ESR age of the Late Pleistocene transgressions in the eastern part of the White Sea coast

Anatoly Molodkov and Anto Raukas

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In the eastern part of the White Sea coast there is a clear evidence of at least two Late Pleistocene transgressive cycles. The deposits of the transgressions are well preserved and abound in malacofauna. Numerical ages obtained by the ESR method on subfossil shell remains suggest a correlation of those sea transgressions with oxygen isotope stages 5 and 3. These two marine transgressions were produced by the glacioeustatic oscillation of the sea level. The present different heights of the corresponding formations above sea level are due to an uneven tectonic uplift. The evidence of the same transgressions has been derived from other localities of Northern Eurasia.

Key words: age, Early Weichselian, Eemian, electron-spin-resonance (ESR) dating, marine deposits, mollusc shells, White Sea

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Anatoly Molodkov, Anto Raukas. Institute of Geology at Tallinn Technical University, 7 Estonia Blvd., EE-0001, Tallinn, Estonia

INTRODUCTION

The formation of the Pleistocene cover in the White Sea area was strongly affected by the numerous glaciations and sea level fluctuations of glacioeustatic origin. Transgressions and regressions of the world ocean caused an essential transgression of marine sands, silts and clays accumulated over the vast coastal area. In the cold epoch that corresponds to the regression of the sea, palaeogeographical conditions sharply changed and the shoreline moved offshore.

A large part of the eastern periphery of the Fennoscandian Shield was covered by the glacier of the Scandinavian centre. During the Boreal (= Eemian in Western Europe) transgression large epicontinental basins such as the White Sea, Petchora, West Siberian and the Taymyr formed, and long estuaries intruded into the continent.

The Boreal Sea deposits in the White Sea area and in Siberia, correlated with the deposits of the Eemian Sea in north-central Europe, serve as a key horizon in the Quaternary stratigraphy all over Northern Eurasia (Лаврова, 1961). But in spite of a great number of well-studied sections, the present knowledge of their absolute age and correlation is still incomplete. One of the reasons is the lack of geochronological data beyond the ^{14}C dating range and discrepancies existing about the Late Pleistocene history in the Northern Hemisphere.

Up to now, the correlation of the sections has been mainly based on the palynological data. Seven assemblage zones (M_2–M_8) of a wide geographical and temporal extent (Гричук, 1961, 1989 и др.) have been established for the last interglacial in the central area of the East European Plain.

However, the palynonologically studied sections alone do not provide sufficient evidence for solving the chronostratigraphical problems. In many cases geographic variations and non-climatic factors inherent, for example, to marine successions shoul be handled with a certain caution while interpreting the regional vegetation history. Besides, there is a basic disagreement as to whether the last interglacial was relatively "short" (~10 ka) or "long" (~60 ka) and how the last interglacial correlates with the deep-sea oxygen isotope stage 5. It is not yet clear whether the distribution of the interglacial seas should be restricted to substage 5e only or to the deep-sea oxygen isotope stage 5 as a whole. For example, the M_2–M_8 pollen zone has been assumed to cover the entire last interglacial period which lasted from about 127 to 70 ka BP (Палеогеография..., 1982). Later on, J. Mangerud (1989) introduced a new chronostratigraphical framework of NW Europe correlating continental stratigraphy with the deep-sea oxygen isotope stages. The proposed chronology implies that the last interglacial existed during substage 5e only and was followed by the two Weichselian glacier advances during substages 5d and 5b, and by two warm interstadials: Brørup during substage 5c (*ca.* 100 ka) and Odderade (5a, *ca.* 80 ka ago). V. Zubakov (Зубаков, 1992) demonstrated that during substage 5b (*ca.* 88 ka BP) the Fennoscandian ice sheet could have reached far out of the sea floor of the White Sea, possibly to a position about 300 km from the White Sea east coast (Fig. 1). Besides, according to the deep-sea oxygen isotope record (Shackleton, 1987), there was at least twofold sea-level lowering of around -60 m during stage 5 which also should have affected the process of sedimentation. Unfortunately, lack of accurate datings has been the main handicap in answering the above questions. To our mind, a new chronologically supported field evidence should show whether or not the Fennoscandian ice sheet ever overrun the eastern part of the White Sea coast during oxygen isotope stage 5 and help to solve, to some extent, the problem concerning the distribution and duration of the Eemian and Boreal seas in the vast areas of NE Europe. It also allows to correlate interglacial events across Northern Eurasia and to ascertain how they relate to the well-established climatic episodes at lower latitudes and in the deep-sea oxygen isotope record.

In the present paper, we report preliminary dating results derived from mollusc shell samples collected from different levels of marine deposits striped by numerous boreholes and outcrops in the eastern part of the White Sea coast. This region is known

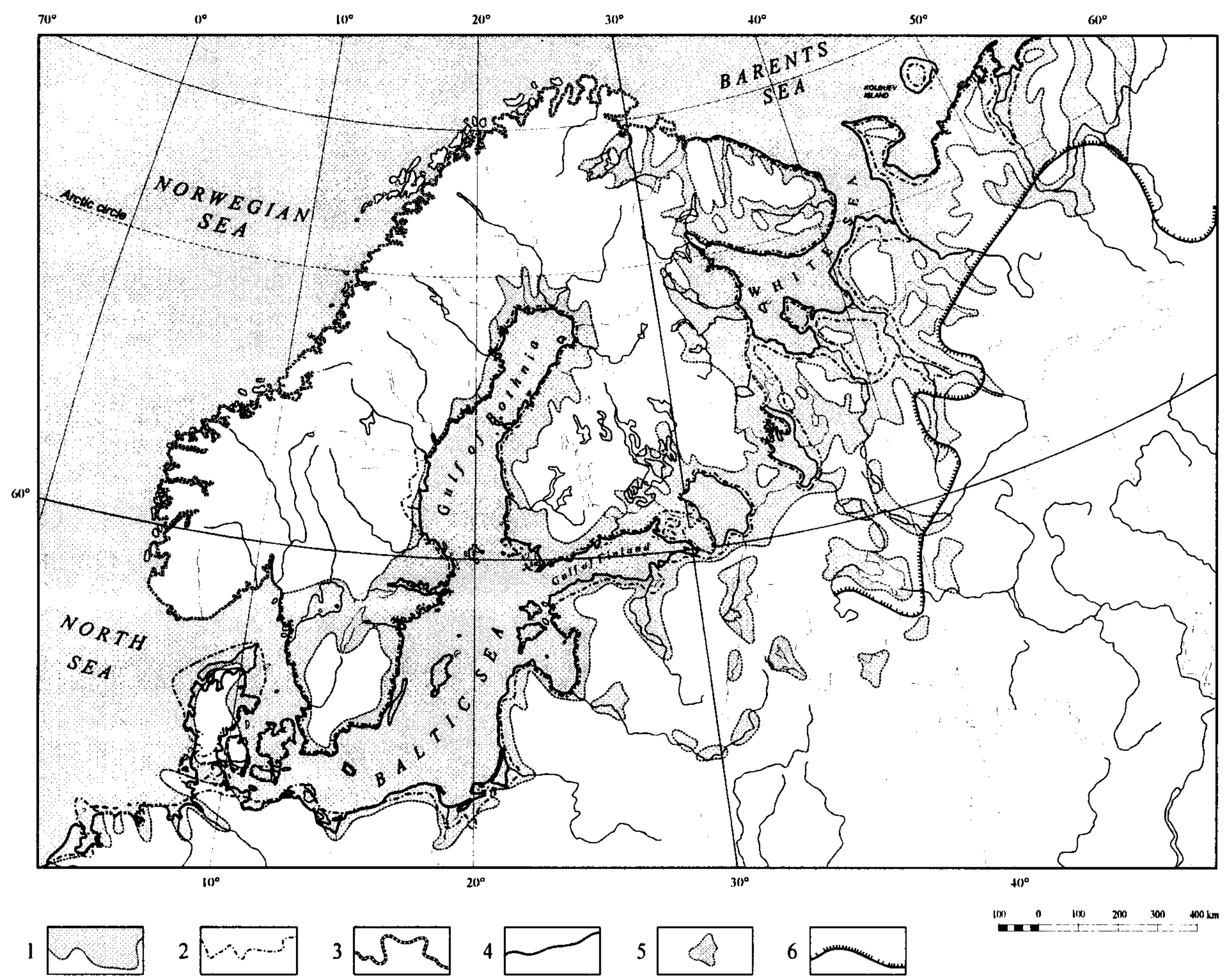

Fig. 1. Eemian shorelines and submerged areas: *1* – after V. P. Grichuk (Гричук, 1982); *2* – after N. S. Blagovolin et al. (Благоволин и др., 1982); *3* – shorelines acknowledged by all authors; *4* – contemporary shorelines; *5* – Eemian inland bodies of water after V. P. Grichuk (Гричук, 1982); *6* – glacier advance during oxygen isotope substage 5b after V. A. Zubakov (Зубаков, 1992)

1 pav. Krantų linijos ir užtvindytos teritorijos Emio tarpledynmečio metu: *1* – pagal V. Gričiuką (1982); *2* – pagal N. Blagoviliną ir kt. (1982); *3* – krantų linijos, pripažintos visų autorių; *4* – dabartinė kranto linija; *5* – Emio tarpledynmečio vandens telkiniai kontinente pagal V. Gričiuką (1982); *6* – ledyno skydo pasistumėjimas 5b deguonies izotopinės substadijos metu pagal V. Zubakovą (1992)

as an important area for studing the coastal evolution and sedimentary dynamics. The ESR dating of mollusc shells is of great interest because of the abundance of these fossils in numerous stratigraphically not investigated and undated marine deposits which are not reliably datable by conventional methods.

All the ages of the shells presented in this paper have been determined by the electron spin resonance (ESR) dating method at the Institute of Geology, Tallinn Technical University, Estonia.

METHOD

The ESR dating method is based on a direct measurement of the amount of radiation-induced paramagnetic centres (radiation damages) that have been created in shell material due to natural radiation. The presence of paramagnetic carbonate centres in mollusc shell material can be detected by ESR spectrometry. It produces a plot of microwave absorption spectra where each paramagnetic centre is characterised by specific signals, the amplitude of which is related to the accumulated palaeodose and hence to the age of the shells. The signals are absent in modern shells, but they increase in intensity as a function of the total radiation dose absorbed by the shell over the time of burial. Shells are dated by measuring the accumulated palaeodose P_s, using analytical signal at g = 2.0012 (Molodkov, 1988, 1993), which has been interpreted as resulting from CO_3^{-3} carbonate centre, and the environmental dose rate $\dot{D}_\Sigma(t)$ affecting the fossil during burial. The dose rate $\dot{D}_\Sigma(t)$ is determined from the analysis of the natural radioactivity of the sample and its immediate environment. Natural radiation is produced by the isotopes in the $^{238}U+^{235}U$ and ^{232}Th decay series and ^{40}K. The environmental dose rate is calculated based on radioactive element concentration in the sediment and in the shell itself. The ESR method used can cover a time range from a few hundred to about a million years BP (Molodkov, 1988, 1989).

RESULTS

The marine formations in the study area are well preserved and abundant in malacofauna which in the Boreal Sea deposits is richer and more thermophilous than the present-day fauna in the same region. The thickness of the deposits frequently reaches 100 m. However, it was not exactly known whether they belong to only one interglacial period (Eemian) or were also formed during the subsequent interstadials or even during the pre-Eemian interstadials or interglacials.

On Kolguev Island, the shells for the ESR analysis were collected from the three stratigraphic levels of a 32 m profile exposed on the east coast of the island (outcrop 30, Fig. 2). Two silt (15–20 m) and sand (3–12 m) layers were rich in shells. A shell sample (135–051) from the lower stratigraphical position was taken at a depth of 19.5 m and was ESR dated at 120.0±8.0 ka BP (Table). Shells from the overlying 9-m-thick sand layer were taken at depths of 11.5 (132–051) and 3.5 (136–051) m and gave stratigraphically consistent ages of 111.0±9.0 and 100.0±10.0 ka, respectively. The results obtained show that the ages of the shells increase in right stratigraphic order from about 120,000 at the lower level to about 100,000 years BP at the upper level.

An 88 m deep boring (No. 34) in the southeastern part of the Kanin Peninsula penetrated a thick sequence of Quaternary deposits. One sand and several clay units were observed along the core. Subfossil shells of three different species (*Hiatella arctica* L. (173–095), *Cyprina islandica* L. (174–095) and *Pecten islandicus* Müll. (175–095)) were collected from the middle part of a 3-m-thick sand layer in the upper part of the core, at a depth of 25 m. All dated shells gave coincident ages with a mean value of 85.6±9.6 ka BP.

Samples 178–095 to 181–095 were taken from a 60-m-long core (No. 641-A) drilled about 25 km southeast from the contemporary shoreline. Several clay, loam and sand layers with an abundance of shells are observed along the entire core. An ESR age of 87.2±8.4 ka was obtained for a *Cyprina islandica* L. shell sample 181–095 taken from a 2.5-m-tkick clay layer in the lower part of the core, at a depth of about 42.5 m. Three different shell species (*Hiatella arctica* L. (178–095), *Astarte borealis* Chemn. (179–095) and *Astarte elliptica* Brown. (180–095)) were collected for ESR analysis from the overlying sand layer at a depth of 21 m. All shells taken from the same stratigraphical level yielded internally consistent dates with an average age of 85.3±6.1 ka BP.

From borehole 625 situated about 20 km south of borehole 641-A, one shell sample (177–095) was taken from the 2-m-thick sand layer at a depth of 5.4 m. The sample from this unit gave an age of 75.6±7.3 ka BP.

In locality 3 situated near to the contemporary shoreline, we studied a section in which the following strata were present from top downwards: diamiction rich in shell fragments with an intercalation of sand. These sediments are underlain by three sand layers containing unbroken shells and shell fragments. From the lowermost layer rich in shingle and boulders, *Cyprina islandica* L. shell samples (187–095) were collected for analysis at a depth of 12.5 m. The shells from this unit were dated with ESR at 71.5±6.4 ka BP.

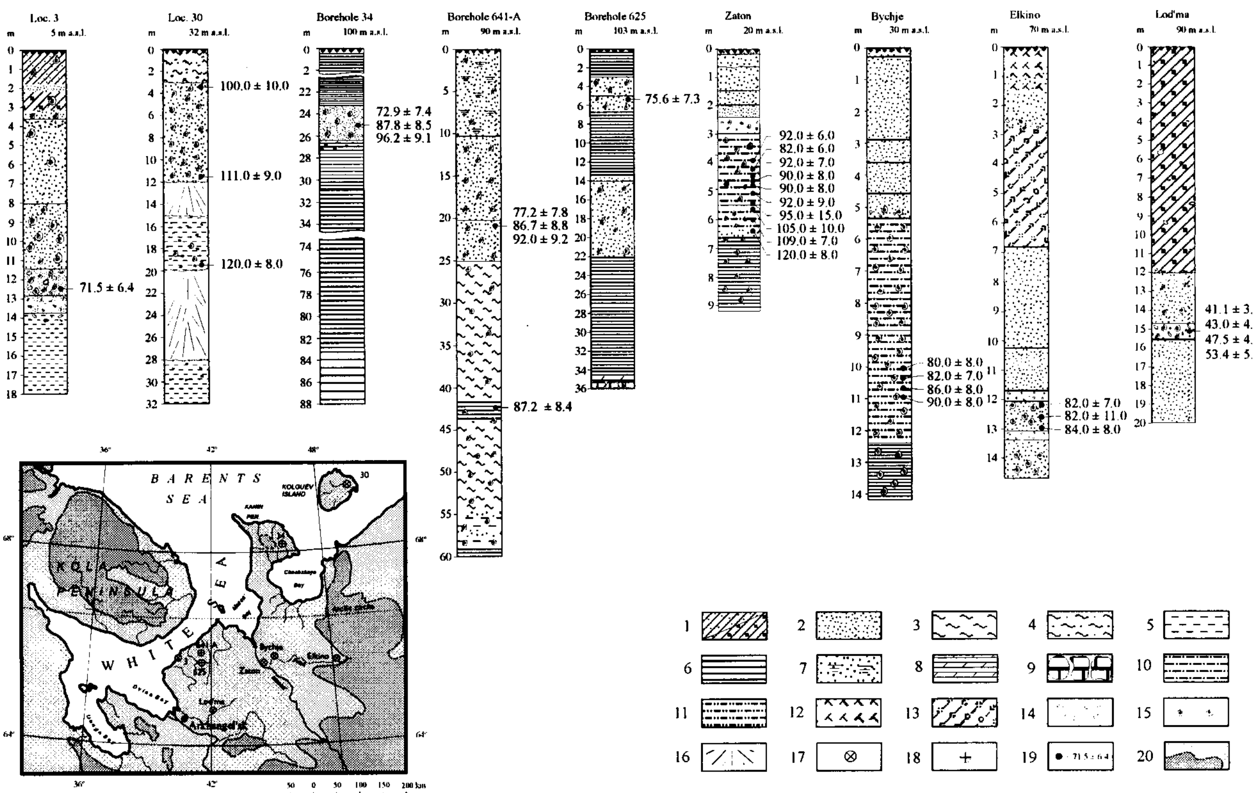

Fig. 2. Location and stratigraphy of the profiles studied in the eastern part of the White Sea coast with the ESR dating results obtained on mollusc shells: *1* – diamicton, *2* – sand, *3* – loam, *4* – sandy loam, *5* – silt, *6* – clay, *7* – argillaceous sand, *8* – granite, *9* – carbonaceous limestone debris, *10* – sandy silt, *11* – silty sand, *12* – peat, *13* – till, *14* – shingle and boulders, *15* – mollusc shells, *16* – talus, *17* – outcrop, *18* – borehole, *19* – sampling site and ESR age, in ka BP, *20* – distribution of the Boreal Sea. Insert: map of the study area showing the Boreal transgression shoreline (after M. A. Lavrova (Лаврова, 1961)) and main localities mentioned in the text

2 pav. Pjūvių, tyrinėtų rytinėje Baltosios jūros kranto dalyje, išsidėstymas ir stratigrafija su moliuskų kiautelių datavimo EPR metodu rezultatais: *1* – morena, *2* – smėlis, *3* – priemolis, *4* – priesmėlis, *5* – aleuritas, *6* – molis, *7* – molingas smėlis, *8* – granitas, *9* – klinčių nuolaužos, *10* – smėlingas aleuritas, *11* – aleuritinis smėlis, *12* – durpės, *13* – morena, *14* – gargždas ir rieduliai, *15* – moliuskų kiauteliai, *16* – nuobyros, *17* – atodanga, *18* – gręžinys, *19* – pavyzdžio paėmimo vieta ir EPR amžius (ka BP), *20* – borealinės jūros išplitimas. Žemėlapyje – tyrimo plotas, borealinės transgresijos kranto linija (pagal Лаврова, 1961) ir svarbiausios tekste minimos vietovės

Samples 024–015 to 032–015 and 036–047 to 033–057 were collected from the Zaton and Bychye profiles, which were described with respect to malacology, palynology and stratigraphy by Devyatova and Loseva (Девятова, Лосева, 1964), Devyatova (Девятова, 1982), Lavrova (Лаврова, 1961) a. o.

The Zaton profile is located on the left bank of the Mezen River about 1.5 km upstream from the Zaton settlement. The Bychye profile is situated on the right bank of the Peza River, about 30 km upstream from the mouth. The basement of both profiles is composed of marine clays with abundant mollusc fauna. Upwards the clays become gradually richer in sand and turn into sandy silt followed by silty sand. Boreal mollusc fauna (*Littorina littorea* L., *Mytilus edulis* L., *Macoma calcarea* Chemn., *M. baltica* L., *Mactra elliptica* Brown., *Neptunea despecta* L., *Astarte borealis* Chemn. and others) dominates. Lusitanian-boreal species such as *Cardium edule* L. var. *rusticum* and *C. fasciatum* Mont. are also represented (Девятова, 1982).

Samples 040–057 to 042–057 were collected from Elkino locality situated about 130 km east of Bychye.

In the Zaton profile our main attention was focused on dating the fauna from silty-sandy deposits at a depth of 3.8 to 6.4 m, in Bychye – at a depth of 8.0 to 10.9 m and in Elkino – at a depth of 12.1 to 13.2 m. Shells of seven different mollusc species were analysed. They gave concordant dates within the time span from about 120,000 to 80,000 years. The results obtained on the most complete Zaton and Bychye profiles show that the whole complex of marine sediments accumulated continuously during Boreal time against the background of ubiquitous regression of the sea. The visible part of underlying marine clays, which accumulated most likely under deep water conditions during the maximum of the interglacial marine transgression (pollen zone M_{4a}) is unambi-

Table. **ESR results and radioactivity data on shell samples from the eastern part of the White Sea coast**
Lentelė. **Rytinės Baltosios jūros kranto dalies kiautelių pavyzdžių tyrimo EPR metodu rezultatai ir radioaktyvumo duomenys**

No.	Lab No.	Site	Depth (m)	d (mm)	U_{in} (ppm)	U (ppm)	Th (ppm)	K (%)	D_c (mGy/a)	D_{int} (mGy/a)	D_{sed} (mGy/a)	D_Σ (mGy/a)	P_s (Gy)	ESR-age, T (ka)
1	024–015	Zaton	3.8–4.3	0.75	0.70	0.75	2.34	0.93	140	130	932	1202	110.60	92.0±6.0
2	026–015	Zaton	4.3–4.7	1.50	0.60	0.55	2.05	1.09	130	104	789	1023	84.00	82.0±6.0
3	025–015	Zaton	4.3–4.7	0.60	0.50	0.55	2.05	1.09	130	98	1044	1272	117.00	92.0±7.0
4	029–015	Zaton	4.7–5.6	2.75	0.90	0.41	1.62	1.10	130	246	587	963	86.66	90.0±8.0
5	030–015	Zaton	4.7–5.6	1.15	0.50	0.41	1.62	1.10	130	106	784	1020	93.80	90.0±8.0
6	028–015	Zaton	4.7–5.6	0.63	0.50	0.41	1.62	1.10	130	85	980	1195	110.00	92.0±9.0
7	027–015	Zaton	4.7–5.6	0.60	0.20	0.41	1.62	1.10	130	28	1000	1158	110.00	95.0±15.0
8	032–015	Zaton	5.6–6.4	1.70	0.50	0.41	1.62	1.10	130	106	705	941	103.40	105.0±10.0
9	032–015a	Zaton	5.6–6.4	1.65	0.50	0.41	1.62	1.10	130	114	705	949	103.40	109.0±7.0
10	031–015	Zaton	5.6–6.4	1.30	0.50	0.41	1.62	1.10	120	111	765	996	119.53	120.0±8.0
11	037–047	Bychye	10.1–10.9	1.30	0.65	0.85	4.90	1.45	100	125	1212	1437	115.00	80.0±8.0
12	036–047	Bychye	10.1–10.9	2.00	0.55	0.85	4.90	1.45	100	120	1066	1286	105.60	82.0±7.0
13	038–047	Bychye	10.1–10.9	1.20	0.95	0.85	4.90	1.45	100	233	1212	1545	132.00	86.0±8.0
14	039–057	Bychye	10.1–10.9	1.50	0.77	0.85	4.90	1.45	100	199	1168	1467	132.00	90.0±8.0
15	040–057	Elkino	12.1–13.2	1.80	0.40	0.63	2.52	0.91	90	79	667	836	68.60	82.0±7.0
16	041–057	Elkino	12.1–13.2	0.80	0.66	0.63	2.52	0.91	90	176	849	1115	91.50	82.0±11.0
17	042–057	Elkino	12.1–13.2	1.20	0.57	0.63	2.52	0.91	90	140	740	970	81.60	84.0±8.0
18	136–051	loc. 30	3.5	3.60	1.60	0.85	2.58	1.48	120	455	798	1373	137.00	100.0±10.0
19	132–051	loc. 30	11.5	1.50	1.30	0.60	2.42	1.84	70	365	1185	1620	180.00	111.0±9.0
20	135–051	loc. 30	19.5	0.85	1.70	1.03	4.63	1.44	70	375	1456	1901	230.00	120.0±8.0
21	173–095	borehole 34	25.0	1.00	0.61	1.75	5.20	1.78	48	147	1623	1819	131.24	72.9±7.4
22	174–095	borehole 34	25.0	0.80	0.33	1.75	5.20	1.78	48	84	1738	1870	162.24	87.8±8.5
23	175–095	borehole 34	25.0	0.80	0.60	1.75	5.20	1.78	48	157	1787	1993	189.13	96.2±9.1
24	177–095	borehole 625	5.4	1.00	0.34	2.15	6.59	2.19	103	83	2009	2195	164.25	75.6±7.8
25	178–095	borehole 641-A	60.0	1.30	0.43	1.55	2.73	1.17	59	109	1008	1175	89.74	77.2±7.8
26	179–095	borehole 641-A	60.0	1.00	0.39	1.55	2.73	1.17	59	101	1095	1255	107.53	86.7±8.8
27	180–095	borehole 641-A	60.0	1.70	0.38	1.55	2.73	1.17	59	105	927	1090	98.92	92.0±9.2
28	181–095	borehole 641-A	42.5	0.55	0.37	1.66	6.42	2.17	23	91	2261	2374	204.40	87.2±8.4
29	187–095	loc. 3	12.5	3.00	1.63	0.67	2.93	1.15	76	425	672	1173	83.14	71.5±6.0
30	189–095a	Lod'ma	15.0	1.40	1.41	0.90	3.17	1.20	71	268	1106	1445	59.05	41.1±3.8
31	189–095b	Lod'ma	15.0	0.85	1.41	0.90	3.17	1.20	71	273	1106	1449	62.05	43.0±4.0
32	190–095	Lod'ma	15.0	1.75	1.45	0.90	3.17	1.20	71	309	898	1277	60.23	47.5–4.3
33	191–095	Lod'ma	15.0	1.50	0.65	0.90	3.17	1.20	71	144	894	1109	58.86	53.4±5.0

Notes: d is the shell thickness; U_{in} is the uranium content in shells; U, Th, K are the uranium, thorium and potassium contents in sediments; D_c is the cosmic dose rate; D_{int} is the time-averaged internal dose rate; D_{sed} is the sediment dose rate; D_Σ is the total dose rate; P_s is the palaeodose. Uncertainties: determination of thickness, ± 40 mm; U determination, ± 2–3%; Th determination, ± 3–4%; K determination, ± 1–2%; U determination in the shells, ± 1–3%; gamma irradiation, ± 3–5%.

guously older than 120,000 years. Marine conditions lasted here until the end of the pollen zone M_8 (Девятова, 1982). In the Zaton and Bychye profiles this time is probably represented by the shell-bearing silty sands overlying the deposits dated by ESR as *ca.* 80 ka BP.

Bisedes the above dales, in the Lod'ma outcrop a series of ESR datings averaging about 46,000 years was also obtained. These datings support the opinion expressed by many scholars that the deposits of the Byelomor transgression, the second huge Late Pleistocene transgression which took place in the Early or Middle Valdai (+Weichselian), occur in this region.

DISCUSSION

Our chronostratigraphical studies in the White Sea area have enabled us to demonstrate the occurrence and temporal extent of the Boreal Sea transgression that was expected on the basis of earlier investigations, and to attempt a preliminary correlation with Eemian marine deposits in Western Europe.

However, it should be mentioned here that straight correlation of the Boreal Sea transgression with the Eemian interglacial is still arguable, since up to now investigators from different fields have disagreed as to the length of the last interglacial. In the latest geochronological subdivisions based mainly on the correlation of north-central Europe continental stratigraphy with the deep-sea oxygen isotope stages (Mangerud, 1989; Behre, 1989; Shackleton, Opdyke, 1973), Eemian interglacial is restricted to substage 5e only. Our geochronological studies cannot contribute much to the solution of the problem concerning the duration of the last interglacial, but the data obtained here have enabled us to place the time of a relatively low global ice volume between 140,000–70,000 years. When all ESR ages on mollusc shells collected from raised marine horizons, correlated with isotope stage 5, are plotted as a frequency histogram (Fig. 3), there is an evidence of a distinct relatively high sea-level stand during this time interval. Therefore, it can be said that in general our results support the standpoint suggesting a relatively long (*ca.* 60,000 years or even more) last interglacial period. It is also possible to assign this time interval to the last interglacial if we accept the sea-level lowering below –60 m as a criterion of interglacial/glacial transition, and *vice versa* (Былинский, 1991).

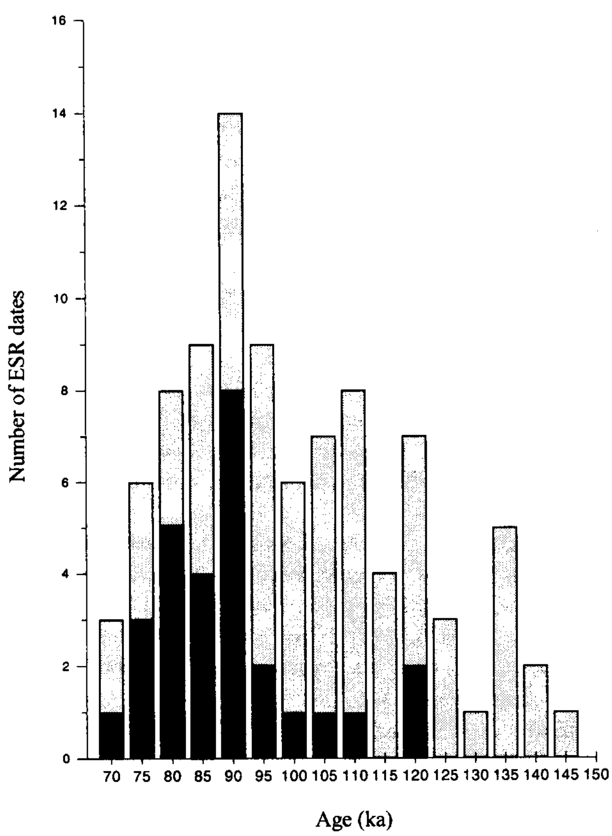

Fig. 3. Frequency histograms of ESR ages for marine and lacustrine deposits from different sites of Eurasia (grey bars) compared to those of marine deposits from the eastern part of the White Sea coast (black bars). Ages plotted are rounded off to the closest 5,000 years
3 pav. Jūrinių ir ežerinių nuosėdų iš įvairių Eurázijos vietovių EPR amžiaus frekvencinės histogramos (pilki stulpeliai) ir jų palyginimas su jūrinėmis nuosėdomis iš rytinės Baltosios jūros kranto dalies (juodi stulpeliai). Pažymėtas amžius suapvalintas iki artimesnių 5000 metų

On the other hand, our results suggest that traces of glacier advance within oxygen isotope stage 5 (*e.g.* during substage 5b, see Fig. 1) can hardly be found in the study area. It is indicated by good preservation of marine deposits on the White Sea coast and by the absence of glaciodislocations and traces of the Early Weichselian (5b, 5d) glaciations in the studied profiles between 120.0–71.5 ka. If the Early Weichselian glacial advances were widespread it is difficult to imagine that the glaciers moving across the area caused neither the erosion of the underlying marine deposits nor the accumulation of till.

If the sea level between 115 and 70 ka BP was in fact relatively high, the implication is that isotope stage 5 was really a period of an "interglacial" character, at least in terms of global ice volume, and isotope stage 5 may be considered as a rather long interglacial period with two short-lived and spatially limited ice expansions during substages 5d and 5b. However, our results do not show the magnitude of the sea-level decrease at that time. Resolution of this problem assumes more studies in the critical areas of the Eurasian northern coast.

The low sea level stands *ca.* –60 m predicted by the deep-sea oxygen isotope record (Shackleton, 1989) did not probably cause any interruption of marine sedimentation in the sections studied, although, according to diatom analysis data and field observations, shoreline fluctuations apparently took place during the Boreal transgression (Девятова, 1982). If the sea-level records derived from deep-sea cores are correct, then the glacioeustatic fluctuation within stage 5 was probably not very significant in this area. This observation agrees with an increasing number of reports of significantly higher sea-level stands during substages 5c and 5a, for instance, with the data from the tectonically stable northern Bahamas, Bermuda, and eastern North America, indicating sea-levels near to or even higher than the present at *ca.* 105 and 80 ka BP (Vacher, Hearty, 1989; Muhs et al., 1987).

The ESR dating results obtained on shells from the sites studied (Fig. 3, black bars) agree well with those obtained by the ESR method on the Eemian Sea deposits in Belgium and Latvia, on lake-and-bog deposits in Lithuania, as well as on the Mga, West-Siberian and Taymyr interglacial basins correlated with oxygen isotope stage 5. Most probably, this Late Pleistocene transgression was an unbroken geological event reflected in the deposits over the vast areas of Eurasia.

Datings from other Northern Eurasian sites indicate that there may have been a relatively high sea level stand around 140 ka. This suggests a sea-level rise at the oxygen isotope stage 6/5 transition, which is much older than the insolation maximum in the

Northern Hemisphere at *ca.* 128 ka BP (Berger, 1978). This observation together with other independent indications (with the new data on the duration of the last interglacial (139 to 117 ka BP) according to the data from the Vostok ice core (Chappellaz et al., 1990; Waelbroeck et al., 1995)) may be regarded as an evidence supporting the start of substage 5e considerably earlier than acknowledged by most investigators.

Some authors believ that during the Eemian transgression the contours of the sea closely coincided with the Litorina Sea limit (see Fig. 1) and, therefore, the Eemian Sea could have a link with the ocean via the Skagerrak, Kattegat and Danish sounds only. Transgressive waters would have inundated the Lake Ladoga depression, small areas at the Vistula and Narva River mouths, and the ancient Neva River valley (Благоволин и др., 1982).

Another group of scientists support a much wider distribution of the last interglacial seas, their connection with the North Sea via the Skagerrak, Kattegat and Danish sounds through the present lake system of Vänern and Mälar in Central Sweden and the area of the current Kiel Canal on the Jutland Peninsula in the west and also a connection between the Eemian and White Sea basins through the system of shallow sounds in the Ladoga–Onega depression (Лаврова, 1961; Гричук, 1982).

Resolution of the question concerning the connection between the Eemian and White seas is of principal importance. If no connection existed, the hydrological regime in the eastern part of the Eemian Sea changed during the course of the interglacial in a way similar to the Holocene (Flandrian) transgression. If the connection did exist, then the situation must have been fundamentally different from that in the Holocene. On the strength of our results obtained in the eastern part of the White Sea coast and disposition of the marine deposits studied, the latter hypothesis seems to be more grounded.

CONCLUSION

The results obtained in the present work demonstrate that the Late Pleistocene marine deposits in the eastern peripheral area of the Fennoscandian Shield can be firmly grouped into two marine events which occurred about 120,000 to 71,000 years and around 46,000 years BP, respectively. The deposits of the former event provide an excellent marker horizon for the studied area and neighbouring regions. They can be confidently referred to the most significant Quaternary transgression, in the north known as the Boreal transgression, which was simultaneous or longer than the Eemian transgression in Western Europe.

Compilation of reliably dated marine sediments from the eastern coast of the White Sea basin, that can be correlated with oxygen isotope stage 5, indicates that low sea-level stands predicted by the deep-sea oxygen isotope record did not probably cause any interruption of marine sedimentation in the sections studied. This suggests that the marine transgressions was long in this area and can be correlaed with some substages or ther whole deep-sea oxygen isotope stage 5.

The data obtained indicate that shell-bearing marine deposits may provide a valuable informations on the last interglacial time, and studies should be continued on other coasts where such deposits are available. For the purpose of reliable correlations, both stratigraphic and geochronological studies of marine units should carried out.

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References

Behre K.-E. 1989. Biostratigraphy of the last glacial period in Europe. *Quaternary Science Reviews.* ***8.*** 25–44.

Berger A. L. 1978. Long-term variations of caloric insolation resulting from the earth's orbital elements. *Quaternary Research.* ***9.*** 139–167.

Chappellaz J., Barnola J. M., Raynaud D., Korotkevich Y. S. and Lorius C. 1990. Ice-core record of atmospheric methane over the past 160,000 years. *Nature.* ***345.*** 127–131.

Mangerud J. 1989. Correlation of the Eemian and the Weichselian with deep sea oxygen isotope stratigraphy. *Quaternary International.* ***3–4.*** 1–4.

Molodkov A. 1988. ESR dating of Quaternary shells: recent advances. *Quaternary Science Reviews.* ***7.*** 477–484.

Molodkov A. 1989. The problem of long-term fading of absorbed palaeodose on ESR-dating of Quaternary mollusc shells. *Applied Radiation and Isotopes.* ***40.*** 1087–1093.

Molodkov A. 1993. ESR-dating of non-marine mollusc shells. *Applied Radiation and Isotopes.* ***44.*** 145–148.

Muhs D. R., Bush C. A. and Rowland T. R. 1987. Uranium-series age determinations of Quaternary eolianites and implications for sea-level history. New Providence Island, Bahamas. *Geological Society of America Abstracts with Programs.* ***19(7).*** 780.

Shackleton N. J. 1987. Oxygen isotopes, ice volumes and sea level. *Quaternary Science Reviews.* ***6.*** 183–190.

Shackleton N. J. and Opdyke N. D. 1973. Oxygen isotope and palaeomagnetic stratigraphy of equatorial Pacific core V28–238: oxygen isotope temperatures and ice volumes on a 10^5 and 10^6 year scale. *Quaternary Research. 3.* 39–55.
Vacher H. L. and Hearty P. 1989. History of stage 5 sea level in Bermuda: Review with new evidence of a brief rise to present sea level during substage 5a. *Quaternary Science Reviews. 8.* 159–168.
Waelbroeck C., Jouzel J., Labeyrie L., Lorius C., Labracherie M., Stievenard M. and Barkov N. I. 1995. Comparing the Vostok ice deuterium record and series from Southern Ocean core MD 88–770 over the last two glacial-interglacial cycles. *Climatic Dynamics. 12.* 113–123.
Благоволин Н. С., Леонтьев О. К., Муратов В. М., Островский А. В., Рычагов Г. И., Серебрянный Л. Р. 1982. Морские бассейны и положение береговых линий восточной Европы в плейстоцене и голоцене. Ред. Герасимов И. П., Величко А. А. Палеогеография Европы за последние сто тысяч лет (Атлас-монография). Москва: Наука. 9–15.
Былинский Е. Н. 1991. Неотектоника, колебания уровня Мирового океана и длинная геологическая запись на континентах. Ред. Вангенгейм Э. А., Мурзаева В. Э. XII конгресс ИНКВА: итоги и перспективы. Москва: Наука. 137–148.
Девятова Э. И. 1982. Природная среда позднего плейстоцена и ее влияние на расселение человека в Северодвинском бассейне и в Карелии. Петрозаводск: Карелия. 156 с.
Девятова Э. И., Лосева Э. И. 1964. Стратиграфия и палеогеография четвертичного периода в бассейне р. Мезени. Ленинград: Наука. 106 с.
Палеогеография Европы за последние сто тысяч лет (Атлас-монография). 1982. Ред. Герасимов И. П., Величко А. А. Москва: Наука. 156 с.
Гричук В. П. 1961. Ископаемые флоры как палеонтологическая основа стратиграфии четвертичных отложений. Рельеф и стратиграфия четвертичных отложений северо-запада Русской равнины. Москва: Изд-во АН СССР. 25–71.
Гричук В. П. 1982. Растительность Европы в позднем плейстоцене. Палеогеография Европы за последние сто тысяч лет (Атлас-монография). Ред. Герасимов И. П., Величко А. А. Москва: Наука. 92–100, карты 9, 10, 11.
Гричук В. П. 1989. История флоры и растительности на Русской равнине в плейстоцене. Москва: Наука. 183 с.
Лаврова М. А. 1961. Соотношение межледниковой бореальной трансгрессии севера СССР с эемской в Западной Европе. *Труды Института геологии АН ЭССР. 8.* Таллинн. 65–88.
Зубаков В. А. 1992. Ледниково-межледниковые циклы плейстоцена Русской и Сибирской равнин в пыльцевых диаграммах. Санкт-Петербург. 122 с.

Anatolijus Molodkovas, Anto Raukas

VĖLYVOJO PLEISTOCENO TRANSGRESIJŲ ERP AMŽIUS RYTINĖJE BALTOSIOS JŪROS PAKRANTĖJE

S a n t r a u k a

Nuosėdų kaupimąsi pleistocene rytinėje Baltosios jūros pakrantės dalyje iš esmės sąlygojo daugkartinės Pasaulinio vandenyno glacioeustatinės transgresijos ir regresijos. Vėlyvajame pleistocene mažiausiai buvo dvi didelės transgresijos epochos, kurios bendrais bruožais sutapo su klimato pašiltėjimu. Transgresijos epochos metu pakrantės zonoje kaupėsi tarpledynmečio nuosėdos. Su transgresijų etapais yra susijęs jūrinės borealinės malakofaunos atsiradimas šioje teritorijoje. Skaitmeninės amžiaus reikšmės, gautos elektroninio paramagnetinio rezonanso (EPR) metodu tiriant subfosilinių moliuskų geldelių liekanas, leidžia minėtas transgresijas koreliuoti su deguonies izotopinės kreivės 5 ir 3 stadijomis. Šiuo metu esantis atitinkamų darinių absoliučių aukščių skirtumas susijęs su neotektoninių judesių nevienoda amplitude. Vėlyvojo pleistoceno transgresijų paleogeografiniai analogai, susidarę rytiniame Fenoskandijos skydo pakraštyje, randami daugelyje Šiaurinės Eurazijos pjūvių.

Анатолий Молодьков, Анто Раукас

ЭПР ВОЗРАСТ ПОЗДНЕПЛЕЙСТОЦЕНОВЫХ ТРАНСГРЕСИЙ НА ВОСТОЧНОМ ПОБЕРЕЖЬЕ БЕЛОГО МОРЯ

Р е з ю м е

Накопление отложений в восточной части Беломорского побережья в плейстоцене в значительной мере определялось неоднократными гляциоэвстатическими трансгрессиями и регрессиями Мирового океана. В позднем плейстоцене здесь имели место по крайней мере две крупные трангрессивные эпохи, в общих чертах совпадавшие с потеплениями климата. В трансгрессивную эпоху в прибрежной зоне накапливались межледниковые отложения. С трансгрессивными этапами развития связано проникновение на эту территорию морской бореальной малакофауны. Числовые значения возрастов, полученные методом электронного парамагнитного резонанса (ЭПР) по раковинным остаткам субфоссильных моллюсков, позволяют коррелировать эти трансгрессии со стадиями 5 и 3 кислородно-изотопной кривой. Наблюдаемая в настоящее время разница в абсолютных высотах соответствующих образований вызвана неодинаковой амплитудой неотектонических движений. Палеогеографические аналоги позднеплейстоценовых трансгрессий, сформировавшихся на восточных окраинах Фенноскандинавского щита, обнаружены во многих разрезах Северной Евразии.