickness. Black triangles on section sides (fragments A and B) denote boundaries of seismostratigraphic units. Thin arrows on fragment A" show irregularities at the top of sands, and a thick short arrow denotes the bedding plane, which presumably marks the generation stage of one of the fans. The arrow on fragment B shows multiple reflection from the bottom.

to downlap structures, onlap structures are also found in fluvioglacial sediments. They are especially developed in a zone characterized by the abundance of moraine hillocks up to 15 m high (Fig. 1C). Both slopes of the structure exhibit a distinct pinchout of beds in the lower part of the silty–sandy section. The base of the sedimentary cover includes structures presumably marking the incipient stage of individual fans. These structures represent positive bodies up to 3–5 m high and <1 km long, which are bounded by arched surfaces leaning on the moraine top and surrounded on each side by additional oblique planes (Fig. 1A). The original bedding of deposits with the oblique pattern of bedding planes is often distorted. This is evident from the presence of numerous, small (2–5 × 50–100 m), prominent irregularities of their top: hillocks made up of acoustically structureless masses and incisions resembling the seismic reflection pattern in sands (Fig. 1A).

These structures can be related to the impact of icebergs and/or the activity of mudflow-type high-density streams, which make up accumulative ridges in their marginal parts. In our opinion, the wide spatial development of sand-rich deposits is accounted for the fact that they were formed by a series of converged, flat-topped, ice-contact fans that made up a submarine apron at the front of waning ice. In depressions between individual cones, horizontally bedded sediments (mostly represented by silts) accumulated due to the activity of proximal glacioturbidites.

The *Goose zone* of ice-contact fans is located in the deeper water region (mainly 200–300 m). The zone is intersected by the two studied regional CSP profiles (Fig. 1, map). The profile passing along the northern slope and bottom of the Goose Trench is the most representative one (its fragment is given in Fig. 1C). Along this profile, the top of the upper Weichselian moraine (altitude from –250 to –350 m) makes up a series of hillocks with very gentle leveled slopes, which were probably eroded by subglacial meltwater flows. The prominent morphological irregularities of the moraine top in Fig. 1C account for the exaggeration of the vertical scale relative to the horizontal one (~1 : 80). In places, these flows washed out the moraine completely. Therefore, sediments of SSU IIb overlie Cretaceous deposits over a distance of about 15 km (Fig. 1C) and include thin residual coarse-clastic sediments at the base. This structure is indicated by very rigid basal acoustic reflections.

Upper Weichselian silty–sandy sediments are developed almost across the entire profile as a cover with an average thickness of 10–30 m. The line of the top of these sediments is unconformable to their base. The sediments include numerous extended (>2–3 km) reflectors usually with a poorly defined arched shape but an oblique rectilinear or irregular pattern in some places. The distinguished bedded units are characterized by the downlap mode of progradation clinoform surfaces. The northwestern part of the profile incorporates an isolated fan in the form of a large (about 15 km across and up to 50 m high), swell-shaped (in the observed section) body (Fig. 1C).

The origin of the whole sand-rich cover of the zone is similar to that of the Kolguev zone. Judging from the CSP profile across the Goose Trench, the sediments under consideration make up a very large clinoform gently inclined from the Goose Bank. Hence, sediments of ice-contact fans in this area are mainly related to the accumulation of products of melting ice masses with the front retreating northward to the Goose Bank shoal.

The Kolguev and Goose zones of ice-contact fans formed at the initial stage of glaciomarine sedimentation on the southeastern Barents Sea shelf. Owing to the slow retreat of the Novaya Zemlya ice sheet edge to the north and east during that period, processes of ice melting were probably very intensive. Therefore, subglacial waters transported enormous masses of coarse mineral substances to the adjacent sea basin. According to observations [7, 9, 10], almost all sandy–coarse-clastic products delivered to the ice-contact basin by subglacial meltwater settle over a distance of some hundreds of meters from the ice edge. During the slow ice retreat (less than 100–200 m/yr), thick fans of fluvioglacial material are formed with an avalanche sedimentation rate (up to 5–9 and even 13 m/yr) at the glacier margin [9]. Hence, submarine ice-contact fans of the Kolguev and Goose zones (width 30–40 km, average thickness of sands from 5–10 to 20–30 m) can be formed in a rather short time interval (probably not exceeding 100–200 yr). Since the silty–clayey component predominates in the matrix of upper Weichselian moraines, the formation of sand-rich fans was accompanied by the influx of immense volumes of fine glacial material to the sea basin. As a result, rather unfavorable ecological conditions developed in the basin over a distance of many kilometers from the glacier front.

Thus, submarine ice-contact fans actively formed in the southeastern Barents Sea shelf at the initial stage of the upper Weichselian glaciomarine sedimentation. Based on the wide development of such sediments, their distinct lithological and seismoacoustic features, and specific features of the overlying glaciosuspensites, we can distinguish two independent subcomplexes of SSU II: the lower subcomplex of fluvioglacial deposits (SSU IIb) and the upper subcomplex of glaciomarine brown clay (SSU IIa). The data obtained are of great importance for understanding the general succession of sedimentation cycles on glacial shelves.

ACKNOWLEDGMENTS

We are grateful to the directorate of AMIGE (Murmansk) for seismoacoustic materials and data on marine geotechnical drilling placed at our disposal.

REFERENCES

1. Yu. A. Lavrushin, V. P. Vasil'ev, and O. G. Epshtein, in *Geological–Paleoecological Environments of the Quaternary* (Moscow, 1991), pp. 68–86 [in Russian].
2. O. G. Epshtein and Yu. A. Lavrushin, Dokl. Earth Sci. **393**, 1227 (2003) [Dokl. Akad. Nauk **393**, 521 (2003)].
3. O. G. Epshtein, B. F. Romanyuk, and V. N. Gataullin, *Byull. Komis. Izuch. Chetvertich. Perioda,* No. 63, 126 (1999).
4. G. J. Fife, Boreas **19**, 147 (1990).
5. L. E. Hunter, R. D. Powell, and G. W. Smith, Geol. Soc. Am. Bull. **108**, 1022 (1996).
6. J. Lundqvist, Sver. Geol. Unders., Ser. C, No. 767, Arsbok 73, No. 8 (1979).
7. N. E. Mackiewicz, R. D. Powell, P. R. Carlson, and B. F. Molnia, Mar. Geol. **57**, 113 (1984).
8. L. Polyak, S. Lehman, V. Gataullin, and A. J. T. Jull, Geology **23**, 567 (1995).
9. R. D. Powell and B. F. Molnia, Mar. Geol. **85**, 359 (1989).
10. J. P. M. Syvitski, Mar. Geol. **85**, 301 (1989).