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SHORE DISPLACEMENT CHRONOLOGY OF THE ESTONIAN STONE AGE

The article gives a close view of a shore displacement chronology compiled on the basis of the material from sixty Stone Age settlement sites discovered on the Estonian mainland coast and on Western Estonian islands. Despite the insufficiency of data the placing of the sites in a distance-elevation diagram and the distinguishing of simultaneous shorelines enables one to create a dating system that could be used for finding seashore-related sites as well as for interpreting the existing ones. It is especially important in case indicator finds needed to distinguish archaeological cultures are missing among the find material.

Artiklis esitatakse 60 Mandri-Eesti rannikul ja Lääne-Eesti saartel avastatud kiviaja asulakoha materjali alusel koostatud rannasiirdekronoloogia. Kuigi andmeid veel napib, võimaldab muististe asetamine kaugus-kõrgusdiagrammile ja samaaegsete rannajoonte eristamine luua dateerimissüsteemi, mis on rakendatav nii uute mererannasidusate muististe otsimiseks kui ka olemasolevate tõlgendamiseks. Eriti oluline on see juhtudel, kui kogutud leiuaineses puuduvad arheoloogiliste kultuuride eristamiseks vajalikud indikaatoresemed.

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Introduction

The research of Estonian coastal areas and islands that gained momentum in the mid–1990s has provided manifold results from generalizing treatments on settlement and economic history (Kriiska 2000a; 2001; 2002a; 2003) to specifications of absolute chronology and periodization of the Stone Age (Kriiska 2001; Lang & Kriiska 2001). Data gathered during survey trips and excavations created the need, on the one hand, and a possibility, on the other, for an alternative chronology with regard to shore displacement.

The need arises predominantly from the fact that no archaeological excavations have taken place so far in most of the discovered sites, wherefore dates obtained by the radiocarbon method are missing. Although most of the settlement sites are datable by finds, many places have been come upon which have not offered clear indicator finds even to enable ascertainment of the archaeological culture.

The question was raised especially harshly with regard to the settlement site of Kõpu X (Hiiumaa Island) that according to the altitude should have been younger than the Early Neolithic settlement site of Kõpu I, but the find material gathered during the excavation lacked pottery entirely. Such places that have been inhabited by people who have known the art of making pottery but who have not left it behind (for example in short-time campsites) or have not taken their vessels along to those places at all, are on the background of other coastal Estonian material (predominantly consisting of quartz only) difficult, practically even impossible to date and connect to archaeological cultures that are mostly based on pottery. Nevertheless the determining and comparing of the altitude relations of sites could at this point present important information and specifications of dating.

The pioneer role in employing and improving shore displacement chronology belongs to Finnish archaeologists. They have demonstrated that by combining data obtained from the shore-related dwelling sites that have followed the changes in water level caused by land upheaval and development of water-bodies, it is possible to gain an independent dating method. The shore-displacement chronologies created in this way have found productive exploitation in attempts to discover new sites (e.g. Saukonen 2000; Jussila 2000, 25) as well as to interpret the existing ones (e.g. Siiriäinen 1982; Schulz 1996; Jussila 1999).

As in the case of Estonia we are also dealing with an area of compensational land upheaval, although it is less extensive than in Fennoscandia, then in principle the method can be employed here as well. Another important requirement is also satisfied, namely, most of the Stone Age hunter-fisher-gatherers dwelling sites were situated directly on the banks of water-bodies, and starting from the Late Mesolithic also on the seashore. The fact that people have indeed lived right on the shore is indicated by both the altitude relations of the cultural layer and its location on landscape that follows the ancient shore line. The settlement traces of foraging Stone Age can often be found on coastal fossilized beach formations and terraces. On seashore the banks of small bays, often capes extending into coves have been inhabited, while in default of more favourable conditions the living places could have been founded also directly on open beach (Figs. 1, 2).

In Estonia sufficient data for creating a shore displacement chronology exists only for the Baltic Sea, but in principle the method should be employable also in the case of lakes, especially Lakes Võrtsjärv and Peipsi. The data necessary for generating such a chronology has been collected systematically during fieldwork in coastal Estonia. In addition to a detailed analysis of the finds, the locations of the settlement sites have been thoroughly observed; while many of those have been mapped more exactly and in several cases also paleogeographic reconstructions have been composed. Radiocarbon dates that already form a considerable part of approximately 90 reliable Stone Age dates that have been obtained in Estonia by the ^{14}C-method from both excavated as well as surveyed settlement sites.

The idea to generate a shore displacement chronology with regard to Stone Age settlement sites located on Estonian ancient beaches occurred to the authors of the present article already in the beginning of the 1990s. Nevertheless it took

almost ten years until the first version was completed (or to be more exact, until a sufficient amount of material for creating the chronology was gathered) and still more years until the results were modelled into an article. Although most of the works connected with establishing the chronology have been done out of free time and free will the research of coastal Estonia which has provided basic knowledge has taken place primarily under the ESF Grant Projects Nos. 1022, 2254 and 3332. The analysis concerning the needs of the present shore displacement chronology and modelling it into a scientific research has been supported by ESF Grants Nos. 4558 and 5238 and the Foreign Exchange Foundation of the Estonian Academy of Sciences.

The methods and a concise research history of shore displacement chronology

The best method for creating a shore displacement chronology that would cover extensive areas is to use a distance-elevation diagram.[1] The chronology gained by this method is based on land inclination that results from the differences of land upheaval intensity in different areas (in Estonian and Southern Finland the upheaval in general increases from southeast to northwest). In the distance diagram the ancient shorelines are presented as levels that are projected in the diagram as straight lines. The distance-elevation from the chosen baseline is demonstrated on the horizontal scale of the diagram, while altitude above the present sea level is shown on the vertical scale. For the baseline usually a straight line that follows the main direction of the isobases of land upheaval is used (Fig. 3).

In the distance-elevation diagram the ground is observed from the direction of the land upheaval isobases. The present beach is horizontal in the diagram and the ancient shores in various ways inclined (Fig. 4). The older shorelines are always provided with a bigger inclination than the younger ones. The gradient of the ancient shore is influenced only by time and the difference in upheaval intensity between the edges of the diagram. The amount of water in a basin determines the altitude position of a shoreline in the diagram. In lake basins one character that determines the amount of water determined by three characteristics, notably, the outflow, the threshold of the basin and its altitude. The inclination axis of the ancient shorelines of the basins stands at the threshold of the outflow. During the marine phases of the Baltic Sea the altitude of the shore levels was determined by changes in the ocean level and as there was no outflow or threshold there was no fixed inclination axis either.

The using and interpretation of the distance-elevation diagram is influenced by the direction of the baseline. In the present article a straight line drawn at an angle of 56º from the north was used (Fig. 3). The baseline originates from the azimuth of the maximal land upheaval of 326º and it has generally been used to

[1] In geological and archeological literature hitherto: *diagram of shore-lines* (Donner 1966, Fig. 3) and *distance diagram* (Siiriäinen 1978, Fig. 2) in English; in Finnish *etäisyysdiagrammi* (Donner 1978, Fig. 47) and in Estonian *maapinna tõususpekter* (Moora & Raukas 2003, Fig. 34).

observe the shore processes of the Litorina Sea (for example Kessel & Raukas 1979; Veski 1998) and located between the neotectonic isobases 0 and +1 mm/year (see for example Miidel 1995, Fig. 1).[2] The change in the direction of the baseline from which the information of the beaches is measured affects the inclination of the shore levels in the distance-elevation diagram. Therefore the inclinations of the beaches in the diagrams compiled on the basis of differently oriented baselines are no longer directly proportional.

The baseline of the distance-elevation diagram is adequate only in a limited territory where the isobases of land upheaval are generally oriented similarly. In Southern Finland it has been verified that the directions of the land uplift isobases could conceivably be irregular, but the isobases of the highest shore of ancient Lakes Saimaa and Päijänne, which are based on a huge amount of sound material, are straight and regular (Hellaakoski 1922, 105; Saarnisto 1970, 18; 1971). Therefore it is risky to use land upheaval isobases as such in distance measurements when constructing shorelines.

In case the land in the studied area has risen as one shield, the image of the ancient beach in the diagram is a straight line and the shore level has one inclination value. A hinge line of land upheaval has been noticed in the south-southwestern side of the Salpausselkä end moraine in South-eastern Finland. The shoreline gradients of the lake district in the north-northwestern side of Salpausselkä are considerably steeper and do not correspond to those gradients determined in the south-southeastern side (Donner 1966; 1970; Miettinen 2002; Siiriäinen & Saarnisto 1970). If the distance-elevation diagram cuts a hinge line, then the synchronous ancient shoreline appears in the diagram as an angled line with two different inclination values.

While creating a shore displacement chronology the data gathered from simultaneous beaches of the studied area are added to the diagram. If there are plenty of simultaneously regarded phenomena, regression analysis and the residual plot method can be used to look for mean water levels (Jussila 1994; 1999). At simplest, two completely simultaneous beach observations in the different ends of the diagram are marked by a line projected between them. Exact determination of the beach altitude connected to a certain (exact) time is difficult and often there are no data available of absolutely simultaneous shore processes, or the data are interpretative (for example the ^{14}C dates). Thus in practice several different methods have to be used to gain synchronized shore levels and date them. It is especially useful to place and date a specific short-term shore forming event as the base level (e.g. the uniform fossilized beach formed due to a sudden outflow of the Vuoksi River on the territory of Lake Saimaa in Finland). The afore-described way of looking for ancient shorelines still holds only for the territories of even land upheaval and only if the diagram does not cut the hinge line.

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[2] Considering the available maps and research of the depression of Lake Võrtsjärv, 330º has been offered as the azimuth of the quicker upheaval of land for maps in the Lambert projection (Moora & Raukas 2003, 88).

This is how simultaneous shore levels are searched for and dated while establishing a shore displacement chronology. The final results depend on the amount of dated shore information and the accuracy of their dates and altitude determinations. The dating of the shore displacement chronology is inaccurate in case changes in the water level have been limited for some reasons. A final and sufficiently exact dating method for archaeologists is thus hardly ever attainable via studying shore displacement. A shore displacement chronology must be constantly completed and made more exact with new data. Archaeologists themselves can contribute to the process by documenting Stone Age settlement sites as accurately as possible and fixing thoroughly the information on fossilized beaches (including altitude data) on the site as well as in its neighbourhood.

Geologists have used the distance-elevation diagram to describe ancient shores and their inclination already in the early 20th century (see, e.g., Hellaakoski 1922). In the 1920s the development of a relative chronology of Finnish prehistoric pottery was started on the basis of the shore displacement of the Baltic Sea (Europaeus 1926). During the same decade the dates of the Stone Age settlement sites were studied also with the help of a distance-elevation diagram (Ramsay 1927). In the 1960s a shore displacement chronology of the Baltic Sea beaches was compiled on the basis of archaeological data and ^{14}C dates by Ari Siiriäinen (1969). In the 1990s Timo Jussila created a shore displacement chronology for the Lake Saimaa basin on the basis of partly geological, partly archaeological data (1994), and dated the rock paintings of Saimaa as well (1999).

In Estonia shore displacement chronology has not been employed for dating archaeological sites so far. Only calculations based on neotectonics have been used to date single sites. By this method attempts have been made to date the settlement sites of the Early Neolithic Vihasoo III (Kriiska 1997a, 25; 1997b, 14), the Middle Neolithic Lemmetsa II, the Middle and Late Neolithic Lemmetsa I (Kriiska & Saluäär 2000, 17, 34) and the settlement of Kihnu Mõisaküla (Kriiska 2002b, 15) supposedly dating from the end of the Bronze Age or the beginning of the Iron Age.

Positioning and dating of the shore surfaces on the basis of Estonian archaeological material

Foundation

While compiling the Estonian shore displacement chronology, 60 Stone Age settlement sites in coastal Estonia and the West Estonian islands have been taken into account (Fig. 3, Table 2). These were placed on a distance-elevation diagram measuring their distances from a baseline projected on the Estonian map with a scale of 1:350 000.[3] The baseline was drawn at an angle of 56 degrees on a straight track of Rannametsa–Olustvere (LAT = 58° 33' 16.4" and LON = 25° 33' 47.4") – Avinurme (LAT = 58° 59' 13" and LOT = 26° 52' 29.7") – Narva (Fig. 3).

[3] Eesti. Teede ja turismi kaart. Moskva 1990. Estonia. (The road and tourist map. Moscow 1990.)

In addition to archaeological data also relief forms have been taken into consideration, which have been analyzed especially thoroughly concerning the settlement sites used as the basis of the dated shorelines. For all sites the altitude of the lower border of the cultural layer has been determined. Also, the assumed sea level of the habitation time (mostly relying on the landscape topography (relief)) has been ascertained. 33 radiocarbon dates (Table 1) have been used to project and date the shorelines.

Table 1. The radiocarbon dates used to create the shore-displacement chronology

Tabel 1. Rannasiirdekronoloogia tegemisel kasutatud radiosüsiniku dateeringud

Site	^{14}C-year	Age with the probability of 95.4% (cal BC)*	Age with the probability of 68.2% (cal BC)	Lab. No.	Archaeological culture
Sindi-Lodja IA	8070±70	7350-6700	7290-6830	Ua-17013	Kunda
Sindi-Lodja II	8035±80	7300-6650	7080-6770	Ta-2769	Kunda
Võhma I	6950±100	6010-5640	5970-5720	Ta-2659	Kunda
Võhma I	6750±50	5730-5560	5715-5620	Ta-2646	Kunda
Võhma I	6330±100	5480-5040	5470-5140	Ta-2649	Kunda
Võhma I	6245±200	5650-4700	5500-4900	Ta-2652	Kunda
Kõpu IV/V	6757±50	5730-5560	5715-5625	Tln-2016	Kunda
Kõpu IV/V	6640±60	5670-5470	5620-5490	Ta-2533	Kunda
Ruhnu II	6400±170	5700-4850	5530-5080	Le-5629	Kunda
Ruhnu II	6150±60	5290-4850	5230-4990	Le-5627	Kunda
Pahapilli I	6370±180	5650-4850	5510-5070	Le-5452	Kunda
Kõpu VII/VIII	6172±51	5290-4950	5260-5040	Tln-2024	Kunda
Riigiküla IV	6023±95	5250-4650	5040-4780	Tln-1989	Narva
Riigiküla IV	5624±115	4800-4200	4590-4340	Tln-1990	Narva
Riigiküla IX	5469±111	4550-4000	4460-4110	Tln-1890	Narva
Riigiküla XII	5268±58	4250-3960	4220-3980	Tln-1992	Narva
Kõpu IA	5698±70	4710-4360	4670-4450	Tln-1901	Narva
Kõpu IA	5604±52	4540-4340	4490-4360	Tln-1873	Narva
Kõpu IA	5575±50	4520-4330	4455-4355	Le-5452	Narva
Kõpu IA	5464±96	4500-4040	4450-4160	Tln-1898	Narva
Kõpu IA	5460±100	4500-4040	4450-4110	Ta-2686	Narva
Kõpu IA	5370±68	4340-4040	4330-4050	Tln-1871	Narva
Kõpu IA	5330±90	4340-3980	4320-4040	Ta-493	Narva
Ruhnu II	5400±150	4550-3800	4360-4040	Le-5628	Narva
Ruhnu II	5400±100	4450-3980	4340-4050	Ta-2716	Narva
Naakamäe	4125±85	2890-2470	2870-2580	Ua-4822	Late Combed Ware
Loona	4270±75	3100-2600	3020-2700	Ua-4824	Late Combed Ware
Loona	4050±80	2900-2350	2860-2460	Ua-4825	Late Combed Ware
Kudruküla	4860±60	3780-3510	3710-3380	Cams-6266	Late Combed Ware
Kudruküla	4835±100	3950-3350	3710-3380	Ua-4827	Late Combed Ware
Kudruküla	4770±60	3660-3370	3640-3380	Cams-6265	Late Combed Ware
Kudruküla	4750±100	3800-3100	3640-3370	Ua-4826	Late Combed Ware
Kudruküla	4180±70	2910-2570	2880-2640	Tln-495	Late Combed Ware

* The basis of the calibrations is the computer program CAL40.DTA OxCal v2. 18 cub r:4 sd:12 prob[chron].

In order to compile the distance-elevation diagram the settlement sites were divided into five main chronological groups: Middle Mesolithic, Late Mesolithic, Early Neolithic, Middle Neolithic and Late Neolithic (Fig. 4 and Table 2).[4] Some settlement sites yielded habitation traces of several periods of the Stone Age. On the Kõpu peninsula (Hiiumaa Island) there are altogether three settlement sites in case of which nothing else could be supposed than that they could be remains of Neolithic dwelling places, and even this hypothesis was based on the comparison of altitude relations of three dated settlement sites of the Kõpu peninsula. In some cases, although the archaeological material was too scarce (Rõuste) or insufficient for a firm distinction (for example Kõpu IX and XII)[5] the age prognosis was still formulated, though consciously taking the risk of error. As one of the tasks of shore displacement chronology is just to contribute to interpreting such problematic sites the authors were interested in seeing if an archaeological-typological solution and thus the given dating overlaps with or differs from that obtained by the shore displacement chronology.

Shore 1[6]

Two Mesolithic shore surfaces can be distinguished by the existing radiocarbon dates: (1) Võhma I and Kõpu IV/V with the age of 5700 years cal BC and (2) Ruhnu II and Kõpu VII/VIII with the age of 5100 years cal BC.

The average radiocarbon dates (probability 95.4%) obtained from the settlement sites of Võhma I and Kõpu IV/V are, respectively, 5825±185, 5645±85, 5260±220, 5175±475, 5670±45 cal BC and 5555±65 cal BC (for base dates see Table 1). The age of the shoreline 1 – 5700 cal BC – has been arrived at considering all dates of the Kõpu IV/V settlement site and the two oldest dates of the Võhma I site. The distances of the sites from the baseline are, respectively, –141.8 km and –105.5 km and their distance from each other is suitable to enable one to draw the shoreline with a sufficient accuracy. Considering the relief of the landscape, the seashore of the habitation time at Kõpu IV/V was presumably 27.5 m, while at the time of Võhma I it was 20.5 m above the present sea level. The projected line between them yields the gradient value of 0.193 m/km as the inclination of shoreline 1.

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4 Beginning of the Late Mesolithic 6500 cal BC, the Early Neolithic 4900 cal BC, the Middle Neolithic 4200/4000 cal BC and the Late Neolithic 3200/3000 cal BC (see Lang & Kriiska 2001).

5 As in the West Estonian archipelago mineral addition dominates in the pottery of foraging Neolithic it is very difficult to distinguish between the end of the typical combed ware and the beginning of the late combed ware as on the mainland the latter is again clearly expressed by a change in the admixture of the clay mass. There the mineral admixture of the typical combed ware is replaced by organic matter: vegetable remains and/or shell debris are characteristic components of the late combed ware (Kriiska 1995, 75–76, 86).

6 The numbers of the shores correspond to their sequence in the distance-elevation diagram presented in Figure 4.

Table 2. Concentrated data about settlement sites embraced in Estonian shore displacement chronology and shore displacement dates

Tabel 2. Rannasiirdekronoloogiasse hõlmatud asulakohtade koondandmed ja dateeringud rannasiirde alusel

Nro	Period	Site	Distance	Z1	Z2	^{14}C cal BC	BP Max.	BP Min.	BP Prob.	Shore displacement date BC	BP Max2	BP Min2	BP Prob2	Alternative shore displacement date BC	Highest shore BP	Highest shore z
1	MM	Sindi-Lodja I	–15.8	3.5	1.8	6990±490	2838	1622	1459	840BC-540AD	>7700	–	–	>5700	6500	10.1
2	MM	Sindi-Lodja II	–15.8	4.6	3.6	6975±325	3546	2514	2919	1550-510	>7700	7680	–	>5680	6500	10.1
3	LM	Kõpu XIV	–143.0	29.0	27.0		7700	7329	7329	5700-5330	–	–	–	–	7500	27.4
4	LM	Kõpu III	–141.8	28.0	27.0		7700	7200	7414	5700-5200	–	–	–	–	7500	27.2
5	LM	Kõpu IV/V	–141.8	28.0	27.5	5600±130	7700	7200	–	5700-5200	–	–	–	–	7500	27.2
6	LM	Kõpu VI	–141.8	29.0	27.0		7700	7414	7414	5700-7410	–	–	–	–	7500	27.2
7	LM	Kõpu VII/VIII	–142.3	29.0	27.7	5120±170	7700	7371	–	5700-5370	–	–	–	–	7500	27.3
8	LM	Kõpu IX	–141.8	29.0	27.0		7700	7414	7414	5700-7410	–	–	–	–	7500	27.2
9	LM	Kõpu XVII	–143.9	34.0	31.0		–	–	–	–	–	–	–	–	7500	27.5
10	LM	Kõpu II	–141.4	29.0	28.0		7600	7450	–	5600-5450	–	–	–	–	7500	27.1
11	LM	Pahapilli II	–106.2	22.0	20.0		7700	6500	6406	5700-4410	–	–	–	–	7200	21.4
12	LM	Võhma I	–105.5	22.0	20.5	5355±655	7700	6540	6540	5700-4540	–	–	–	–	7200	21.3
13	LM	Võhma II	–105.5	22.0	20.0		7700	6540	6425	5700-4430	–	–	–	–	7200	21.3
14	LM	Võhma III	–105.5	22.0	20.0		7700	6540	6425	5700-4430	–	–	–	–	7200	21.3
15	LM	Võhma VI	–105.5	22.0	20.0		7700	6540	6425	5700-4430	–	–	–	–	7200	21.3
16	LM	Võhma VII	–105.5	22.0	20.0		7700	6540	6425	5700-4430	–	–	–	–	7200	21.3
17	LM	Pahapilli I	–105.9	22.0	20.0	5250±400	7700	6540	6425	5700-4430	–	–	–	–	7200	21.3
18	LM	Võhma IV	–105.2	22.0	20.0		7675	6580	6443	5680-4440	–	–	–	–	7000	21.2
19	LM	Võhma V	–105.2	22.0	20.0		7675	6580	6443	5680-4440	–	–	–	–	7000	21.2
20	LM	Valge-Risti	–100.8	21.0	20.0		7700	6441	6580	5700-4440	–	–	–	–	7000	20.6
21	LM	Ruhnu I	–10.9	12.0	11.0		–	–	–	–	–	–	–	–	6500	9.5
22	LM	Ruhnu V	–10.9	13.0	11.0		–	–	–	–	–	–	–	–	6500	9.5
23	LM	Ruhnu VI	–10.2	13.0	11.0		–	–	–	–	–	–	–	–	6500	9.4
24	LM	Ruhnu III	–10.9	12.0	11.0		–	–	–	–	–	–	–	–	6500	9.5

Table 2 continued

Nro	Period	Site	Distance	Z1	Z2	^{14}C cal BC	BP Max.	BP Min.	BP Prob.	Shore displacement date BC	BP Max2	BP Min2	BP Prob2	Alternative shore displacement date BC	Highest shore BP	Highest shore z
25	LM-EN	Ruhnu II	–10.9	13.0	11.5	5260±270 4175±375	–	–	–	–	–	–	–	–	6500	9.5
26	EN	Kõnnu	–72.3	16.0	15.0		6354	5989	6111	4350-3990	7700	7387	7617	5700-5390	6700	16.9
27	EN	Vihasoo III	–85.1	19.0	18.0		7560	6390	6500	5560-4390	–	–	–	–	7000	18.5
28	EN	Ruhnu IV	–10.5	12.0	10.0		–	–	–	–	–	–	–	–	6700	9.5
29	EN	Riigiküla IV	–2.3	9.0	8.0	4950±300	6973	5857	6179	4970-3860	–	–	–	–	6500	8.5
30	EN	Riigiküla V	–2.1	9.0	8.0		6973	5857	6179	4970-3860	–	–	–	–	6500	8.5
31	EN	Riigiküla VI	–2.1	9.0	8.0		6973	5857	6179	4970-3860	–	–	–	–	6500	8.5
32	EN	Riigiküla VII	–2.1	9.0	8.0		6973	5857	6179	4970-3860	–	–	–	–	6500	8.5
33	EN	Riigiküla VIII	–2.1	9.0	8.0		6973	5857	6179	4970-3860	–	–	–	–	6500	8.5
34	EN	Riigiküla IX	–1.9	9.0	8.0	4275±275	6970	5857	6179	4970-3860	–	–	–	–	6500	8.5
35	EN	Riigiküla X	–1.9	9.0	8.0		6970	5857	6179	4970-3860	–	–	–	–	6500	8.5
36	EN	Riigiküla XI	–1.9	9.0	8.0		6970	5857	6179	4970-3860	–	–	–	–	6500	8.5
37	EN	Riigiküla XV	–1.8	8.0	7.0		6223	5185	5531	4220-3190	7178	6809	7067	5180-4810	6500	8.4
38	EN	Riigiküla XII	–1.8	9.0	8.0	4105±145	6945	5877	6223	4950-3880	–	–	–	–	6500	8.4
39	EN	Riigiküla XIII	–1.8	9.0	8.0		6945	5877	6223	4950-3880	–	–	–	–	6500	8.4
40	EN	Kõpu I A	–141.4	26.0	25.0	4345±355	7000	6500	6643	5000-4640	–	–	–	–	7500	27.1
41	EN	Riigiküla II	–3.2	9.0	8.0		7000	5793	6114	5000-3790	–	–	–	–	6500	8.6
42	EN	Riigiküla I	–2.8	9.0	8.0		7000	5840	6140	5000-3840	–	–	–	–	6500	8.6
43	EN	Riigiküla III	–2.6	9.0	8.0		6973	5857	6179	4970-3860	–	–	–	–	6500	8.5
44	MN	Kõpu I B	–141.4	23.5	22.0		6347	6119	6119	4350-4120	–	–	–	–	7500	27.1
45	MN-LN	Lemmetsa II	–31.6	11.0	10.0		6162	5600	5787	4160-3600	7412	7100	7324	5410-5100	6700	12
46	MN	Malda	–31.4	11.0	10.0		6187	5600	5796	4190-3600	7406	7086	7312	5410-5090	6700	12
47	MN	Rõuste	–73.2	17.5	16.5		7457	6334	6453	5460-4330	–	–	–	–	6700	17
48	MN	Sindi-Lodja III	–15.8	9.0	8.5		5979	5229	5742	3980-3230	7335	7050	7175	5340-5050	6500	10.1
49	MN	Jõekalda	–15.9	9.0	8.5		5979	5229	5742	3980-3230	7335	7050	7175	5340-5050	6500	10.1

Table 2 continued

Nro	Period	Site	Distance	Z1	Z2	^{14}C cal BC	BP Max.	BP Min.	BP Prob.	Shore displacement date BC	BP Max2	BP Min2	BP Prob2	Alternative shore displacement date BC	Highest shore BP	Highest shore z
50	MN-LN	Naakamäe	–86.1	15.0	14.0	2680±210	5820	5482	5600	3820-3480	–	–	–	–	7000	18.6
51	N	Kõpu XIII	–143.0	26.0	23.0		6925	6470	6245	4930-4250	–	–	–	–	7500	27.4
52	N	Kõpu XVI	–141.8	24.0	23.0		6424	6195	6271	4420-4200	–	–	–	–	7500	27.2
53	N	Kõpu X	–141.4	22.0	20.0		6119	5890	5814	4120-3810	–	–	–	–	7500	27.1
54	LN	Kõpu XII	–144.2	21.0	20.0		5930	5705	5780	3930-3700	–	–	–	–	7500	27.6
55	LN	Kõpu XV	–141.8	18.0	15.0		5502	5256	5011	3500-3010	–	–	–	–	7500	27.2
56	LN	Kõpu XI	–141.2	19.0	17.0		5675	5433	5350	3680-3350	–	–	–	–	7500	27.1
57	LN	Loona	–101.2	12.0	11.0	2725±375	4914	4543	4700	2910-2540	–	–	–	–	7200	20.7
58	LN	Kaseküla	–72.3	11.0	10.0		5097	4700	4832	3100-2700	–	–	–	–	6700	16.9
59	LN	Lemmetsa I	–29.8	10.0	9.0		5835	5214	5429	5830-5210	7522	7271	7447	5520-5270	6700	11.8
60	LN	Kudruküla	–5.6	7.0	6.0	3260±690	5343	4373	4700	3340-2370	7391	7178	7323	5390-5180	6500	8.9

Nro — site number in the map and the distance diagram
Period — estimated archaeological time period
Distance — distance from the baseline km
^{14}C — combined all rc-dates and calibrated with cal40.dta
Z1 — elevation of the slowest cultural layer
Z2 — elevation of the estimated shore level during the settlement
Max. — oldest possible dating, when waterlevel at z1
Min. — youngest possible dating, when waterlevel a z-1.5 m
Prob. — most propable dating when water level at z2
Shore displacement date BC rounded to nearest ten
Age of the highest Litorina shore BP at the site
Highest shore z, elevation of the highest Litorina shore at the site

Alternative min., max., prob. and dating occurs when site terrain has been under Litorina transgression

The settlement site of Võhma I has yielded two radiocarbon dates that are a few hundred years younger, yet remain between the afore-described shore surface and the Late Mesolithic one that will be treated next. As the latter is approximately two meters higher than the oldest shore (1) described in our research, then in order to fit the reasoning the youngest habitation traces of the settlement site of Võhma I should be found higher than the older ones. The kind of difference in stratigraphy can be seen in the results of the excavation of 1997, where the youngest dates were obtained from hearths located on the higher part of the ancient shore ridge and the older ones, respectively, lower (Kriiska 1998).

Shore 3

According to radiocarbon dates the following time horizon is represented by three settlement sites: Ruhnu II, Kõpu VII/VIII and Pahapilli I (Figs. 3, 4) the average dates of which acquired by the radiocarbon method (with a 95.4% probability) are, respectively, 5275±425, 5070±220; 5120±170 and 5250±400 cal BC (for base dates, see Table 1). Considering their altitudes of the habitation time (positioned in the same way as with the settlement sites of the previous shore

Fig. 3. The Stone Age settlement sites discussed in the article (numbers correspond to Table 2) and the baseline used to generate the distance diagram.

Joon 3. Artiklis käsitletud kiviaegsed asulakohad (numbrid vastavad tabelile nr 2) ja kaugus-kõrgusdiagrammi tegemisel kasutatud põhiliin.

surface) there are three possibilities to draw the shorelines: (1) Ruhnu II and Pahapilli I, (2) Kõpu VII/VIII and Pahapilli I and (3) Ruhnu II and Kõpu VII/VIII. It is not possible to project the shore surface between Ruhnu II and Pahapilli I, since its inclination would be smaller than the following (Early Neolithic) shore (6) and this is unfeasible. The change of the inclination compared to the older shore (1) is too abrupt as well. Also, the settlement site of Kõpu VII/VIII would be a little too high from the sea level of the time. According to the shoreline projected between Kõpu VII/VIII and Pahapilli I the settlement sites of Ruhnu would have been over 4 meters above the sea level back then and we would not be dealing with shore related dwelling sites.

A third possibility still remains – to project the shoreline between the settlement sites of Ruhnu II and Kõpu VII/VIII. This would not generate any conflict of principle, but assumes the flooding of at least part of the settlement site of Pahapilli I by a short-term transgression. The latter is not excluded by the existing data. Including the date of the settlement site of Kõpu VII/VIII and the younger Mesolithic date of the Ruhnu II settlement, the shoreline was dated to 5100 cal BC. The line projected between them gives 0.1255 m/km as the inclination gradient of the shoreline.

A radiocarbon date that is a few hundred years older originates from the settlement site of Ruhnu II. Since two other dates taken into account in projecting the shoreline are the same, they could be regarded as representatives of a simultaneous water level. In case we take the older date into consideration, then the other positioned Late Mesolithic shoreline (1) is a little older than the age that we have used.

Shore 6

Five settlement sites with dates obtained by the radiocarbon method can be exploited to distinguish the Early Neolithic shoreline. The average dates of the sites Riigiküla IV, Riigiküla IX, Riigiküla XII, Kõpu I and Ruhnu II (with a 95,4% probability) are, respectively, 4950±300, 4500±300; 4275±275; 4105±145; 4535±175, 4440±100, 4425±95, 4270±230, 4270±230, 4190±150, 4160±180; 4215±235 and 4175±375 cal BC (for base dates, see Table 1).

Considering their altitude (defined the same way as the settlement sites of the oldest shoreline) there are two possibilities to draw the shorelines: (1) the settlement sites of Riigiküla and the site of Ruhnu II, and (2) the settlement sites of Riigiküla and the site of Kõpu I. The settlements of Riigiküla cannot be used for the task independently because of their limited distance from each other. The settlement site of Ruhnu I, situated higher than even the oldest shoreline (1) treated here, differs very clearly from the others and cannot in any case be on the same shore with the settlements of Kõpu I and Riigiküla. The settlement traces of Narva Culture at Ruhnu II which has been inhabited since the Mesolithic are presumably not to be found on the Early Mesolithic beach, but inland. Considering the landscape relief in the area it can be assumed that by that time the original lagoon at the Litorina Sea had changed into a remnant lake and the bank of the lake situated a few meters higher was used as a campsite (for a location map of the Ruhnu Stone Age sites see Kriiska & Saluäär 2000, Fig. 1).

Thus, the only possibility is to project the shoreline between the simultaneous settlement sites in Riigiküla and Kõpu. The shore of the time of the oldest dates (approximately 4500 cal BC) of the Kõpu I settlement has been, considering the landscape relief (a foot of a clear coastal terrace), about 24.5 meters higher than the present sea level (Table 2). The altitude of 8.5 m above the present sea level corresponds to this period at the settlement site of Riigiküla IV (Table 2). Thus the shore is distinguished as dated to 4500 cal BC with the gradient of 0.115 m/km, which inclination is completely in accord with the earlier shorelines.

The oldest date of Riigiküla IV (Table 1) is problematic as a medium but within the limits of a considerable dating error it can still be fitted into our shore-displacement chronology.[7] The considerably younger date of the Riigiküla IX settlement site (Table 1) can represent the water level situated half a meter lower and accords with the distinguished shoreline as well. The acquired result suggests that the settlement site of Riigiküla XII that yields the youngest date might not have been situated directly on the seashore anymore. It is possible that during that period the river of Tõrvajõgi formed on the border of the lagoon, which had become a swamp by the time, and the dwelling place was situated on its bank (for a location map see Kriiska 2000a, Fig. 2). As the changes in the water level caused by land upheaval are slow starting from the discussed era in the areas that are situated near our baseline, thus the shore displacement dates are made even less accurate.

Shore 7

The projecting of the shoreline of the Middle Neolithic is hindered by the fact that no reliable radiocarbon dates have been obtained from the Typical Combed Ware Culture settlement sites in Estonia. Thus, some other solution is needed to position and date the shoreline. In order to do that the finds of the settlements were analyzed archaeologically-typologically, while the task was helped by the present situation with the typical combed ware that on the scale of the Stone Age has been used for a rather short term (Lang & Kriiska 2001, 90–92). The typical combed ware that is clearly and unambiguously distinguished from the rest of the ceramics has been gathered from the coastal Estonian settlement sites of Kõpu IB, Lemmetsa II, Malda, Sindi-Lodja III, Jõekalda and Naakamäe (Jaanits *et al.* 1982, 85; Kriiska & Saluäär 2000, 15; Kriiska *et al.* 2002, 31).

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[7] Of course the using of considerably older wood for fire material cannot be excluded either. This phenomenon can actually affect most of the radiocarbon dates obtained from Estonian coastal settlement sites.

After placing these settlement sites into the distance diagram it is obvious that the sites do not station themselves on the same shore level and they also seem to be set apart in time (Fig. 4). Of that list, Lemmetsa II and Naakamäe are the two lowermost. Typical combed ware has not been detected from any sites situated lower than those. The two sites are linked together by the extent of their settlement period – both have been inhabited after the Typical Combed Ware Culture and during the Late Combed Ware Culture period, while at the same time they lack habitation traces from the era before the Typical Combed Ware Culture (Kriiska & Saluäär 2000, 15; Jaanits *et al.* 1982, 85). Thus they have served as dwelling sites at the time when typical combed ware was replaced by late combed ware. Considering the dates of the beginning of the Late Combed Ware Culture in Estonia, Finland and Latvia (Lang & Kriiska 2001, 92) the transition period can be dated approximately to 3600 cal BC, and the same date can be applied to the shoreline drawn between the settlements. The position of the shoreline gained in this way and its inclination in the distance diagram are in accord with the other shorelines. The gradient of the shoreline (7) is 0.083 m/km.

If the line of the shore is drawn through the settlements of Malda and Kõpu IB, it is situated near the shoreline (6) dated to 4500 cal BC both by position and by inclination. This suggests that the mentioned settlement sites represent the early stage of the Typical Combed Ware Culture, which according to the diagram could have started already a little earlier than 4000 BC. This does not contradict the dates of the typical combed ware either (Kriiska 2001).

Shore 8

Younger foraging settlement sites in coastal Estonia belong to the Late Neolithic and are connected to the Late Combed Ware Culture. Distinct late combed ware that could be dated to the Late Neolithic has been found from the settlements of Loona, Naakamäe, Kaseküla, Lemmetsa I and Kudruküla (Kriiska 1995, 93). In other cases the pottery might also be older than 3200/3000 years cal BC, which has become the border separating the Middle and the Late Neolithic in Estonia (Lang & Kriiska 2001, 93). From the settlement sites of Loona, Naakamäe and Kudruküla radiocarbon dates have also been obtained, respectively, 2850±250, 2625±165; 2680±210; 3645±135, 3650±300, 3515±145, 3450±350 and 2740±170 cal BC on the average (95.4% probability) (for base dates, see Table 1).

Similarly to the previous shoreline two settlement sites, Loona and Kudruküla, the lowermost on the diagram, are distinguished here. Their radiocarbon dates differ, though. In the case of Loona the shore of the habitation time can be determined, considering the landscape relief. As the relief is gentle it could not have been a very long-term coastal settlement, but the paleogeography of Kudruküla is in the most part unclear (Kriiska 1995, 58–59). Moreover, a small river (Kudruküla brook) might have formed there already during the Stone Age, which could have enabled continuation of settlement after the retreat of the sea as well.

Thus, considering the date of Loona, the height of the water level at 2700 cal BC can be assumed as 11 m from the present sea level (Table 2). The inclination of the shore is problematic. In any case the shoreline of that period must obviously have been lower than the settlement site of Kudruküla. At the same time it cannot have been much lower than the latter, as the inclination of the shore formed in this way would be too steep and thus not in accord with the older shores. As long as more exact research has not been carried out the assumption must be accepted. As the change in the inclination between the previous shore surfaces has been approximately 0.000035 m/km a year, it can be considered that at 2700 cal BC the gradient of the shoreline should have been 0.0523 m/km. If we try to project the line via the altitude of Loona, the shore level at that time was situated 1 m lower than the supposed lower border of the settlement site of Kudruküla.

Checking of the results with the assistance of a time gradient curve and specifications

A time gradient curve must be regular and even. In the curve enabled by our results there is a noticeable exception at 5100 cal BC (Fig. 5A). As this is impossible we were forced to redefine our basis for projecting the shoreline. As the curve is regular and even above the Neolithic shores and as, on the basis of archaeological evidence, it is absolutely impossible to reduce the inclination of the shorelines enough to correct the younger Late Neolithic shore part in the curve, the error must be in the shoreline dated to 5100 cal BC.

Also the oldest shoreline (1) could be subjected to fine adjustment either by making the dating older or the gradient more shelving. The date cannot be changed if the inclination can be made gentler. It is not possible to alter the water level at the settlement site of Võhma I, whereas in the case of the Kõpu VI/V settlement it does not make an essential difference if we lower the water level by 0.5 meters and set the shore level of the habitation time at the altitude of 27 meters (for a location map of the Late Mesolithic Kõpu IV/V site, see Kriiska 1996, Fig. 2). The rectified shoreline gradient acquired this way is 0.179 m/km.

As mentioned above, the shoreline (3) of 5100 cal BC is impossible and needs a radical change in its dates and/or gradient. Knowing that during the discussed era the transgression of the Litorina Sea caused by the rise in the ocean level has been metachronous in the Baltic Sea valley (Kessel & Punning 1995, 227; Raukas 1997, 273), then the method used so far, especially considering the lack of data, is difficult to employ. Thus the time gradient curve was made primary and using the oldest rectified shore surface as well as the Neolithic ones a graphically homogeneous and even time gradient curve was manually drawn (Fig. 5B).

Considering the dated settlement sites for which it is not possible to clearly demonstrate their inundation by transgression, a series of Mesolithic shorelines were projected with the help of the time gradient curve. Due to the inaccuracy of dates and the scantiness of data it would still not provide a sufficiently good

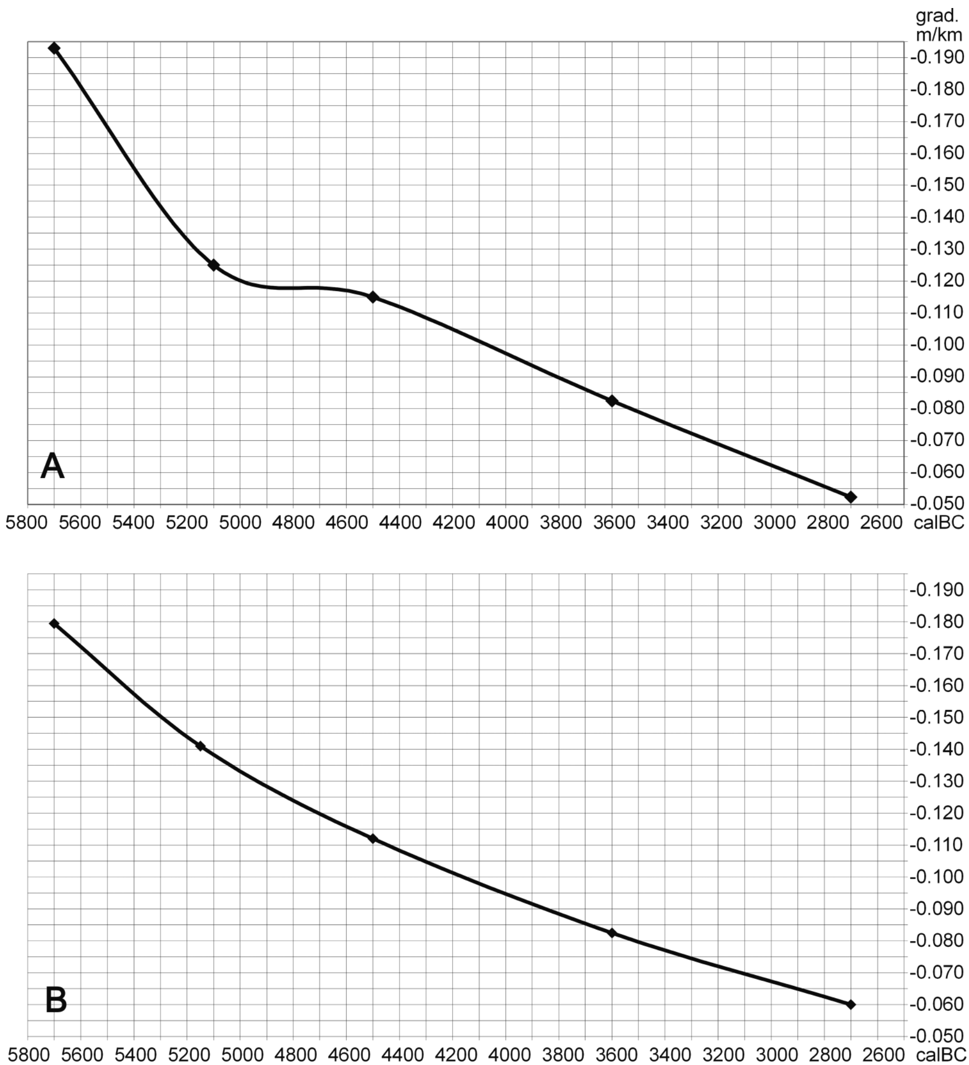

Fig. 5. The time gradient curve (A) gained on the basis of the initial distance-elevation diagram and its "improved" version (B).

Joon 5. Esialgse kaugus-kõrgusdiagrammi põhjal saadud aeggradientkõver (A) ja selle "parandatud" variant (B).

outcome, as far as the Mesolithic settlement sites of Ruhnu are apparently different from the others. If we included these, the assumed water level in Kõpu would rise above 30 meters and this would contradict both archaeological and geological data gathered from the peninsula so far (Lõugas *et al.* 1996). Moreover, all settlement sites of Saaremaa Island would remain under a transgression of several meters.

Thus it remains to be confirmed that the material from Ruhnu cannot be exploited in our shore displacement chronology, the reason being either a difference in the settlement mode or land upheaval. Both alternatives need to be checked before the data can be used.

Considering all of the data the result of the present research is to be regarded as a prognosis, made in order to gain a basis for studies to follow and a tool for pursuing fieldwork. To do that, four lines dated 5500, 5200, 5000 and 4700 cal BC were set into the diagram on the basis of the time gradient curve. They were fitted in the diagram manually, trying to keep the curve of their shore upheaval even, which is in accord with the existing geological matter, and to avoid contradiction with archaeological data, notably the material of Kõpu, Võhma and Pahapilli.

The result refers to a slow metachronous transgression of the Litorina Sea and the genesis of the highest Litorina Sea coastal beach formation dating from 5500 cal BC (Kõpu) to 4700–4500 cal BC (lower reaches of the Pärnu and Narva rivers) in Estonia. In the areas located between –120 meters and –70 meters in the distance diagram the transgression was slow and the changes in the water level were limited during a long period. Thus the dating of the settlement sites of the end of the Mesolithic and the Early Neolithic is difficult.

Interpretation and comparison

The changing of seashores is a process characteristic of the whole Baltic Sea area. In regions with quick compensational land upheaval the process is discernible even within a few generations. Although land upheaval in Estonia is modest comparing to Fennoscandia it has determined and affected our coastal areas over time. This enables us to use the dates of the Stone Age dwelling sites situated directly on the seashore with the help of shore displacement chronology.

The present research includes most of the known Stone Age settlement sites on the Estonian mainland coast and the Western Estonian archipelago. The majority of them have been found or inspected during a series of fieldwork by Aivar Kriiska. Only the sites that have not revealed sufficient information on their location (mostly Northwestern and North Estonian sites; see Lang 1996, 411, 412, 420) are left out of the analysis.

Out of the sixty observed settlement sites, 51 can be dated by shore displacement. According to sufficiently reliable radiocarbon dates the oldest of them – the sites of Sindi-Lodja I and II – originate from the beginning of the Litorina Sea period (Kriiska et al. 2002), when the water level was several meters lower than the maximum of the Litorina Sea transgression. Scarcity of data from the viewed period makes it impossible to date the sites that have later been inundated by the sea and buried under sand layers several meters thick, more exactly than before 5700 years cal BC.

At this moment the settlement sites on the Isle of Ruhnu have to be ignored completely. As was mentioned above, the reason for this can be either a difference in the settlement mode or land upheaval. Either we are dealing here with dwelling sites situated on a small coastal lake higher than the sea or a fold of land upheaval directly between Ruhnu and the rest of Estonia.

Of the settlements on the Isle of Hiiumaa, the site of Kõpu XVII has never been on the seashore. This dwelling site, located 34 meters above the present sea level, has apparently been founded on the shore of a remnant lake situated above the present Kõivasoo Bog and thus the site cannot be dated with a shore displacement chronology following the shore changes of the Baltic Sea (for a location map of the Late Mesolithic Kõpu XVII site, see Kriiska 2003, Fig. 4:3).

In general the dates obtained by us are in accord with the radiocarbon ones as well as those based on artefact typology (Table 2). The settlement sites (on the Isle of Saaremaa and in Western Estonia) situated 100–110 km away from the baseline and on the altitude of 21–22 meters are problematic, since the water level there has long remained in the direct vicinity of the settlements and therefore the coastal sites might have continued in the same places for even longer than a thousand years. In this case it is impossible to distinguish the Late Mesolithic and the Early Neolithic settlement sites without radiocarbon dates or indicator finds in the archaeological material.

The same situation holds for the areas that have been under a Litorina Sea transgression and suitable for seashore settlements during both the transgressive as well as the regressive phase. E.g. Kõnnu in southern Saaremaa, which could have been inhabited in the Late Mesolithic as well as the Early Neolithic, is one of such sites. There the settlement phase of the Early Neolithic has been well represented by pottery of the Narva type. Whether the place was settled also in the Mesolithic as suggested earlier (Jaanits 1995), is impossible to determine by the archaeological material at the present stage of research. Our chronology has given new supportive data to the Typical Combed Ware Culture, which so far has lacked a radiocarbon dating from a reliable context. The dates obtained on the basis of shore displacement, considering only the more probable ones (Table 2), remain between 4120–3600 BC, which corresponds perfectly to the age specifications of the Typical Combed Ware Culture gained from the neighbouring countries (see Kriiska 2001; Lang & Kriiska 2001).

Our shore displacement chronology does not considerably contradict the geologists' conclusions on shore displacement in Estonia. Comparing the altitude of the maximal shore line of the Litorina Sea (Table 3) the results are similar, especially on the Kõpu peninsula where the fossilized beaches have been the most thoroughly fixed so far.

The shore displacement chronology created on the basis of Estonian Stone Age material could also be applied to the Karelian Isthmus up to the hinge line discernible in the northwestern part of the area (Donner 1966; Miettinen 2002). Considering the measuring error the altitude prognoses of the maximum of the Litorina Sea transgression gained by our chronology correspond considerably well with the relevant geological observations. These are slightly higher than the research results of Arto Miettinen in the southern and western part of the Karelian Isthmus

Table 3. The altitude of the maximum of the Litorina Sea transgression by different researchers

Tabel 3. Litoriinamere transgressiooni maksimumi kõrgused eri uurijate alusel

The maximal altitude (m) of the Litorina Sea transgression	The lower reaches of the Pärnu River	The lower reaches of the Narva River	Kõpu peninsula	Northwestern part of Saaremaa Island
Jussila & Kriiska	10.1 (Sindi-Lodja, see Table 2)	8.5 (Riigiküla, see Table 2)	27.4 (Ülendi, see Table 2)	21.4 (Võhma, see Table 2)
Kents 1939	–	–	27.8	–
Кессел Х. & Раукас А. 1981	10	–	25–26	20
Raukas *et al.* 1995	8–10	–	–	–
Moora & Lõugas 1995	–	–	between 26 and 30	
Lepland *et al.* 1996	–	10	–	–

(2002), but are quite similar to the outcome reached by Esa Hyyppä (1937). The greatest difference appears at Babinskoye, where the altitude calculation and dating of Miettinen is distinctly different from ours, though the place under discussion is the closest to our research area, being situated only 30 km off Narva.

According to Miettinen (2002) the Litorina Sea transgression reached its peak on the Karelian Isthmus and in Ingria in 7200-6800 cal BP (Table 4). According to our chronology, there the transgression has been more metachronous, as it gained its highest level at first in the northwestern part of the area (7500 cal BP) and later in the southeastern part (6500 cal BP). Comparing the dates one should take into account that while calibrating the dates Miettinen used an older calibration curve (cal20) that can in places give a remarkably younger result than the more recent calibration curve applied by us (cal40). Miettinen's altitude data for the Russian part of the region have been estimated on the basis of considerably older maps. Thus his and our knowledge cannot be compared quite so directly.

Unfortunately there are no Stone Age seashore settlement sites dated by the radiocarbon method on the Karelian Isthmus and therefore a comparison with the archaeological locations is, as yet, difficult to accomplish. As for archaeological finds the dated material of the four tested settlement sites do not contradict our chronology.[8]

[8] The Tokarevo 1 settlement site (altitude 14 m asl), which is situated on the Karelian Isthmus on the fossilized beach of the Gulf of Finland 88–90 km from the baseline, and whose material included combed ware, is dated to 3500–3300 cal BC by the shore displacement chronology. The shore displacement date of the Tokarevo 2 settlement site (altitude 12 m asl) that also included combed ware is 3100–2900 cal BC. The date of Vaahtola Karhusuo (altitude 14 m asl) with its biface flint arrowhead characteristic of combed ware cultures is 3500–3300 cal BC by the shore displacement chronology. The shore displacement date of the settlement site of Metsäkylä Sulfiittitehdas (altitude 18 m asl), a site without any pottery, is 4400–4200 cal BC and in case the site has been under transgression 5600–5700 cal BC (for information on the sites and their find material see Uino *et al.* 2004).

Table 4. The altitude and dates of the maximum of the Litorina Sea transgression on the Karelian Isthmus and in Ingria by different researchers

Tabel 4. Litoriinamere transgressiooni maksimumi kõrgused ja dateeringud Karjala kannasel ja Ingerimaal eri uurijate alusel

Site	Distance from the baseline (km)	The altitude of the maximum of the Litorina Sea transgression (m) – Miettinen 2002	The date of the maximum of the Litorina Sea transgression cal BP – Miettinen 2002	The altitude of the maximum of the Litorina Sea transgression (m) – Jussila & Kriiska	The date of the maximum of the Litorina Sea transgression cal BP – Jussila & Kriiska distance-elevation diagram with Estonian Stone Age sites, lengthened to the Karelian Isthmus	The altitude of the maximum of the Litorina Sea transgression (m) – Ramsay 1920	The altitude of the maximum of the Litorina Sea transgression (m) – Hyyppä 1937
Virolahti	–127	23–26	7300–6900	24.8	7500–7200	–	–
Vysokinskoye	–60	13 (15)	7200–6900	15.4	7000–6500	17–18	14–15
Privetninskoye	–34	11	7200–6800	12.3	6700–6500	14	12
Glukhoye	–7	8–9	7100–6800	9	6700–6500	10–11	8–9
Babinskoye	–4	11	7100–6800	8.7	6700–6500	–	–

The shore displacement chronology of the Estonian Stone Age is hereby presented only as a first version and it suffers from shortage of material: there are not enough sites, especially those studied more thoroughly and dated by the radiocarbon method, while occasionally paleogeographic information on the settlement sites is insufficient as well. Nevertheless, the general layout is complete now and the archaeologists who study Estonian coastal areas have an example to follow and their new data can be integrated in the shore displacement chronology in the future.

The results of our chronology can be used to detect new sites (after having made a prognosis for potential dwelling places) as well as to interpret the existing ones. It does not only produce information on the settlements situated directly on the seashore but it enables one to explain how far the sea was at the time of the existence of the observed dwelling or burial sites. Our chronology has been successfully used to calculate, for example, the distances of the Estonian Corded Ware Culture settlement sites from the sea (Kriiska & Tvauri 2002, 79).

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Timo Jussila ja Aivar Kriiska

EESTI KIVIAJA RANNASIIRDEKRONOLOOGIA

Resümee

1990. aastate keskel hoogustunud Eesti rannikuala ja saarte kiviaja uurimine on toonud mitmesuguseid tulemusi alates asustus- ja majandusajaloolistest üldistustest kuni kiviaja absoluutse kronoloogia ja periodiseeringu täpsustamiseni. Inspektsioonikäikudel ja kaevamistel kogunenud andmed lõid aga ühelt poolt vajaduse ja teisalt ka võimaluse alternatiivse, rannasiiret arvestava kronoloogia loomiseks. Vajaduse sellise dateerimisviisi järele tingib eelkõige asjaolu, et enamikul avastatud muististest ei ole seni toimunud ja küllap ei toimu veel ka lähemas tulevikus arheoloogilisi väljakaevamisi. Seetõttu puuduvad neist muististest radiosüsinikumeetodil tehtud dateeringud. Kuigi suur osa asulakohtadest on üldjoontes dateeritav leiuainese järgi, on avastatud ka selliseid kohti, kust ei ole saadud selgeid indikaatorleide, määramaks isegi arheoloogilist kultuuri.

Rannasiirdekronoloogia rakendamise ja arendamise pioneerideks on olnud soome arheoloogid. Nad on näidanud, et veesidusatest elupaikadest, mis on järginud maakerkest ja veekogude arengust tingitud veetaseme muutusi, saadud andmeid (vanus, kõrgus tänapäevasest merepinnast jne) ühendades on võimalik saada iseseisev dateerimismeetod. Rannasiirdekronoloogiat on Soomes edukalt rakendatud nii uute muististe väljaselgitamisel kui ka olemasolevate tõlgendamisel. Kuna Eesti puhul on tegemist samuti kompensatsioonilise maatõusu alaga, siis võib meetodit põhimõtteliselt siingi rakendada. Täidetud on teinegi oluline tingimus: nimelt on ka Eesti ala püügimajanduslikud kiviaja elupaigad asetsenud enamjaolt vahetult veekogude ääres, hiljemalt hilismesoliitikumist alates mererannal (joon 1, 2).

Metoodika ja lühike uurimislugu

Laiu alasid katva rannasiirdekronoloogia loomiseks on parim meetod kaugus-kõrgusdiagramm. Selle abil tehtud kronoloogia põhineb maa kallakul, mis tuleneb piirkondlikest erinevustest maakerkes. Kaugus-kõrgusdiagrammis esitatakse muistsed rannajooned tasapindadena, mis projitseeritakse diagrammi sirgetena. Diagrammi horisontaalskaalal näidatakse kaugus valitud põhiliinist (joon 3) ja vertikaalskaalal kõrgus praegusest merepinnast. Tänapäevane rand on diagrammis horisontaalne ja muinasrannad eri viisil kaldes.

Rannasiirdekronoloogia loomisel liidetakse diagrammi uuritavalt alalt kogutud andmed samaaegsetest randadest. Tavaliselt piisab kahest üheaegsest rannast diagrammi eri osades, mille vahele projitseeritav sirge markeerib selle konkreetse aja rannajoont. Kindla ajaga liituva rannajoone täpne määratlemine on aga raske ja sageli ei ole olemas andmeid täiesti samaaegsetest randadest või on need tõlgenduslikud (näiteks ^{14}C dateeringud). Seepärast ollakse praktikas sunnitud kasutama mitmeid eri meetodeid sünkroonsete randade saamiseks ja dateerimiseks.

Niisiis otsitakse rannasiirdekronoloogia tegemisel samaaegseid rannajooni ja dateeritakse need. Igal üksikjuhul on tarvilik vaagida kõrguse kohta käiva teabe usaldusväärsust ja vanusemäärangute täpsust ning kiviaja asulate puhul otsustada, kas tegemist on olnud rannasidusa elupaigaga. Lõpptulemused sõltuvad dateeritud randade kohta oleva teabe hulgast ning nende vanuse- ja kõrgusmäärangute täpsusest.

Geoloogid on kasutanud kaugusdiagrammi muinasrandade ja nende kallaku kirjeldamiseks juba 20. sajandi algul. 1920. aastatel algas Läänemere rannasiirdel põhineva Soome esiajaloolise keraamika suhtelise kronoloogia loomine ja samal kümnendil prooviti kiviaegseid asulakohti juba kaugus-kõrgusdiagrammi abil dateerida. Hiljem on seda andmestikku oluliselt täiendatud ja võetud arvesse radiosüsiniku dateeringud.

Eestis ei ole seni arheoloogiliste muististe dateerimiseks kaugus-kõrgusdiagrammi kasutatud. Üksikmuististe dateerimiseks on tehtud vaid lihtsaid neotektoonikal põhinevaid arvutusi.

Rannapindade paigaldamine ja dateerimine Eesti arheoloogilise ainese põhjal

Eesti kiviaja rannasiirdekronoloogia koostamisel on võetud arvesse 60 Mandri-Eesti rannikul ja Lääne-Eesti saartel paiknevat kiviaegset asulakohta (joon 3, 4; tabel 2). Need asetati kaugus-kõrgusdiagrammile, mõõtes iga objekti kauguse 1 : 350 000 mõõtkavas Eesti kaardile projitseeritud põhiliinist. Viimane joonistati 56º-se nurga all joonel Rannametsa–Olustvere–Avinurme–Narva. See lähtub (on risti) maksimaalse maakerke asimuudist, mida Eestis on Litoriinamere rannaprotsesside vaatlemisel üpris üldiselt paigutatud suunda 326º ning mis paikneb laias laastus neotektooniliste isobaaside 0 ja +1 mm/aastas vahel (vt nt Miidel 1995, joon 1).

Lisaks arheoloogilistele andmetele on arvestatud pinnavorme. Kõikidel muististel on määratud kultuurkihi alumise piiri kõrgus praegusest merepinnast ja peamiselt maastiku reljeefi alusel prognoositud asustusaegne veetase. Rannajoonte projitseerimiseks ja dateerimiseks on kasutatud 33 radiosüsiniku dateeringut (tabel 1). Kaugus-kõrgusdiagrammi koostamisel jagati asulakohad olemasolevate teadmiste põhjal viide põhilisse kronoloogilisse rühma: keskmesoliitikum, hilismesoliitikum, varaneoliitikum, keskneoliitikum ja hilisneoliitikum (joon 4; tabel 2).

Radiosüsiniku dateeringute järgi võib vanimana eristada rannajoont vanusega 5700 aastat eKr Võhma I ja Kõpu IV/V asulakohtade vahel. Muististe kaugused põhiliinist on vastavalt –141,8 km ja –105,5 km ning kaugus teineteisest sobiv, et projitseerida piisava täpsusega rannajoon. Maastiku reljeefi arvestades paiknes Kõpu IV/V asustusaegne mererand arvatavasti 27,5 m ja Võhma I asustusaegne rand 20,5 m kõrgusel praegusest merepinnast (joon 2). Neid ühendav joon annab maa kalde gradiendiks 0,193 m/km.

Järgmisse ajahorisonti kuulub radiosüsiniku dateeringute järgi kolm asulakohta: Ruhnu II, Kõpu VII/VIII ja Pahapilli I, kusjuures rannajoone saab tekitada vaid esimese ja teise muistise vahele. Radiosüsiniku määrangud neist kohtadest võimaldavad selle dateerida aastaga 5100 eKr. Neid ühendav joon annab maa kalde gradiendiks 0,1255 m/km.

Varaneoliitilise rannajoone eristamiseks on kasutada viis radiosüsinikumeetodil dateeritud asulakohta: Riigiküla IV, Riigiküla IX, Riigiküla XII, Kõpu IA ja Ruhnu II. Nende kõrgusi ja paiknemist kaugus-kõrgusdiagrammis arvestades on ainuke võimalus projitseerida rannajoon samaaegsete asulakohtade vahele Riigikülas ja Kõpus. Kõpu IA asulakoha vanimate dateeringute aegne (umbes 4500 aastat eKr) meri oli maastiku reljeefi arvestades umbes 24,5 m kõrgusel praegusest merepinnast (joon 1). Riigiküla IV asulakohal vastab sellele ajale veetase kõrgusel 8,5 m üle praeguse merepinna. Nii eristub aastaga 4500 eKr dateeritav rannajoon gradiendiga 0,115 m/km, mis on kaldelt igati sobiv varasemate rannajoontega.

Keskneoliitilise rannajoone projitseerimist takistab asjaolu, et tüüpilise kammkeraamika kultuuri asulakohtadest ei ole Eestis seni ühtki usaldusväärset radiosüsiniku dateeringut. Seetõttu on rannajoone paigaldamiseks ja dateerimiseks vajalik leida muu lahendus, milleks on käesolevas uurimuses kasutatud leiuainese arheoloogilis-tüpoloogilist analüüsi. Selget ja muust keraamikast ühemõtteliselt eristuvat tüüpilist kammkeraamikat on leitud Ranniku-Eestis Kõpu IB, Lemmetsa II, Malda, Sindi-Lodja III, Jõekalda ja Naakamäe asulakohtadest. Asetades need asulakohad kaugus-kõrgusdiagrammile, nähtub, et need ei asetu ühele rannajoonele, vaid näivad ajaliselt hajuvat. Lemmetsa II ja Naakamäe on alumised ja neist madalamal paiknevatest muististest ei ole tüüpilist kammkeraamikat leitud. Mõlemat asulakohta ühendab ka see, et elutegevus jätkus neis paikades veel tüüpilisele kammkeraamikale järgnenud hilise kammkeraamika perioodil, samas puuduvad aga tüüpilise kammkeraamika kultuurist vanemad asustusjäljed. Seega elati seal just perioodil, kui tüüpiline kammkeraamika vahetus hilise kammkeraamikaga. Arvestades hilise kammkeraamika alguse dateeringuid Eestis, Soomes ja Lätis, võib selle üleminekuaja dateerida umbes aastaga 3600 eKr ja nii ajaldada ka neid asulakohti ühendava rannajoone. Viimase asend ja kalle (0,082 m/km) kaugus-kõrgusdiagrammil on teisi rannapindu arvestades sobivad.

Noorimad püügikultuuri asulakohad Ranniku-Eestis kuuluvad hilisneoliitikumi ja seonduvad hilise kammkeraamika kultuuriga. Hilist kammkeraamikat, mis ajaliselt võiks kuuluda hilisneoliitikumi, on leitud Loona, Naakamäe, Kaseküla, Lemmetsa I ja Kudruküla asulakohtadest. Teistes muististes võib seda tüüpi keraamika olla ka vanem kui 3200/3000 aastat eKr, mis on kokkuleppeliseks kesk- ja hilisneoliitikumi piiriks Eestis. Nii nagu eelmise rannajoone puhul, eristuvad kaks asulakohta – Loona ja Kudruküla –, mis on diagrammil kõige alumised. Radiosüsiniku dateeringud on neis aga erinevad (tabel 1).

Kui Loona puhul on asustusaegne mererand maastiku reljeefi arvestades suhteliselt hästi määratav ja lauget pinnamoodi arvestades ei olnud see väga pikaajaline rannaasulakoht, siis Kudruküla paleogeograafia on paljus ebaselge. Lisaks võis seal juba kiviajal kujuneda väike jõgi (Kudruküla oja), mis andis seal ka mere taandudes ehk võimaluse asustuse jätkumiseks. Nii võib Loona dateeringut arvestades prognoosida veetaseme kõrguseks 2700. aastal eKr 11 m praegusest merepinnast. Kuna Kudruküla ei sobi oma andmete ebatäpsuselt Loonaga üheaegse rannajoone projitseerimiseks, tuleb esialgu leppida vaid arvutusliku prognoosiga. Arvestades eelnevate rannajoonte vahelise kallaku muutuseks aastas umbes 0,000035 m/km, peaks aastasse 2700 eKr kuuluva rannajoone gradient olema 0,0523 m/km. Kui selle kalde järgi esitada rannajoon Loona kõrguse kaudu, paiknes toonane meri Kudruküla asulakoha oletatavast alumisest piirist 1 m allpool.

Aeggradientkõvera abil tulemuste kontrollimine ja täpsustused

Kaugus-kõrgusdiagrammi põhjal tekkiv aeggradientkõver peab olema korrapärane ja ühtlane. Meie tulemuste järgi saadud kõveras on aga märgatav erand 5100. aasta kohal eKr (joon 5A). See sunnib rannajoonte projitseerimisel kasutatud aluseid uuesti ja põhjalikumalt vaatlema. Kuna neoliitiliste rannajoonte kohal on aeggradientkõver korrapärane ja ühtlane ning arheoloogilise ainese põhjal on võimatu nende kallet vähendada nii palju, et noorema hilismesoliitilise rannapinna osa kõverat parandada, peab viga olema rannajoones vanusega 5100 aastat eKr.

Ka vanim rannajoon vajab veidi kohendamist, muutes kas dateeringut vanemaks või gradienti laugemaks. Viimane on võimalik, sest Kõpu VI/V asulakoha puhul ei ole olulist vahet, kui veepinda alandada 0,5 m võrra ja oletada asustusaegne veepind 27 m kõrgusele tänapäevasest merepinnast. Saadud parandatud rannajoone gradient on 0,179 m/km.

Nagu eelnevalt tõdetud, on aastaga 5100 eKr dateeritud rannajoon võimatu ja vajab dateeringutes ja/või gradiendis radikaalseid muutusi. Teades, et vaadeldaval ajajärgul on ookeani pinnatõusust tingitud Litoriinamere transgressioon Läänemere nõos olnud metakroonne, on siiani kasutatud meetod (eriti andmete vähesust arvestades) raskesti kasutatav. Seetõttu võeti primaarseks aeggradientkõver, ning kasutades vanimaid parandatud ja neoliitilisi rannajooni, joonestati käsitsi graafiliselt korrapärane ja ühtlane aeggradientkõver (joon 5B).

Võttes arvesse radiosüsinikumeetodil dateeritud asulakohad, mille puhul ei ole võimalik selgelt näidata nende jäämist transgressiooni alla, projitseeriti hulk mesoliitilisi rannapindu aeggradientkõvera abil. Dateeringute ebatäpsuse ja andmete vähesuse tõttu ei anna see siiski piisavalt head tulemust, kusjuures Ruhnu mesoliitilised asulakohad erinevad teistest silmatorkavalt. Nende kaasamisel peaks Kõpus veetase tõusma kõrgemale kui 30 m ja see oleks vastuolus praeguseks poolsaarelt kogunenud nii arheoloogilise kui ka geoloogilise andmestikuga ning ka kõik Saaremaa asulakohad jääksid mitmemeetrise transgressiooni alla. Nii tuleb tõdeda, et Ruhnu aines ei ole praegu meie rannasiirdekronoloogias kasutatav, põhjuseks on kas erinevus asustusviisis või maakerkes. Mõlemad võimalused nõuavad kontrollimist.

Kogu andmestikku arvestades võeti suund prognoosivale väljundile, saamaks aluse edasisteks uurimisteks ja abivahendi välitööde teostamiseks. Selleks asetati aeggradientkõvera põhjal diagrammi neli joont dateeringutega 5500, 5200, 5000 ja 4700 aastat eKr, sobitades need käsitsi diagrammi arvestusega, et nende rannatõusu kõver oleks ühtlane (mida eeldab olemasolev geoloogiline aines), nii et need ei oleks Kõpu, Võhma ja Pahapilli arheoloogilise ainesega vastuolus.

Saadud tulemus osutab Litoriinamere aeglasele metakroonsele transgressioonile, kusjuures Litoriinamere kõrgemate rannamoodustiste kujunemise võib Eesti alal dateerida vahemikku 5500 aastat eKr (Kõpu) kuni 4700–4500 aastat eKr (Pärnu ja Narva jõe alamjooks).

Tõlgendus ja võrdlus

Uurimusse kaasatud 60 Mandri-Eesti ranniku ja Lääne-Eesti saarte kiviaja asulakohast on 51 dateeritavad rannasiirde järgi.

Piisava usaldusväärsusega radiosüsinikumeetodil dateeritud Sindi-Lodja I ja II asulakohad pärinevad Litoriinamere algusest, mil meri oli mitmeid meetreid allpool hilisemast Litoriinamere transgressiooni maksimumist. Andmete vähesus sellest perioodist ei võimalda neid hiljem mere poolt üle ujutatud ja mitme meetri paksuse liivakihi alla mattunud muistiseid dateerida rannasiirdekronoloogia abil hilisemasse aega kui 5700 aastat eKr.

Ruhnu saare asulakohad peab esialgu täiesti välja jätma. Nagu öeldud, võib selle põhjuseks olla erinevus asustusviisis või maakerkes. Tegemist on kas merest kõrgemal paiknenud väikese rannajärve kaldal asunud elupaikadega või on Ruhnu ja muude Eesti alade vahel maakerke murdejoon.

Hiiumaa asulakohtadest ei ole mererannas paiknenud Kõpu XVII asulakoht. See praegusest meretasemest 34 m kõrgemal asuv elupaik rajati tõenäoliselt praeguse Kõivasoo kohal olnud jäänukjärve kaldale ning seetõttu ei ole seda võimalik dateerida Läänemere randade muutust jälgiva kronoloogia abil.

Laias laastus on rannasiirdekronoloogiaga saadud dateeringud vastavuses muististest saadud radiosüsiniku vanusemäärangute ja esemetüpoloogiast lähtuvate dateeringutega (tabel 2). Probleemsed on põhiliinist 100–110 km kaugusel ja 21–22 m kõrgusel paiknevad (Saaremaa ja Lääne-Eesti) asulakohad, kus veetase on püsinud pikka aega asulate vahetus läheduses, mistõttu on rannaasulad võinud samades paikades olla isegi enam kui tuhat aastat. Niisugustel juhtudel on hilismesoliitikumi ja varaneoliitikumi asulakohti ilma radiosüsiniku dateeringute või arheoloogilise ainese süvaanalüüsita võimatu eristada. Sama tuleb rakendada juhtudel, kui asulakohad on jäänud transgressiooni alla ja paigad on olnud mererannaasulateks sobilikud nii transgresseeruvas kui ka regresseeruvas faasis.

Häid ajalisi pidepunkte pakub meie koostatud rannasiirdekronoloogia tüüpilise kammkeraamika kultuurile, millest seni ei ole Eestist ühtki kindla kontekstiga radiosüsiniku dateeringut. Rannasiirdedateeringud jäävad tõenäosemaid vanuseid arvestades (tabel 2) vahemikku 4120–3600 aastat eKr, vastates hästi naabermaadest saadud vanusemäärangutele.

Käesolevas artiklis esitatavas kronoloogias ei ole märkimisväärseid vastuolusid varem geoloogiliselt põhjalt tehtud järeldustega rannaprotsesside kohta Eestis. Võrreldes näiteks Litoriinamere maksimaalse rannajoone kõrgust (tabel 3), on tulemused üpris sarnased, eriti Kõpu poolsaarel, kus muinasrandu on fikseeritud seni kõige põhjalikumalt.

Eesti kiviaja ainese baasil tehtud rannasiirdekronoloogia peaks põhimõtteliselt olema rakendatav ka Karjala kannasel kuni piirkonna loodeosas täheldatud maakerke murdeliinini. Arvestades mõõtmistäpsust, vastavad meie kronoloogia põhjal saadavad Litoriinamere transgressiooni maksimumi kõrgusprognoosid võrdlemisi hästi geoloogilistele tähelepanekutele, eriti 1930. aastatel E. Hyyppä poolt saadud tulemustele. A. Miettineni (2002) hiljutiste uurimustega võrreldes on meie kronoloogia kohaselt Karjala kannasel ja Ingerimaal olnud transgressioon metakroonsem, kusjuures piirkonna loodeosas saavutas see kõrgeima taseme varem (5500 aastat eKr) ja kaguosas hiljem (4500 aastat eKr). Kahjuks ei ole Karjala kannasel radiosüsiniku meetodil dateeritud mereranna asulakohti, mistõttu on võrdlus sealsete arheoloogiliste muististega raskendatud. Kasutades aga arheoloogiliste leidude dateeringut, ei ole nelja testimiseks võetud Karjala kannase asulakoha (Tokarevo 1, Tokarevo 2, Vaahtola Karhusuo ja Metsäkylä) aines meie kronoloogiaga vastuolus.