



Pleistocene marine deposits in the coastal areas of Kola Peninsula (Russia)

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ABSTRACT

On the basis of field data, datings from both electron spin resonance – and optically stimulated luminescence, and micro- and macrofauna, in addition to presence of diatoms, three Late Pleistocene marine units have been identified in the coastal areas of the Kola Peninsula. The stratigraphically lowest sequence is correlated to the Ponoï Beds and the Boreal transgression, attributed to the marine isotope stages (MIS) 5e to 5d in the White Sea depression and to MIS 5e to 5c in the Barents Sea. Thermophilic fauna and diatoms indicate normal water salinity and a water temperature above zero. The second marine unit, referred as the Strel'na Beds, can be correlated with the Early Weichselian transgression, termed the Belomorian transgression. With low water salinity and a water temperature similar or colder than the present times, Belomorian transgressions are reliably detected in the White Sea and are not clearly found in the Barents Sea. The results obtained from the sediments of the Ponoï and Strel'na Beds indicate a continuously existing marine reservoir from 130 to 80–70 ka ago (entire MIS 5) in the White Sea depression. The early Middle Weichselian Barents–Kara ice-sheet invasion and its recession might have caused the glacioeustatic Middle Weichselian (MIS 3) transgression, and the third Late Pleistocene marine sequence has been deposited in the regressing shallow cold sea with less saline waters. The results help in the understanding of the history of Late Quaternary ice sheets in North Eurasia and provide evidence for the debatable Early and Middle Weichselian marine events.

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1. Introduction

Initial studies of Pleistocene marine deposits in one of the natural exposures in the western part of the Terskii Coast of the White Sea (Fig. 1) were carried out in the period 1898–1900 (Rippas, 1899). Perspectives on the age and genesis of the Pleistocene marine deposits vary, associated with the analytical nature of the scientific studies and the state of the general concepts regarding the sequence of geological events in the Pleistocene. Though these deposits were minutely investigated in the 1930s–1940s, they are of great interest for researchers even now.

The main questions posed today in a regional context are the stratigraphical position of the marine units and the chronology of Pleistocene interglacial–glacial developments. The stratigraphic subdivision of the Pleistocene deposits on the Kola Peninsula is still debated. On the basis of on-field geological data (Lavrova, 1932, 1960) and evidence related to diatoms (Cheremisinova, 1962), pollen, and molluscs (Armand and Lebedeva, 1966; Lavrova, 1960), some researchers proposed that the marine sediments formed during the Last Interglacial (100–70 ka) as a result of two independent consecutively developed marine transgressions – Boreal

and Belomorian. On the basis of the same date and the synthesized concept of interglacial–glacial history, other workers (Apukhtin, 1957; Yakovlev, 1956) argued that the marine deposits associated with the three interglacial transgressions were sandwiched between the Dnieper, or Moscowian, and the Late Valdaian tills (Saalian and Late Weichselian in Western Europe). Later, the Boreal and Belomorian marine transgressions were correlated with two individual (i) Interglacial–Miculinian (Eemian in Western Europe) Interglacial (100–70 ka), with warm-water Boreal transgression, and (ii) Middle Valdaian (Middle Weichselian) Interglacial (50–25 ka), with cold-water Belomorian transgression (Nikonov, 1964, 1966).

In the 1970s–1980s, after Gudina and Yevzerov (1973) expressed doubts about the existence of the Boreal transgression deposits (100–70 ka) within the Kola Peninsula and, on the basis of primary radiocarbon dates, all the marine interglacial sequences were attributed to the Middle Valdaian Interglacial (50–25 ka). Gudina and Yevzerov (1973) asserted that the Ponoï marine transgression occurred in the first half of the Interglacial, accumulating the Ponoï Bed deposits with warm-water fauna. In the second half of the Middle Valdaian Interglacial, the cold-water Strel'nian marine transgression, associated with the Strel'na Bed marine deposits, occurred. Later, U-series ages (86 ± 3.9 ka, 97 ± 4 ka, and 114 ± 4 ka) of the marine molluscan shells enclosed in the Ponoï Beds were determined (Arslanov et al., 1981). Because of these new

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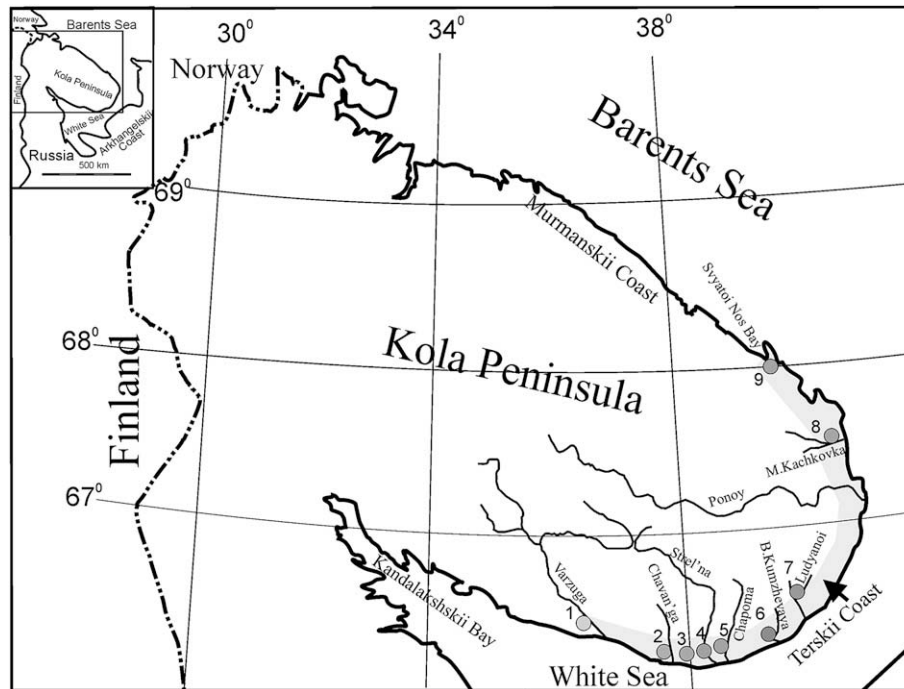


Fig. 1. Key map of the Kola Peninsula. Locations of the section described in the text are marked by numeral: (1) Varzuga, (2) Chavan'ga, (3) Kamenka, (4) Strel'na, (5) Chapoma, (6) Bol'shaya Kumzhevaya, (7) Ludyanoi, (8) Malaya Kachkovka, (9) Svyatoi Nos Bay.

data, the researchers concluded that there was no Ponoï transgression; Ponoï Bed deposits were the consequence of Boreal transgression; Strel'na Beds were attributed to the subsequent relatively colder Strel'ninian transgression.

After reexamination of the section in the southern part of the Kola Peninsula (Section 1 of Fig. 1), Yevzerov and Kolka (1993) suggested that the Belomorian marine transgression was erroneously discerned in the Kola region. This long-debated stratigraphic problem in the sedimentary basin of the Kola Peninsula is discussed in the present article. In a wider context, a synthetic approach to the question of the Late Pleistocene stratigraphy in northwestern Russia is provided by Larsen et al. (2006).

In the late 1990s and the early 2000s, new geological and geochronological data were published (e.g., Mangerud et al., 1996; Mangerud et al., 1999; Helmens et al., 2000; Mangerud et al., 2002; Korsakova et al., 2004; Mangerud et al., 2004; Molodkov and Yevzerov, 2004; Svendsen et al., 2004; Lambeck et al., 2006; Grøsfjeld et al., 2006; Larsen et al., 2006), which were obtained from Pleistocene deposits located in northern Eurasia, particularly in the Kola area. The Late Quaternary history of northern Eurasia was presented by Mangerud et al. (2004) and Svendsen et al. (2004). Researchers noted that the Late Pleistocene interglacial–glacial events on the Kola Peninsula were more controversial because this area was covered several times by ice sheets, with the center of each sheet situated over the Scandinavian and the Barents and Kara sea shelves. Moreover, coastal Kola was affected by several marine inundations during the Late Pleistocene. The space and time position of marine deposits associated with the Interglacial Boreal transgression of the Ponoï Beds in the coastal Kola Peninsula were relatively coordinated in northern Europe. The Early Weichselian marine deposits associated with the Strel'na Beds in the southeastern coastal areas of Kola were discussed by many researchers. According to geological data and optically stimulated luminescence (OSL)-ages, Mangerud et al. (2004) and Svendsen et al. (2004) concluded that the Early Weichselian glacialacustrine silt, clay, and fine sand superimposed the Eemian marine sediments; the fine-

grained glacialacustrine units were deposited in the White Sea Basin 90–80 ka before, and this basin was a part of a huge ice-dammed lake. On the basis of geological and paleontological data, in addition to OSL- and ESR-ages, other researchers (Molodkov and Bolikhovskaya, 2002; Korsakova et al., 2004; Molodkov and Yevzerov, 2004), suggested that the same deposits overlaying the Eemian marine sediments in the southern and southeastern regions of coastal Kola could be referred back to the marine transgression, which was longer than the Eemian Boreal transgression in western Europe. The most debatable region comprised the Middle Weichselian marine sediments unit because of the scarcity of data.

The present study deals with the main sedimentological, paleontological, and available geochronological characteristics of the Pleistocene coastal deposits in the Kola Peninsula. The purpose of this study was to reconstruct the temporal and spatial position of the late Pleistocene marine events and examine the interglacial–glacial history of the Kola region, to elucidate the true stratigraphic position of the marine units, and to reconstruct the conditions under which the marine deposits were formed in the Kola region, for a suitable understanding of the history of the Late Quaternary ice sheets of North Eurasia and for providing evidence for the highly debated Early and Middle Weichselian marine events.

2. Materials and methods

Research was carried out in the Terskii Coast of the White Sea (Fig. 1) and in the eastern part of the Barents Sea coast (Fig. 1), where the Middle and Late Pleistocene sediments, including the interglacial marine deposits, are exposed along the steep slopes of the river valleys and sea cliffs. Nine geological sections were studied (Fig. 1).

The fieldwork was carried out for 3–5 weeks during each summer from 2001 to 2005. The sequences investigated were located from existing literature. The sections located in the southern Kola Peninsula (Fig. 1) were reached by an all-terrain vehicle, Section 9 in The Barents Sea coast (Fig. 1), aboard the vessel

“Klavdiya Elanckaya” and fishing boat “Anchous”; the data from Section 8 (Fig. 1) include published material (Gudina and Yevzerov, 1973; Arslanov et al., 1981) and that from the archives of the Geological Institute of Kola Science Center, RAS. To obtain the data, traditional geological methods used in field research were applied: mainly sampling and structural, sedimentological, and geological investigations of the deposits exposed in the coastal and river sections. Sections were sketched in the field and logged with a vertical resolution of 1:50 or 1:100. Sediments were visually classified into the following based on their sizes, following a decimal scale:

- (i) boulders: measuring more than 100 mm,
- (ii) pebbles: 10–100 mm,
- (iii) gravels: 1–10 mm,
- (iv) sands: <1 mm,
- (v) clays: <0.01 mm.

The texture of marine deposits is the evidence of transgressive or regressive sequences. The regressive part of the sequence is correlated with the series of fine-grained sediments (clay, loam, and sandy-loam) in the bottom, overlaid by coarse-grained sediments (sand, sand with gravel, pebbles, and boulders). A transgressive sequence is correlated with the reverse series of sediments.

The chronostratigraphy of the Late Pleistocene marine records was based on electron spin resonance (ESR) and OSL. Molodkov at the Research Laboratory for Quaternary Geochronology of the Institute of Geology, Tallinn University of Technology, carried out the ESR/OSL dating on samples from the Kola Peninsula. The dating technique and analytical procedure have been described by Molodkov (Molodkov and Yevzerov, 2004; Molodkov et al., 1998). Several dates for the Kola Peninsula were obtained earlier by using the uranium–thorium (U–Th) method. Arslanov et al. (1981) described the U–Th technique and the results. Age estimates are listed in Table 1 and plotted in Fig. 2.

To explain the paleoenvironmental records from marine deposits, the diatomic data from reports by Cheremisinova (1962), Kagan (Samsonova) (Grave et al., 1969), and Poretsky (Lavrova, 1960), the foraminiferal data from the study of Gudina (Gudina and Yevzerov, 1973), and macrofauna data from the publication of Lavrova (1960) and Strelkov (Strelkov et al., 1976) were considered, in association with the field identification of species conducted by the current authors. The mollusc and cirriped species found in the examined sections are listed in Table 2. Table 3 provides the summarized list of the diatom taxa, and Table 4 lists the foraminifera.

The geochronology of the unconsolidated cover formation in the Kola region encompasses the Middle Pleistocene Moskovian Glaciation, the Late Pleistocene Miculinian Interglacial, the Late Pleistocene Valdaian Glaciation, and the Holocene. For the first three periods, the western European terms Saalian, Eemian, and Weichselian are used, which correlate with MIS 6, MIS 5e (130–117 ka), and MIS 5d – MIS 2 (117–10 ka) respectively. The Weichselian is traditionally subdivided into the Early Weichselian (MIS 5d–a; 117–75 ka), the Middle Weichselian (MIS 4–3; 75–25 ka), and the Late Weichselian (MIS 2; 25–10 ka).

3. Results

According to the geological and geochronological data presented in this study and those available from literature (Gudina and Yevzerov, 1973; Arslanov et al., 1981; Korsakova et al., 2004; Molodkov and Yevzerov, 2004), the coastal deposits of the Kola Peninsula present three diverse Late Pleistocene marine events, which generally are correlated with the Eemian, the Early

Weichselian, and the Middle Weichselian. Glacial erratics are also present here in the unconsolidated cover.

3.1. The lowest marine sequence – the Ponoï Beds

According to the sequences examined in the coastal areas of the Kola Peninsula, the oldest Pleistocene marine unit is present in the lower parts of the sections along the valleys of the Varzuga, Strel'na, Chapoma, and Malaya Kachkovka, in addition to the cliff in the head of the Svyatoi Nos Bay of the Barents Sea (Fig. 1). The sketched sequences are shown in Fig. 3. Arranged from the bottom to the top, these marine sediments (stratigraphic unit (U) 3 in Fig. 3) are represented by clay or compact loams, sandy loams, and fine-grained sands. As mentioned above, such types of textured series correlate with regressive marine deposits.

The bottom of the lower marine unit is exposed at an altitude of 5–8 m a.s.l. in the lower parts of the examined sections along the Chapoma valley (Section 5, Figs. 1 and 3) and at 126 m a.s.l. along the Malaya Kachkovka valley (Section 8, Figs. 1 and 3). In Sections 5 and 8, the marine sediments of the Ponoï Beds (U3m in Fig. 3) unconformably overlay the Saalian till (U2g in Fig. 3). In the head of the Svyatoi Nos Bay of the Barents Sea (Section 9, Figs. 1 and 3), these sediments overlay the Saalian Late Glacial laminated clay (U2gm in Fig. 3) at an altitude of 9–14 m a.s.l. In other sections examined in the Kola Peninsula, namely in the Sections 1 and 4 (Figs. 1 and 3), the bottom portion of the Ponoï Beds is not exposed.

The present-day position of the uppermost Ponoï Bed surface varies from 10 to 35 m a.s.l., in the sections situated in the south and southeastern parts of the Kola Peninsula, to 134 m a.s.l., in the eastern part. In all the sections known, except for the Malaya Kachkovka section (Section 8, Figs. 1 and 3) located in the Eastern Kola Peninsula, the Ponoï Beds are overlain by the marine unit, which is correlated with the Early Weichselian (U4m in Fig. 3), according to the current geochronological data available (Table 1; Figs. 2 and 3). In the westernmost Varzuga section (Section 1, Fig. 1), the lower marine unit occupies a peculiar position: it is probably deformed and occurs as both a bedding in situ and an erratic mass directly beneath the Late Weichselian till (U7g in Fig. 3).

The Ponoï Beds are characterized by abundant fragments and intact molluscan shells. Lavrova (1960) and Strelkov et al., 1976 recognized some tens of mollusc species, characteristic of the Ponoï Beds. Among all the molluscs found, boreal and arcto-boreal species predominate (Table 2). Of all the boreal species, the species not currently inhabiting the White Sea, such as *Dentalium entalis* L., *Cardium elegantulum* Beck., *Panopaea norvegica* Spengl., and *Mytilus edulis* L. (indicative of warm environmental conditions), are special, deserving attention. These species are present today only in the nonfreezing Barents Sea. Nearer to the uppermost Ponoï Beds, the remnants of the boreal molluscs, which are present everywhere in the lower sequences, disappear, and more cold-resisting species become dominant (Strelkov et al., 1976).

Some foraminifera and ostracoda species have been identified in the deposits of the lower marine sequence by Gudina (Gudina and Yevzerov, 1973). The recorded foraminifera and ostracods are listed in Table 3. Thermophilic and cold-resisting species (Table 3) dominate the assemblage. Cryophilic species (Table 3) are also present here. Generally, the microfaunistic assemblage is composed of species that live today in the arctic and boreal seas. It indicates both a water salinity that is nearly normal and a water temperature above zero, i.e. higher than the temperature of the White Sea today.

Cheremisinova (1962) has identified about 100 diatomic species (Table 4) in the Ponoï Bed deposits, with many of these being attributed to the Boreal marine transgression. For instance, of the 100 species of diatoms present in the deposits of the lower marine unit in the Chapoma section, 51 species are marine, 15 reside in brackish water, 6 – in fresh brackish-water, 26 – fresh-water

Table 1
Summary of geochronology dates obtained for Pleistocene marine sediments from sections in the Kola Peninsula.

No	Section location	Section coordinates	Sampling site altitude, m a.s.l.	Dating method	Age, ka	References
1	Varzuga River valley	N66°23'49" E37°13'53"	26.0	ESR	103.0 ± 4.2	Molodkov and Yevzerov, 2004
2	Varzuga River valley	N66°23'49" E37°13'53"	26.0	OSL	104.0 ± 8.	Molodkov and Yevzerov, 2004
3	Chavan'ga River valley	N66°09'02" E37°46'55"	33.0	OSL	63.6 ± 8.0	Korsakova et al., 2004
4	Chavan'ga River valley	N66°09'02" E37°46'55"	28.5	ESR	99.0 ± 7.6	Korsakova et al., 2004
5	Kamenka River valley	N66°05'41" E38°17'10"	36.5	ESR	58.7 ± 4.4	Korsakova et al., 2004
6	Strel'na River valley	N66°05'54" E38°31'37"	59.0	OSL	85.6 ± 9.3	Korsakova et al., 2004
7	Strel'na River valley	N66°05'54" E38°31'37"	39.5	ESR	90.4 ± 6.7	Korsakova et al., 2004
8	Strel'na River valley	N66°05'54" E38°31'37"	35.5	OSL	101.9 ± 12.2	Korsakova et al., 2004
9	Strel'na River valley	N66°05'54" E38°31'37"	33.5	ESR	111.5 ± 12.4	Korsakova et al., 2004
10	Chapoma River valley	c.N66.0° E38.9°	c. 23.0	U-Th	85.5 ± 3.2 86.0 ± 3.9	Arslanov et al., 1981
11	Chapoma River valley	N66°06'47" E38°50'39"	9.0	ESR	128.7 ± 7.5	Molodkov and Bolikhovskaya, 2002
12	Bol'shaya Kuzmzhevaya River valley	N66°13'39" E39°40'32"	22.5	OSL	44.4 ± 3.2	Korsakova et al., 2004
13	Ludyanoi Creek valley	N66°19'34" E39°56'47"	51.5	OSL	80.5 ± 7.0	Korsakova et al., 2004
14	Ludyanoi Creek valley	N66°19'34" E39°56'47"	47.5	ESR	85.5 ± 6.6	Korsakova et al., 2004
15	Malaya Kachkovka valley	c. N67.4° E40.9°	c. 131.0	U-Th	102.0 ± 4.0 114.0 ± 4.0	Arslanov et al., 1981
16	Svyatoi Nos Bay	N 68°01' E39°52'	c. 13.0–11.0	U-Th	97.0 ± 4.0	Arslanov et al., 1981
17	Svyatoi Nos Bay	N68°01'47.6" E39°52'10.1"	29.0	OSL	64.3 ± 6.0	determined by Molodkov at the Research Laboratory for Quaternary Geochronology of Institute of Geology of Tallinn University of Technology
18	Svyatoi Nos Bay	N68°01'47.6" E09°52'10.1"	28.4	OSL	74.1 ± 6.9	the same
19	Svyatoi Nos Bay	N68°01'47.6" E39°52'10.1"	25.9	OSL	61.7 ± 5.7	the same
20	Svyatoi Nos Bay	N68°01'47.6" E39°52'10.1"	22.8	OSL	138.5 ± 12.9 (?)	the same
21	Svyatoi Nos Bay	N68°01'57.9" E39°52'26.9"	22.7–23.0	ESR	94.0 ± 7.6	the same
22	Svyatoi Nos Bay	N68°01'58.0" E39°52'25.0"	11.75	ESR	89.0 ± 5.2	the same
23	Svyatoi Nos Bay	N68°01'58.0" E39°52'25.0"	11.0–11.2	ESR	62.7 ± 2.8 (?)	the same
24	Svyatoi Nos Bay	N68°01'59.2" E39°52'22.9"	9.0–9.2	OSL	109.9 ± 10.9	the same

species, with the boreal species, such as *Synedra crystallina* (Ag.) Ktz., *Diploneis bombus* (Ehr.) Cl., *Navicula lyra* Ehr., *N. lyra* var. *subelliptica* Cl., *Amphora robusta* Greg., dominating.

According to the current geochronological data available (Table 1, Figs. 2 and 3), the Ponoï Beds formed in the period from 130 to 120 ka to 105–100 ka (MIS 5e–d) in a rather warm sea in the White Sea depression. The lower marine sequence in the Barents Sea coast is somewhat younger. As follows from Fig. 2 (Section 9) and Fig. 3, the available ESR- and U–Th-ages (89.0 ± 5.2, 97.0 ± 4.0) indicate the presence of a sea reservoir, earlier by at least 90 ka (Fig. 2).

3.2. The middle marine sequence – the Strel'na Beds

In all the sections studied, the Ponoï Beds are overlain by the deposits attributed to another marine unit referred to in literature as the Strel'na Beds (Gudina and Yevzerov, 1973). The Strel'na Beds are represented by sands, sandy loams, loams, and clays (Sections 1, 2, 4, 5, 7, and 9, Figs. 1 and 4), containing fragments and rarely unbroken molluscan shells and other fossils. The Strel'na Bed sediments (U4m in Fig. 4) are exposed in parts as compact loams with abundant molluscan shells under fluvio-glacial sands (U5fg in Fig. 4) near the water level of the Chavan'ga River (Section 2, Figs. 1 and 4) at altitudes of 29 m a.s.l. or lower. The Strel'na Beds (loams and sandy loams, with molluscan shells, pebbles, boulders; and fine- to medium-grained sands, with lenses of coarse-grained varieties), sandwiched between fluvio-glacial (U7fg in Fig. 4) and probably glacio-marine (U4gm? In Fig. 4) sediments, are observed at 42–52 m a.s.l. near the mouth of the Ludyanoi Creek (Section 7, Figs. 1 and 4). Similar sediments are also exposed in the sections along the Varzuga and Chapoma valleys (Sections 1 and 5, Figs. 1 and 4), where they overlie the eroded surfaces of the Ponoï Beds. In the section in the Barents Sea coast of the Kola Peninsula, the Strel'na Beds (loams and clays, with lenses of inequigranular sands, rare gravels, pebbles, and boulders) occur at altitudes of 15–35 m a.s.l. on the Ponoï Beds, overlapped by fluvio-glacial sands (Section

9, Figs. 1 and 4). This marine sequence is generally represented by the sediments of shallow littoral and sublittoral facies.

The Strel'na Beds (U4m in Fig. 4) are characterized by a more complicated structure than the Ponoï Beds (U3m in Fig. 3). The sequence is composed of both transgressive and regressive marine deposits in the sections located in the southern part of coastal Kola. As mentioned above, the transgressive part of the sequence is correlated with the series of coarse-grained sediments (sand, sand with gravel, pebbles, and boulders) in the bottom, overlaid by fine-grained clay, loam, or sandy-loam; the regressive part is correlated with the reverse series of sediments. In the Section 1, at an altitude of 18.5–2.5 m a.s.l., in the Section 4, at 36–49 m a.s.l., in the Section 5, at 11–13 m a.s.l., in the Section 7, at 46–51 m a.s.l. (Fig. 4) clay or loam deposits are underlain by sand or sandy-loam sediments. These are the transgression parts of the sequence. In addition, the clay or loam deposits are also overlain by the sandy or sandy-loam sediment, which is correlated with regression. In the Sections 1, 4, 5, and 9 (Fig. 4), the thicknesses of the lower sandy parts are considerably thinner than the upper portions.

The most complete section of the Strel'na Beds is exposed and observed in the right bank of the eponymous river valley at altitudes of 35.5–59.5 m a.s.l., where they occur with local unconformity on the Ponoï Beds (Section 4, Figs. 2 and 4). Sin-layer loose sands of 0.5 m thickness, with small boulders and pebbles in the bottom, are bedded on the compact sands of the Ponoï Beds. These sediments are overlain by loams, varied sands, and sandy loams (Section 4, Fig. 4). The lower thin sandy or sandy-loam parts and the upper thick parts of the Strel'na Beds contain fragments and single intact valves of molluscan shells (Table 2). Over 15 foraminifera species (Table 4), have been recognized in these sediments (Gudina and Yevzerov, 1973). Diatoms are represented by marine, fresh brackish-water and fresh-water species, such as *Isthmia nervosa* Ktz., *Stephanopyxis turris* Grev. et Arn., *Hyalodiscus scoticus* (Ktz.) Grun., *Coscinodiscus kützingii* A. S., *Melosira sulcata* (Ehr.) Ktz., *Navicula hungarica* Grun., *Synedra* sp., and *Pinnularia* sp. (Table 3), which occur in situ in the lower and upper parts of the Strel'na

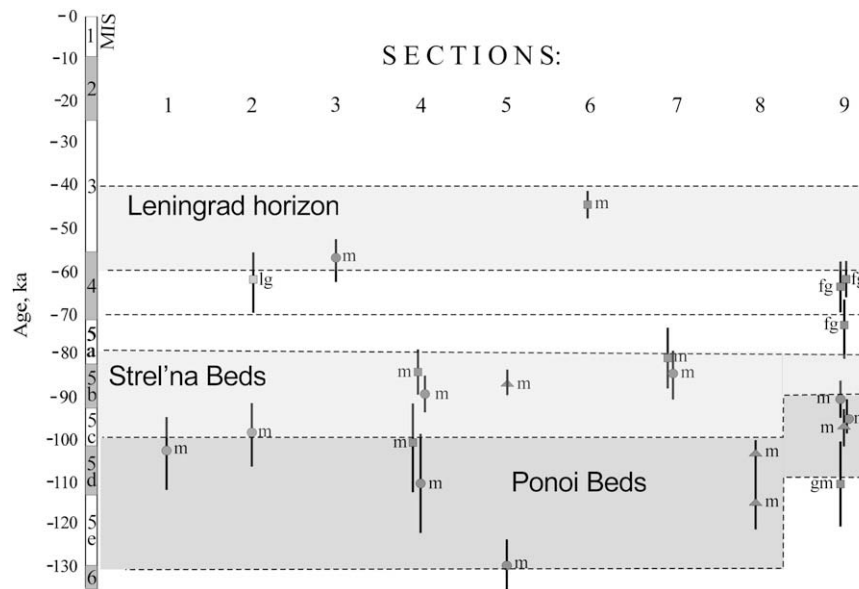


Fig. 2. Comparison OSL dates (squares), ESR dates (circles) and U–Th dates (triangles) from Kola Peninsula with MIS. The dates are plotted from Varzuga River valley (no. 1) to Svyatoi Nos Bay (no. 9) as the sections locations in the White Sea coast shown in Fig. 1. Dated material lettered by indices is glaciomarine (gm), glaciolacustrine (lg) and glaciofluvial (fg) sands, sandy loams, loams and shells. See Table 1 for technical details on dates.

Beds. The middle, loamy part of the Strel'na Bed sequence contains a small amount of molluscan shells of the same, mainly arctic, arcto-boreal, and mainly boreal species, in addition to other paleontological remnants. Dominating among diatoms are the marine species, although their quantities are termed as “scarce” and “singular”, except for *Melosira sulcata* (Ehr) Ktz. that has an index of “ordinary” (Grave et al., 1969).

In all the sites, the sediments contain fragments or single intact valves of molluscan shells, foraminifera, and diatoms. The faunal assemblage and ratio of quantity of the diatom species indicate that the Strel'na Bed sediments were deposited in shallow water with low (less than 30‰) salinity and that the temperature parameters were similar or a bit colder than those of the present days (Strelkov et al., 1976). The geochronological data (Table 1, Figs. 2 and 4) show that the middle marine sequence, referred to as the Strel'na Beds, corresponds to the Early Weichselian (MIS 5c–a).

3.3. The upper Late Pleistocene marine beds

The youngest, stratigraphically higher marine unit (U6m in Fig. 5) has been studied in sections in the Kamenka and Bol'shaya Kumzhevaya valleys (Sections 3 and 6, Figs. 1 and 5). It is composed of loams, sandy loams, and sands occurring on glacial (U5g in Fig. 5) and glacial-marine (U5gm in Fig. 5) deposits and is overlain by till (U7g in Fig. 5) or glacial-marine (U7gm in Fig. 5) sediments.

The most informative section is above the Kamenka valley (Section 3, Figs. 1 and 5). This marine sequence is composed of a regressive sedimentary series, i.e. loams with valves of molluscan shells are overlain by sandy loams and sands, with gravel, pebbles, and rare fragments of shells. Fragments and valves from the shells of arcto-boreal and arctic molluscan species (Table 2), such as *Chlamys islandicus* Müll, *Astarte crenata* Gray, *A. crenata* var. *crebricostata* Andr. et Forb., *Mya* sp. (*truncata*), and *Pecten islandicus*, have been found here. Among diatoms, species such as *Isthmia nervosa* Ktz., *Isthmia* sp., *Rhabdonema* sp., *Melosira sulcata* (Her.) Ktz. have been identified. No thermophilic diatom species have been found here (Grave et al., 1969). These scarce paleontological data suggest that the sediments composing this marine unit were

formed under the conditions of a littoral and sublittoral of a rather cold sea reservoir and that the environmental conditions were more severe than at the present time.

According to the geochronological data, the upper marine beds were formed 60–40 thousand years ago, which corresponds to the early MIS 3 (Table 1, Fig. 2). In the regional stratigraphic classification, the deposits of such an age are referred to as the so-called Leningrad horizon.

4. Discussion

Present data and those from numerous studies of adjacent areas (e.g., Grøsfjeld et al., 2006; Helmens et al., 2000; Lambeck et al., 2006; Larsen et al., 2006; Lunkka et al., 2004; Mangerud et al., 1996; Mangerud et al., 1999; Mangerud et al., 2002; Mangerud et al., 2004; Svendsen et al., 2004) show that marine deposits were accumulated on the Kola Peninsula during the Pleistocene due to the combined effects of glacioeustatic, glacioisostatic, and tectonic processes. Comprehensive and detailed work carried out in the Arkhangelskii Coast of the White Sea by Grøsfjeld et al. (2006) suggests that, in the Interglacial time, after a short period of glacioeustatic increase in sea level, the glacioisostatic emergence became dominant, causing marine regression. In contrast to the Arkhangelsk area, the Kola Peninsula is a part of the Fennoscandian Shield, which experienced tectonic uplift from the Oligocene to the Holocene, reflected as a local sea-level decrease in the coastal areas. The Ponoï Beds is stratigraphically the lowest, most ancient Pleistocene marine sequence representing the deposits in this region, which are the deepest of all the known deposits in the Kola region, containing the most abundant and thermophilic faunistic and diatom complexes that indicate stronger advection of warm Atlantic water at the time of the early Eemian global sea-level increase. Marine sediments with interglacial fauna that accumulated during the Eemian–Boreal transgression are also found up to 100 m a.s.l. on the Kola Peninsula and 70 m in the Arkhangelsk region (Svendsen et al., 2004).

The Ponoï Beds are composed only of a regressive series of marine sediments. The absence of transgressive sedimentology series in the known sections on the Kola Peninsula suggests the

Table 2
The occurrence of molluscs and cirriped taxa at the different sites of the Kola Peninsula coastal areas (× indicates presence for the section, * indicates the species not presented in the White Sea today). Section locations are shown on the map in Fig. 1.

Macrofauna species names	Sections								
	1	2	3	4	5	6	7	8	9
Boreal and mainly boreal species									
<i>Actaea (Tecture) virginea</i> (Müll.)								×	
<i>Anomia ephippium</i> L.	×								
<i>Anomia striata</i> Broc.								×	
<i>Astarte borealis</i> Chemn. var. <i>arctica</i> Gray				×				×	
<i>Balanus hameri</i> Asc.	×	×			×				×
<i>Buccinum undatum</i> L.								×	
<i>Cardium echinatum</i> L.									
<i>Cardium elegantulum</i> Beck.*		×			×				
<i>Cardium fasciatum</i> Mont.	×	×						×	×
<i>Cyprina islandica</i> L.	×	×			×			×	×
<i>Dentalium entalis</i> L.*	×	×			×				×
<i>Hydrobia ulvae</i> Pennant.								×	
<i>Lacuna divaricata</i> Fabr.								×	×
<i>Lucina borealis</i> L.									×
<i>Mactra elliptica</i> Brown.							×	×	×
<i>Modiolus modiolus</i> (L.)	×							×	×
<i>Mytilus edulis</i> L.*	×								
<i>Neptunea despecta</i> (L.)	×				×			×	
<i>Panopaea norvegica</i> Spengl.*	×			×	×				×
Arcto-boreal species									
<i>Acribia (Amauropsis) islandica</i> (Gmel.)	×							×	
<i>Anomia squamula</i> L.					×		×	×	×
<i>Astarte elliptica</i> Brown.	×	×		×	×		×		×
<i>Balanus balanus</i> L.	×						×		
<i>Balanus crenatus</i> Brug.	×				×				
<i>Boreonatica clausa</i> (Brod. et Sow.)	×							×	×
<i>Boreotrophon truncatus</i> (Ström.)								×	
<i>Chlamus islandicus</i> (Müll.)	×	×	×	×	×		×	×	×
<i>Crenella decussata</i> (Mont.)									×
<i>Euspira pallida</i> (Brod. et Sow.)					×			×	×
<i>Hiatella arctica</i> (L.)	×	×			×		×	×	×
<i>Leda pernula</i> (Müll.)	×				×			×	×
<i>Leda minuta</i> (Müll.)					×				
<i>Lepeta coeca</i> (Müll.)	×								×
<i>Macoma calcarea</i> Gmel.	×				×				×
<i>Margarites cinereus</i> (Couth.)								×	
<i>Margarites groenlandicus</i> (Chemn.)	×							×	
<i>Mya truncata</i> L.	×		×	×	×		×	×	×
<i>Natika clausa</i> Brod. et Sow.									×
<i>Nucula tenuis</i> (Mont.)	×								×
<i>Pecten islandicus</i> Müll.			×		×				
<i>Puncturella noachina</i> (L.)					×			×	×
<i>Saxicava arctica</i> L.									×
<i>Vetulina undata</i> Brown.								×	
Arctic and mainly arctic species									
<i>Acmaea rubella</i> Fabr.								×	×
<i>Admete viridula</i> Fabr.	×				×				
<i>Astarte borealis</i> Chemn.	×			×	×		×	×	×
<i>Astarte crenata</i> (Gray)*	×	×	×		×		×	×	×
<i>Astarte crenata</i> (Gray) v. <i>crebricostata</i> Andr. et Forb.	×	×	×		×		×	×	×
<i>Astarte montagui</i> (Dillw.)	×				×		×	×	×
<i>Astarte montagui</i> Dillw. v. <i>striata</i> Leach	×								×
<i>Bathyarca glacialis</i> Gray.									×
<i>Cardium ciliatum</i> Fabr.	×							×	
<i>Hemithris psittacea</i> (Gmelin)	×				×				
<i>Lora scalaris</i> (Möll.)									×
<i>Propeamussium groenlandicum</i> Sow.									×
<i>Serripes groenlandicus</i> (Chemn.)	×			×	×			×	×
<i>Trichotropis borealis</i> Brod. et Sow									×
<i>Yoldiella lenticula</i> (Möll.)									×

glacioeustatic nature of the Eemian Sea, caused by the Middle Pleistocene ice-sheet degradation, and if so confirmed, the transgression maximum occurs during the Late Glacial and earliest Interglacial. In the North-East Kola Peninsula, in the Barents Sea coast, sandy loams of the Ponoï Beds are underlain by Middle Pleistocene glacial-marine (laminated clay) deposits that have not been found in the White Sea coastal areas. In the White Sea

depression, the Eemian marine clays, loams, and sandy loams of the Ponoï Beds sharply overlay the Saalian till.

At present, the Ponoï Beds occupy the highest hypsometric position at 126–134 m a.s.l. in the eastern part of the Kola Peninsula (Section 8, Figs. 1 and 6). It can testify to a more active tectonic-block uplift of the eastern part of the Kola Peninsula. One should also consider the glacioisostatic origin of the hypsometric

Table 3

Diatoms from the Kola Peninsula Late Pleistocene marine units (× indicates presence, * indicates the species not presented in the White Sea today).

Marine and brackish-water diatoms	Ponoi beds	Strel'na beds	Leningrad Horizon
<i>Actinocyclus Ehrenbergii</i>	×	×	
<i>Actinoptychus undilatus</i>	×		
<i>Amphora robusta</i>	×		
<i>Bacterosira fragilis</i>	×	×	
<i>Biddulphia</i> sp.	×		
<i>Campylodiscus echeneis</i>	×	×	
<i>Centrales</i> (fragments)	×	×	×
<i>Chaetoceros</i> sp.	×	×	
<i>Cocconeis scutellum</i> Ehr.	×	×	
<i>Concinodiscus antiquus</i> Grun.	×		
<i>C. asteromphalus</i> var. <i>centralis</i> Ehr.	×	×	
<i>C. bathyomphalus</i> Cl.	×		
<i>C. curvatus</i> var. <i>minor</i>	×	×	
<i>C. granulatus</i> Crun.	×		
<i>C. Hauckii</i>	×		
<i>C. kützingii</i> A. S.	×	×	
<i>C. marginatus</i> Ehr.	×		
<i>C. oculus iridis</i> Ehr.	×		
<i>C. plicatus</i>	×	×	
<i>C. stellaris</i> var. <i>symbolophora</i> (Grun.) Jorg.	×		×
<i>C. sublineatus</i> Grun.	×		
<i>Diploneis bombus</i> Ehr.	×	×	
<i>D. bomboides</i>	×	×	
<i>D. interrupta</i>	×	×	
<i>D. subcincta</i> (A. S.) Cl.	×	×	
<i>Grammatophora angulosa</i> var. <i>islandica</i> (Ehr.) Grun.	×	×	
<i>G. arctica</i> Cl.	×	×	
<i>G. marina</i> (Lynob) Ktz.	×	×	
<i>Grunowiella gemmata</i> (Grun.) V. H.	×	×	×
<i>Hemiaulus elegans</i> (Helb.) Grun.	×	×	
<i>Hemiaulus</i> sp.	×	×	×
<i>Hyalodiscus scoticus</i> (Ktz.) Grun.	×	×	
<i>Isthmia nervosa</i> Ktz.	×	×	×
<i>Isthmia</i> sp.	×		×
<i>Melosira fausta</i> A. S.	×	×	
<i>M. sulcata</i> (Ehr.) Ktz.	×	×	×
<i>M. sulcata</i> var. <i>biseriata</i> Grun.	×	×	×
<i>M. sulcata</i> var. <i>crenulata</i> Grun.	×	×	×
<i>M. sulcata</i> var. <i>sibirica</i> Grun.	×	×	×
<i>M. ornata</i> Grun.	×		×
<i>Navicula distans</i> W. Sm.	×	×	
<i>N. forcipata</i> *	×		
<i>N. forcipata</i> var. <i>nummularia</i> *	×		
<i>N. lyra</i> Ehr.*	×	×	
<i>N. lyra</i> var. <i>elliptica</i> *	×		
<i>N. lyra</i> var. <i>Ehrenbergii</i> *	×		
<i>N. lyra</i> var. <i>subelliptica</i> Cl.*	×		
<i>N. monilifera</i> var. <i>heterosticha</i> Cl.	×		
<i>N. paepebralis</i> *	×		
<i>Nitzschia granulata</i>	×		
<i>Podosira delicatissima</i> Tscher.	×		
<i>Podosira</i> sp.	×		
<i>Pterotheca</i> sp.	×		×
<i>Pyxilla ascidiformis</i> Jouse	×		×
<i>Rhabdonema arcuatum</i> (Lyngb.) Ktz.	×	×	×
<i>Rhabdonema</i> sp.	×		
<i>Rhizosolenia</i> sp.	×	×	
<i>Silicoflagellata</i> (fragments, <i>Distephanus speculum</i> var. <i>septenarius</i>)	×		×
<i>Stephanopyxis Broschii</i> Grun.	×		×
<i>St. turris</i> (Grev. et Arnott.) Ralfs.	×	×	
<i>Stephanopyxis</i> sp.	×		×
<i>Synedra crystallina</i> (Ag.) Ktz	×		
<i>S. kamtschatica</i>	×	×	
<i>S. tabulata</i>	×		
<i>Thalassionema nitzschioides</i> Grun.	×		
<i>Thalassiosira excentrica</i>	×	×	
<i>Th. excentrica</i> var. <i>minor</i>	×	×	
<i>Th. gravida</i> Cl.	×	×	
<i>Trachyneis aspera</i> var. <i>intermedia</i> Grun.	×	×	
<i>Triceratium</i> sp.	×		
Fresh- brackish and fresh-water diatoms:			
<i>Cocconeis placentula</i> var. <i>euglipta</i>	×		
<i>Cymbella aspera</i>	×		
<i>Diploneis</i> sp.	×		×
<i>Epithemia zebra</i> var. <i>porcelus</i> (Ktz.) Grun.	×		×

(continued on next page)

Table 3 (continued)

Marine and brackish-water diatoms	Ponoi beds	Strel'na beds	Leningrad Horizon
<i>E. sorex</i>	×		
<i>Eunotia lunaris</i>	×		
<i>E. revolutai</i> A. Cl.	×		
<i>E. sudetica</i>	×		
<i>Fragilaria pinnata</i>	×		
<i>Hantzschia amphioxys</i> (Ehr.) Grun.	×		×
<i>Melosira distans</i> (Ehr.) Ktz.	×		
<i>M. distans</i> var. <i>lirata</i> (Ehr) Bethge	×		
<i>M. granulata</i> (Ehr.) Ralfs.	×		
<i>M. islandica</i> s. sp. <i>helvetica</i> O. Müll.	×		
<i>M. scabrosa</i> Oester	×		
<i>Navicula hungarica</i> Grun.	×	×	
Pennales (fragments)	×	×	×
<i>Pinnularia borealis</i> Ehr.	×		×
<i>P. fasciata</i>	×		
<i>P. lata</i> (Breb.) W. Sm.	×		×
<i>P. viridis</i> var. <i>subetica</i>	×		
<i>Pinnularia</i> sp.	×	×	×
<i>Synedra</i> sp.	×	×	

domination of the recent spatial position of the Eemian horizon in the eastern part of the Kola region. This origin is particularly true in case the Saalian ice sheet that expanded to the Kola Peninsula was centered above the shelves of the Kara or Barents Seas.

The position of the Ponoi Bed deposits in the westernmost, easily accessible Varzuga section (Section 1, Figs. 1, 3 and 6) caused the long-debated stratigraphic problem in the sedimentary basin of the Kola Peninsula. In her earlier studies of this section, Lavrova (1960) identified a lens of clay sediments, with abundant malacofauna, microfauna, and diatoms, which mainly had more cold-water species than the underlying marine clays (Ponoi Beds). In Lavrova's opinion, the lens is related to sandy deltaic sediments and underlies the Late Weichselian basal till. Lavrova correlated the sediments of the lens with a new (Belomorian) transgression phase, which progressed after a short-term regression of the Boreal sea and after erosion of the relevant sediments. Moreover, there was a suggestion that this debatable part of the Varzuga section contained the marine sediments of the Late Glacial (Gotiglacial) basin (Nikonov, 1966). The presence of the erratic mass removed from the north-eastern area of the Kola Peninsula in the Varzuga section of the Ponoi Beds was reported by Gudina and Yevzerov (1973), who considered these rocks to be similar to those exposed in the head of the Svyatoi Nos Bay, the Barents Sea (Fig. 1). Although neither erratic mass nor lens is exposed in the present-day section, covered now by many land-slides, some field evidences from earlier studies, such as erosional contact of clayey sediments containing molluscan shells with underlying sands correlated with the Strel'na Beds and occurrence of a till remnant along the contact as described by Molodkov and Yevzerov (2004), indicate that the probable cause of displacement here is the thrust-type dislocation caused by glaciers. These fossil-bearing sediments were most probably redeposited and thus might represent the underlying Ponoi Bed sediments.

The Strel'na Beds, the second Late Pleistocene marine unit reliably established on the coastal area of the Kola Peninsula, occurs in the known sections on the Eemian sediments of the Ponoi Beds, except for the Malaya Kachkovka section (Section 8, Figs. 1 and 3) located in the Eastern Kola Peninsula, which is Early Weichselian in age (MIS 5c–a). In the southern coastal Kola sections, the sands underlying the loams or clays in the sequences of Strel'na Beds, i.e. its transgression part, are thin in thickness, and the sands overlying them, i.e. the regression part, are thicker. It can testify to the rapid transgression and slow regression of the sea during the sedimentation. The bottom position of the Strel'na Beds indicates that, before the transgression, the shoreline was depressed at least

up to 10 m a.s.l. It is proved by the fact that the lowest position of the bottom of the Strel'na Beds in all the known sections has been identified at altitudes of 10 m a.s.l. (Section 5, Figs. 1, 4 and 6). The appearance of thin to thicker transgressive sediments in the sequence of the Strel'na Beds can be explained by local factors in the White Sea Basin. The limited isostatic emergence here was combined with the more rapid increase in sea level caused by eustatic variations. Early Weichselian marine inundation, up to levels of around 100 m a.s.l. (Möller et al., 1999), yield younger ages (96–70 ka) than the ages of the Boreal transgression (Svendsen et al., 2004) identified along the Kara Sea. It is unclear whether the sea also covered the coastal areas in the Barents region at that time. There is an opinion (Mangerud et al., 2004; Svendsen et al., 2004) that the Early Weichselian silt, clay, and fine sand overlying the Eemian marine deposits in the southern Kola Peninsula are glaci-lacustrine sediments formed in an ice-dammed lake facing the ice margins of the Eurasian ice sheet, although the exact ice-front position is not yet known. Others (Larsen et al., 2006) conclude that the Scandinavian- and Kara Sea-dominated ice sheets did not merge in the Early Weichselian and that no lake formed in the White Sea Basin. Moreover, it is believed that the ice-dammed Komi lake located in the East (on the Pechora Lowland) and the water reservoir in the White Sea basin had their outlets draining between the Kanin and Kola peninsulas into the Barents Sea until 75 ka before present.

According to the geological and paleontologic data presented above (Tables 2–4), the Strel'na Bed sediments, exposed along the river valleys in the coastal areas of the Kola Peninsula, were deposited in shallow sea water of low salinity under environmental conditions similar to the present or under a colder climate. Its accumulation in the coastal area of the Kola Peninsula was caused by a low-amplitude marine transgression, which started around 100–105 thousand years ago. In the White Sea depression, under the conditions of the cyclic climatic cooling that had begun, the brackish-water reservoir existed until the late Early Weichselian, i.e. not less than 80–70 ka (Fig. 2). After Lavrova (1932), the low-amplitude Early Weichselian (MIS 5c–a) transgression of relatively cold water is referred to as the Belomorian transgression. According to the scarce geochronological and geological data obtained in studies of the only section located on the Barents Sea coast, it is proposed that the marine basin existed at this location mainly during the Eemian, when the Ponoi Beds were formed, and partly in the Early Weichselian, when the Strel'na Beds were formed, i.e. earlier than 85–90 thousand years ago (Fig. 2). The Belomorian transgression could not be clearly detected here.

Table 4

List of foraminifera taxa from the Kola Peninsula Late Pleistocene marine units (× indicates presence).

Foraminifera taxa	Ponoi beds	Strel'na beds and Leningrad horizon
Termophilic (lusitanian and boreal-lusitanian) species		
<i>Amphicoryna scalaris forma compacta</i> Parr	×	
<i>Discorbis punctulatus</i> (d'Orb.)	×	
<i>Elphidium excavatum</i> (Terquem)	×	
<i>Fissurina latistoma</i> Seguenza	×	
<i>Gavelinopsis praegeri</i> (Heron-Allen et Earl.)	×	
<i>Globulina inaequalis</i> Reuss	×	
<i>Guttulina lactea</i> (Walker et Jakob)	×	
<i>Hyalinea balthica</i> (Schroeter)	×	×
<i>Lenticulina orbicularis</i> (d'Orb.)	×	
<i>Rosalina globularis</i> (d'Orb.)	×	
<i>Sigmomorphina undulosa</i> (Terquem)	×	
<i>Trifarina angulosa</i> (Williamson)	×	×
Cold-resisting (boreal and arcto-boreal) species		
<i>Alabaminoides mitis</i> (Gud.)	×	
<i>Asrtonion gallowayi</i> Loeb. et Tappan	×	×
<i>Bolivina pseudoplicata</i> Heron-Allen et Earl.	×	
<i>B. pseudopunctata</i> Höglund	×	
<i>Buccella frigida</i> (Cushm.)	×	×
<i>B. troitzkyi</i> Gud.	×	
<i>Bulimina aculeata</i> d'Orb.	×	
<i>Cassandra cf. norcrossi</i>		×
<i>Cassidulina laevigata</i> d'Orb.	×	
<i>Cibicides refulgens</i> Montfort		×
<i>C. rotundatus</i> Stshedrina	×	×
<i>Clobbulimina auriculata arctica</i> Höglund	×	
<i>Cribronion incertus</i> (Williamson)	×	×
<i>Discorbinella squamata</i> Phleger	×	
<i>Eggerella scarba</i> (Williamson)	×	
<i>Elphidiella tumida</i> Gud.	×	×
<i>Elphidium boreale</i> Nuzhdina	×	×
<i>E. margaritaceum</i> Cushm.	×	×
<i>Eponides wrightii</i> (Brady)	×	×
<i>Fissurina laevigata</i> Reuss	×	
<i>F. marginata</i> (Walker et Bovs)	×	×
<i>F. serrata</i> (Schlumberger)	×	
<i>Fursenkoina gracilis</i> Gud.	×	
<i>Globigerina quinqueloba</i> Natland	×	
<i>G. pachyderma</i> (Ehrenberg)	×	
<i>Globigerinita glutinata</i> (Egger.)	×	
<i>Islandiella islandica</i>		×
<i>Lagena apiopleura</i> Loeb. et Tapp.	×	×
<i>L. gracillima</i> (Seguenza)	×	
<i>L. semilineata</i> Wright	×	
<i>L. sulcata</i> Walker et Jacob	×	
<i>Melonis zaandamae</i> (Voorth)	×	×
<i>Nonionella auricula</i> Heron-Allen et Earl.	×	×
<i>Oolina globosa</i> (Walker et Jacob)	×	×
<i>O. hexagona</i> (Williamson)	×	
<i>O. melo</i> d'Orb.	×	×
<i>Pateoris hauerinoides</i> (Rhumbler)	×	
<i>Paromalina bilateralis</i> Loeb. et Tappan	×	×
<i>Protelphidium asterotuberculatum</i> (Voorth.)	×	×
<i>Pr. parvum</i> Gud.		×
<i>Pseudopolymorphina novangliae</i> (Cushm.)	×	
<i>Pullenia sphaeroides</i> (d'Orb.)	×	
<i>Pyrgo williamsoni</i> (Silvestri)	×	
<i>Quinqueloculina arctica</i> Cushm.	×	
<i>Q. oviformis</i> Gud.	×	
<i>Stainforthia loeblichii</i> Feyling-Hanssen	×	×
Cryophilic (arctic and boreal-arctic) species		
<i>Buccella acutata</i>		×
<i>B. hannai arctica</i> Voloshinova	×	×
<i>B. inusitata</i> Andersen	×	
<i>Cassandra inflata</i> (Gud.)	×	×
<i>C. teretis</i> (Tapp.)	×	×
<i>Cassidulina subacuta</i> (Gud.)	×	×
<i>Clobulina glacialis</i> Cushm. et Ozawa	×	×
<i>Cribroelphidium goesi</i> (Stshedr.)	×	×
<i>Cr. granatum</i> (Gud.)	×	×
<i>Cribronion obscurus</i> Gud.		×
<i>Dentalina baggi</i> Galloway et Wissler	×	×
<i>D. flobisherensis</i> Loeb. et Tapp.	×	×
<i>D. ittai</i> Loeb. et Tapp.	×	

(continued on next page)

Table 4 (continued)

Foramifera taxa	Ponoi beds	Strel'na beds and Leningrad horizon
<i>Elphidiella arctica</i> (Parker et Jones)	×	×
<i>Globigerina pachyderma</i> (Ehrenberg)		
<i>Islandiella islandica</i> (Norv.)	×	×
<i>Nonionellina labradorica</i> (Dawson)	×	×
<i>Patellina corrugata</i> Williamson	×	
<i>Planocassidulina norcrossi</i> (Cushman)	×	×
<i>Protelphidium orbiculare</i> (Brady)	×	×
<i>Quinqueloculina borea</i> Gud.	×	
<i>Tappanella arctica</i> Gud. et Said.	×	

In the southeastern part of the Kola Peninsula, in one of the sections near the mouth of Ludyanoi Creek (Section 7, Figs. 1 and 4), the Strel'na Beds are underlain by probable glacial-marine deposits of the same Early Weichselian age. After examination of the geological and geochronological data from the Kola Peninsula, Korsakova et al. (2004) and Molodkov and Yevzerov (2004) came to the conclusion that there is not yet any reliable evidence to support a constitutive glacier advance within MIS 5 on the Kola Peninsula and in the eastern part of the White Sea coast. It is possible to suggest that, during one of the Early Weichselian cold substages, there was a local glacier on the inner Kola Peninsula and that a marine basin was present in the White Sea depression. According to the geochronological data (85.5 ± 6.6 ka, 80.5 ± 7.0 ka; nos. 13 and 14 in Table 1), this event can correspond to MIS 5b.

The regression of the Early Weichselian sea can be explained by the development of the early Middle Weichselian (MIS 4) glaciation and by the expansion, to the Kola region, of the ice sheet from the Barents Sea and the Kara Sea shelves (Korsakova et al., 2007). The domination of the Barents-Kara ice sheet is proved by the latest multiple data obtained in regions adjacent to the Kola Peninsula (Andersen and Mangerud, 1990; Mangerud et al., 1996; Mangerud et al., 1999; Mangerud et al., 2002; Mangerud et al., 2004; Svendsen et al., 2004; Grøsfjeld et al., 2006; Lambeck et al., 2006; Larsen et al., 2006). In theory, the Early Weichselian (MIS 5b) or early Middle Weichselian (MIS 4) Scandinavian ice sheet could expand to the Kola Peninsula. The investigations of Finnish researchers (Helmens et al., 2000) have revealed the presence of the Early Weichselian (MIS 5b) till horizon in the Finnish Lapland. The environmental reconstructions carried out for both the northern

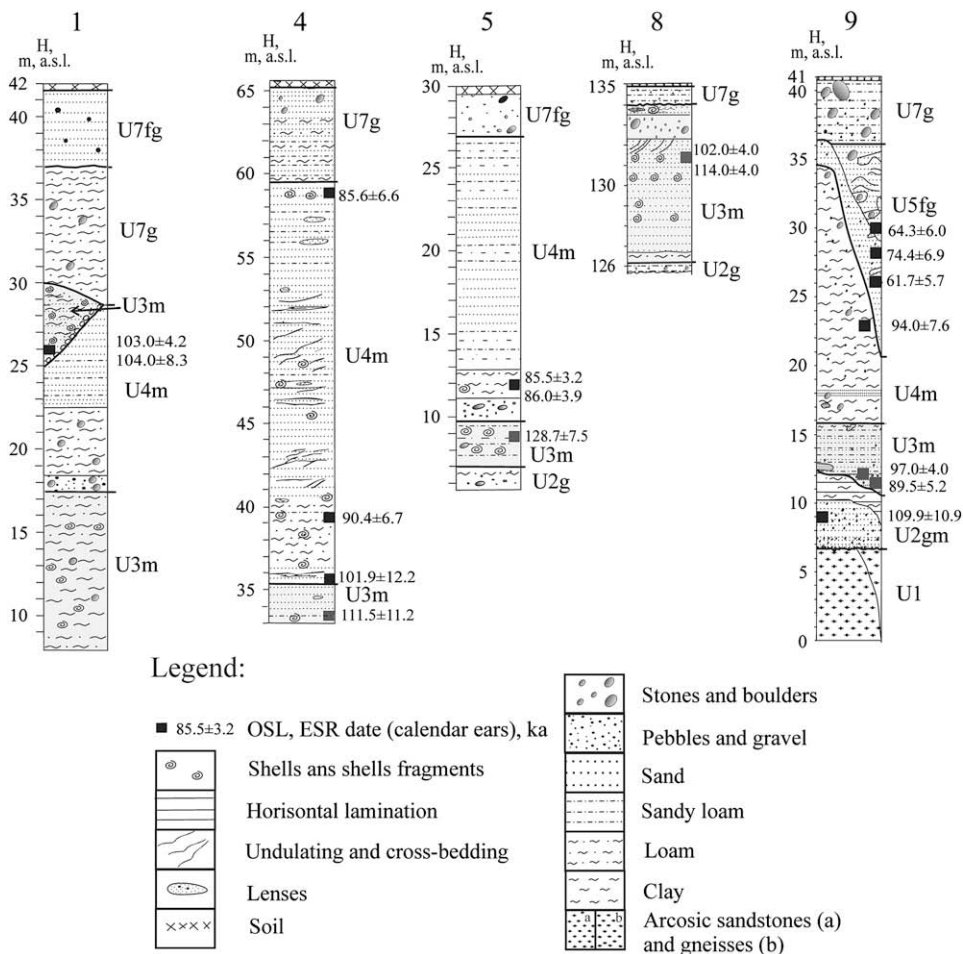


Fig. 3. Simplified logs of the sections exposed Boreal marine transgression sediments (Ponoi Beds) along the south and south-east coasts of the Kola Peninsula. Locations on the map in Fig. 1 are given as section numbers above each log. Stratigraphic units (U) are denoted by number: U1 – pre-Quaternary, U2 – Saalian, U3 – Eemian (Ponoi Beds), U4 – Early Weichselian (Strel'na Beds), U5 – early Middle Weichselian, U6 – Middle Weichselian (Leningrad Horizon), U7 – Late Weichselian. Sedimentary facies are marked by indices: m – marine, g – glacial (till), gm – glaciomarine, fg – glaciofluvial, lg – glaciolacustrine sediments.

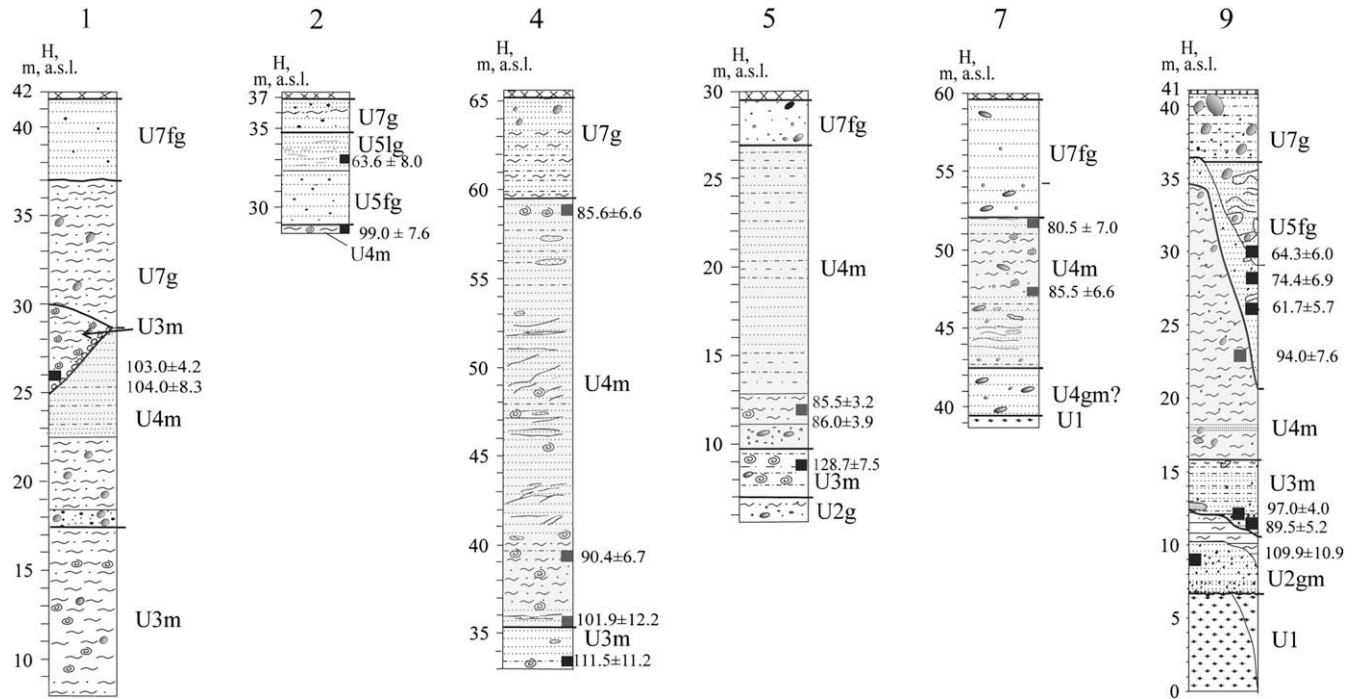


Fig. 4. Simplified logs of the sections exposed Belomorian marine transgression sediments (Strel'na Beds) along the south and south-east coasts of the Kola Peninsula. Locations on the map in Fig. 1 are given as section nos. above each log. Stratigraphic units and sedimentary facies are marked by indices (see Fig. 3). The legend is given in Fig. 3.

and southern parts of Finland, have shown, however, that the Early Weichselian or Middle Weichselian Scandinavian Ice Sheet has not reached the Kola Peninsula in its expansion (Lunkka et al., 2004). Investigations on the southern part of the Kola Peninsula (Svendsen et al., 2004) suggest that the Scandinavian Ice Sheet was located close to the northwestern Kandalakshskii bay of the White Sea and that the Kola region was ice-free during the Early Weichselian, whereas during the early stages of the Middle Weichselian, the Barents-Kara Ice Sheet covered a large extent of area in the White Sea and the Arkhangelsk and Kola regions.

The early Middle Weichselian Barents-Kara Ice Sheet degradation caused the development of the glacioeustatic transgression and the deposition of the third marine sequence in the coastal area of the Kola Peninsula, in the White Sea depression. This sediment unit is most debatable because of the scarcity of data. According to the available paleontological and, mainly, geochronological data, this third Late Pleistocene marine unit has been identified in some

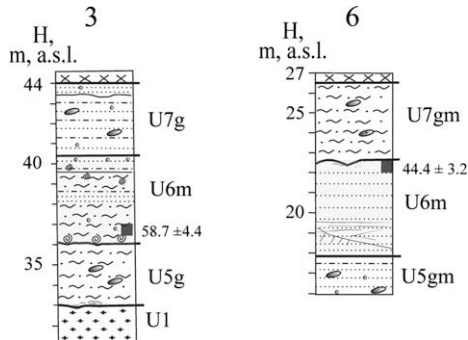


Fig. 5. Simplified logs of the sections exposed Middle Weichselian marine transgression sediments (unnamed unit to the Leningrad Horizon in Russian stratigraphic classification) along the south coast of the Kola Peninsula. Locations on the map in Fig. 1 are given as section nos. above each log. Stratigraphic units and sedimentary facies are marked by indices (see Fig. 3). The legend is given in Fig. 3.

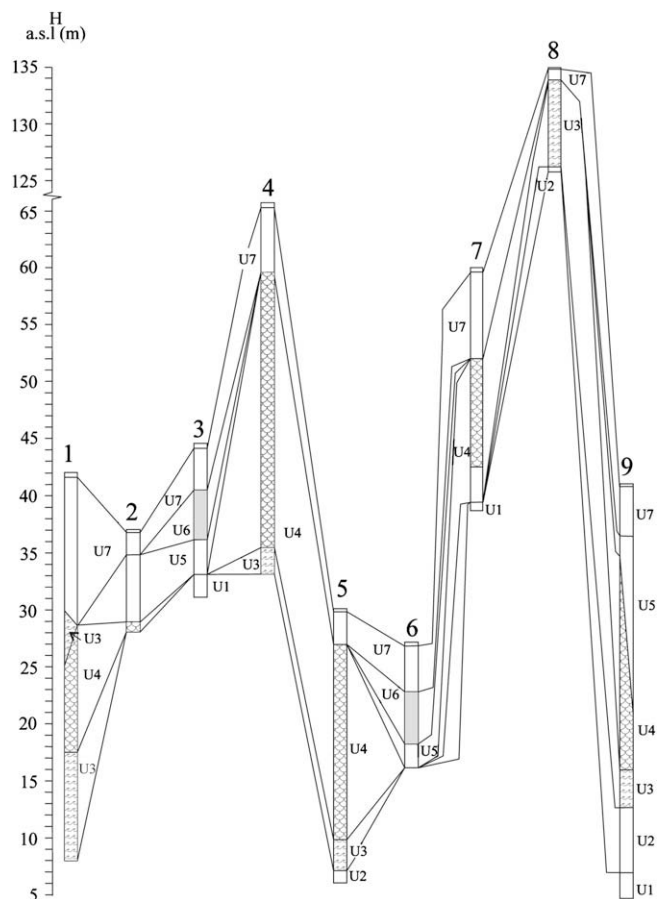


Fig. 6. Correlated stratigraphic successions of examined sections. Locations on the map in Fig. 1 are given as section numbers above each log. The stratigraphic units (U) are denoted by number (see Fig. 3).

sections located in the coastal Kola Peninsula. Both ESR and OSL dates from these sections yield ages around 60–40 ka. This marine sequence has not been given any name in the regional stratigraphic classification yet. It belongs to the Middle Weichselian (MIS 3) age and was probably deposited in a regressing, shallow, cold-water sea, with low water salinity. Marine-inundated glacioisostatic depression, produced by the preceding early Middle Weichselian ice sheet, is probably the cause for the advance, as suggested herein by the author. The Middle Weichselian marine sediments were OSL-dated to around 70–56 ka and 60–50 ka and were found in the Arkhangelsk region (Kjær et al., 2003; Svendsen et al., 2004). The Middle Weichselian marine terraces were described from same islands in the Barents and Kara Sea regions (Mangerud et al., 1998; Forman et al., 1999).

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