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# Drowned Early Mesolithic Landscapes on the Baltic Sea Bed in the Lithuanian Waters

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**Abstract:** This paper presents underwater relict forest fossil and ancient coast formation exploration results in the eastern Baltic Sea. Tree fossils and sediment layers discovered in the sea-bed were dated with $^{14}C$ along with palynological and dendrological analysis. Based on the obtained data, a fragment of submerged early Holocene landscape, coastline of the Yoldia Sea and Ancylus Lake has been reconstructed. The research data determine that vegetation and natural conditions of the Yoldia Sea coastal were favourable for Early Mesolithic communities. Well-preserved relict pine forest dates are also crucial to Baltic Sea water level dynamics analysis during the period: end of Yoldia Sea-Ancylus Lake.

**Key words:** Underwater relict forests, underwater archaeology, Yoldia Sea and Ancylus Lake coasts, Baltic Sea level fluctuations.

## 1. Introduction

In 2002, submerged fossil tree stumps were discovered for the first time in the eastern Baltic Sea in situ Lithuania territorial waters. Explorations of the relict forest in 2010-2014 included reconstruction of the Early Holocene Baltic Sea coastline and also an investigation of the ancient coastal landscape. The work included three phases: exploration with SSS (side scan sonar) using multi-beam technology. Direct underwater exploration was carried out by diving and analysis of the materials in laboratory (palynological, radiocarbon and dendrological). Based on the geological and underwater archaeological explorations, attempt was made to reconstruct Baltic Sea bed relief, coastline of the Baltic Sea at different formation stages and the natural as well as cultural landscapes of the Yoldia Sea and Ancylus Lake coasts in detail. In addition, Baltic Sea water level fluctuations and possible human living conditions on the ancient coasts were established as well.

## 2. The Baltic Sea Coasts in the Late Pre-Boreal and Boreal

During Pre-Boreal (9600-8250 BC[1]), a part of Baltic Ice Lake water effused into the Atlantic Ocean [1, 2]. A reverse flow of saline ocean water into the formerly fresh water basin formed the brackish Yoldia Sea which presumably existed in the area of Gotland Island about 10300-9300 BP[2] (9600-8700 cal.[3] BC) [3]. The Yoldia Sea water level was low. Yoldia Sea coasts on the eastern and south-eastern parts of the Baltic Sea are expected to be found at a depth of 50-40 m b.s.l. (below the present sea level) [4-9].

Another fresh Baltic Sea basin—the Ancylus Lake—existed from the second half of Pre-Boreal and through Boreal to the beginning of the Early Atlantic, approximately 10,700-8,300 years ago [2, 3] or 9300-8000 BP and 8700-7400 BP [10, 11]. On the Lithuanian coastal line, three phases of Ancylus Lake have been determined: transgression (10,700-9,970 years ago), regression (9,970-9,230 years ago) and the 2d transgression (9,230-8,300 years ago) [12].

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[1]Before Christ.
[2]Before the present.
[3]Calibrated.

The data about the Ancylus Lake coasts in the eastern part of the Baltic Sea are scanty and much of them are contradictory. The researchers are at variance as to the maximal water level during the Ancylus Lake transgressions and regressions.

## 3. Methods of Underwater Exploration

In 2002, URC IBSRHA[4] archaeologists found the tree stumps [13] 3.5 km from the present coast, at a depth of 27 m. This spot was marked as RF-I (relict forest I). This location (coordinate of the middle point 55°31′000″ N, 21°00′000″ E) is on the edge of the underwater peninsula Curonian Plateau[5] (Fig. 1). More detailed investigations of RF-I were carried out in 2010, 2011[6] and 2014. Total explored sea bed area amounted to 30 km$^2$. The depth in the study area varied from 16 m to 47 m; the distances from the shore ranged within 2.5-18.5 km.

In the investigated area, the Baltic Sea bed is covered by Quaternary deposits and sediments. The thickness of the Holocene sediments in the open sea makes only a few to some centimetres. The stumps and logs in the first research area are marked RF-I-A[7]. The radiocarbon dated root age is 9160 ± 60 BP, 8090 cal. BC. Anatomic analysis of wood showed that the fossils belonged to *Pinussylvestris*. The absolute age of the root indicates that the pine grew in Pre-Boreal when the water level in the Baltic basin was 30 m b.s.l. [14]. In 2010-2014, a few tens of relict forest fossils were explored under the water.

An object identification problem occurred on the sea-bed during SSS relict forest exploration in RF-I region. During the diving works in situ, it turned out that some objects were not stumps or trunks as it was preliminary identified. The small size of stumps in growth position prevented their detection in the SSS records. The acoustic backscatter is similar to that for stones. The difference showed up only at a small distance (5-6 m) of the sonar “fish” to the sea bottom. The acoustic backscatter is for the stumps with black mark (boon) in the middle of the object. The backscatter values from the area around the stump edge differ, the sides having higher backscatter intensities than the boon (Fig. 2).

Applying authentication method, from 477 selected targets in the RF-I site, 109 objects were identified as likely trees stumps and logs. However, the underwater research has shown that some of the lying trunks, especially the smaller ones, were partially or almost completely covered up by sediment, therefore invisible by SSS. So it can be claimed that in the 30 km$^2$ area, there can be twice as many relict forest tree stumps and trunks preserved.

Analysis of the data showed that tree stumps and trunks were unevenly distributed over the explored area on the sea-bed. According to SSS data, the greatest accumulations of underwater objects were observed in the north-eastern and central parts of the area explored in 2010/2011. For underwater exploration carried out in 2011-2014, a few sites with higher concentrations of stumps and trunks were chosen.

During the exploration, relict tree groups RF-I-A, RF-I-B, RF-I-C, RF-I-E and RF-I-H were identified and investigated (Fig. 3).

There were two goals of exploration: (1) to register the preserved stumps, fallen trunks and other vegetation elements in a chosen area and to saw off samples for dendrochronological and other analysis; (2) to explore the bed area for traces of human activity in Early Mesolithic.

### *3.1 Location of Relict Trees*

During these investigations, 32 tree stumps and lying trunks were examined and measured under water.

[4]The Underwater Research Centre of the Institute of Baltic Sea Region History and Archaeology, Klaipėda University.
[5]The underwater Curonian Plateau is situated in the Lithuanian and Russian (Kaliningrad region) waters near the Curonian Spit. It extends north-west of the recent coast for 50 km to a depth of 50 m. 20 km north-west of the coast there is a projection about 30 km in length and 35 km in width [9].
[6]This research was funded by a grant (No. MIP-005/2011) from the Research Council of Lithuania.
[7]Relict Forest one, group A.

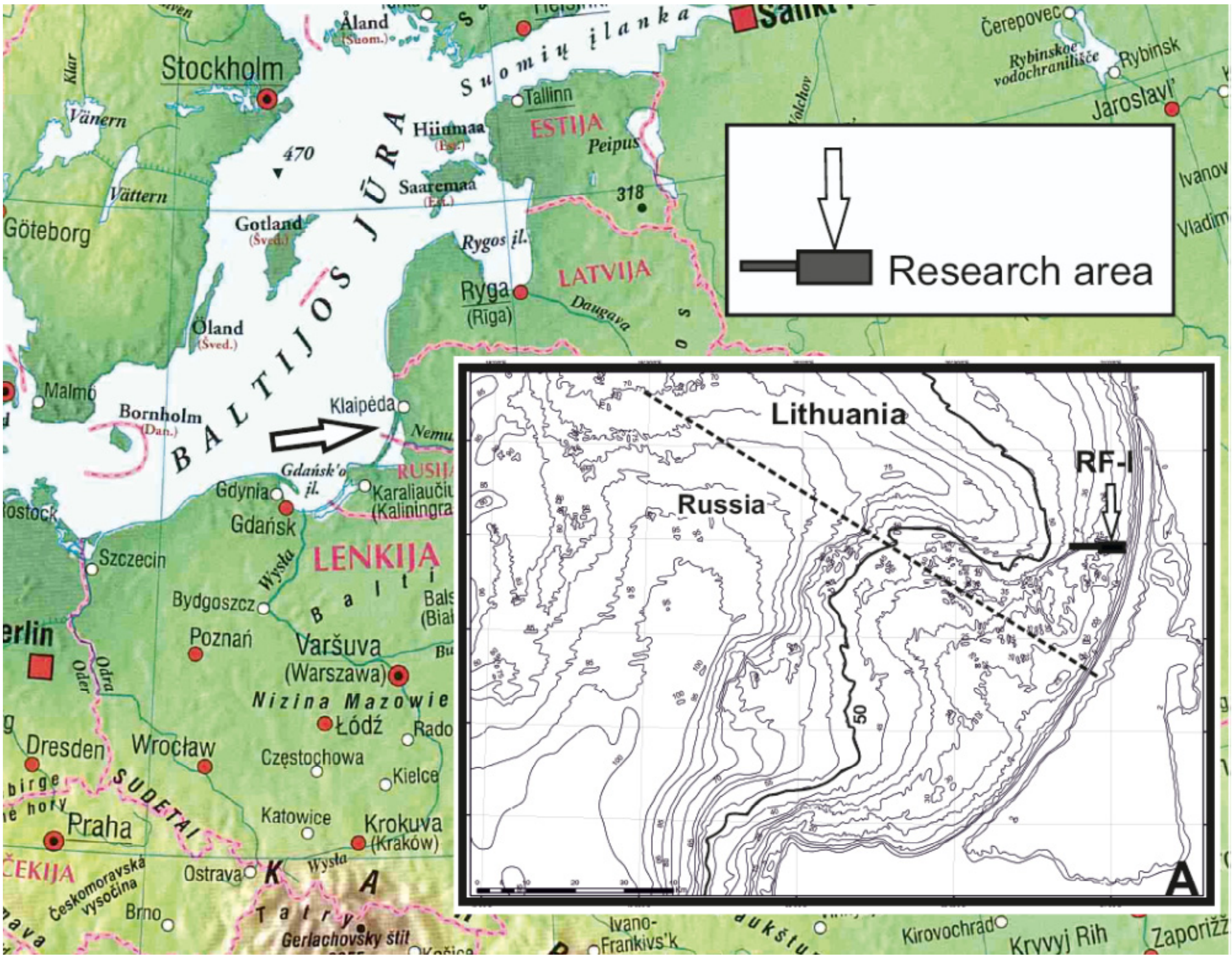


**Fig. 1 Location of the research area. A underwater Curonian Plateau [9].**

The roots of all stumps were in loam layer which almost everywhere consists of sand or siltys and deposits (Fig. 4).

All stumps were found in situ. The rooted out stumps were not discovered. Five groups of relict trees were examined in greater detail. Positions of pine trunks were determined. The trunks were lying side by side. None of them were lying criss-cross, at right angle to each other or atop of each other. It was determined that all relict pine trunks were oriented towards E-W[8] direction. There was not a single trunk oriented N-S[9]. Moreover, all rooted out trunk roots were positioned towards west to the sea-side. The pine trunks had broken tops. The preserved stumps also belonged to broken trees. In some places, stumps were found near the lying trunks.

A small group of the tree stumps RF-I-A were found at a 27 m depth, near a terrace about 1 m in height. The remains of trees from group RF-I-B were discovered at a depth of 25 m to 25.5 m and they were lying very close to each other (Figs. 5-7). A part of the chosen area RF-I-C was explored in greater detail at a depth of 24.5 m to 25 m. A few stumps with denuded roots were lifting up to 70 cm above the sea-bed.

There were a few small fallen trees and two 3 m and 4 m long fallen trunks with exposed roots. One of the trunks (RF-I-C-3) was 57 cm in diameter. In this site, a well preserved jaw of Atlantic cod (*Gadus morhua*) was found in a 5-10 cm thick layer of sand with shells underlying the surface of 20-25 cm thick

[8] East-west.
[9] North-south.

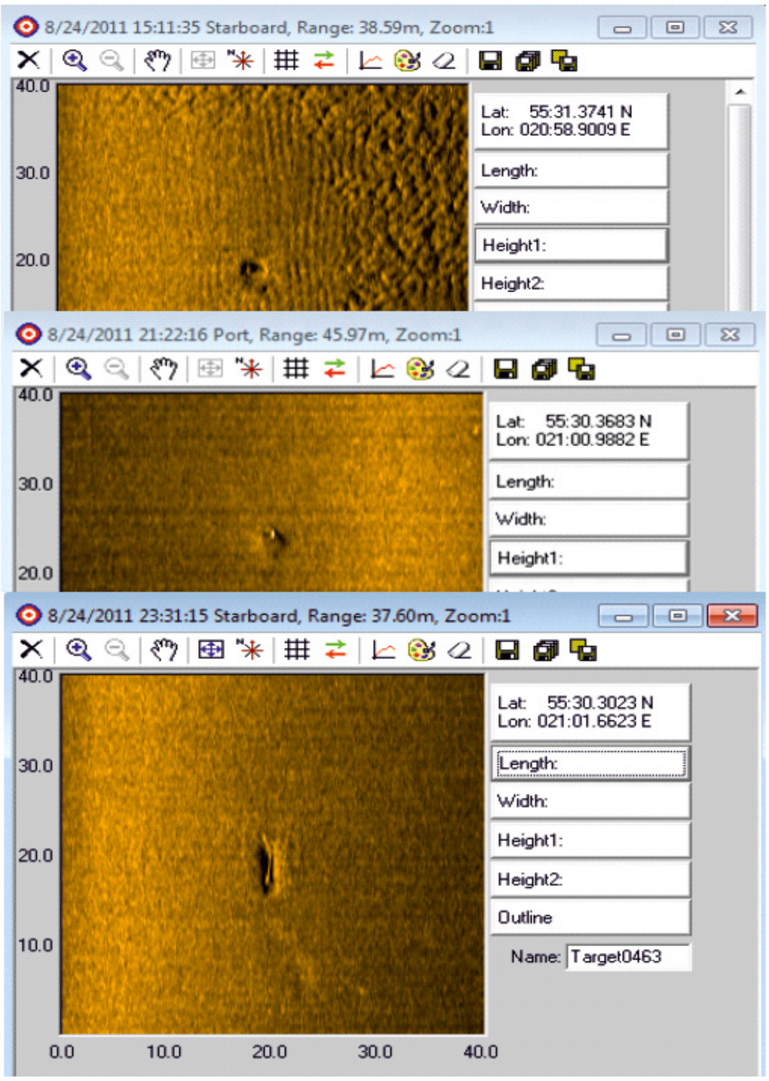


**Fig. 2 The acoustic backscatter from a side-scan sonar identified like relict tree stumps and trunk [15].**

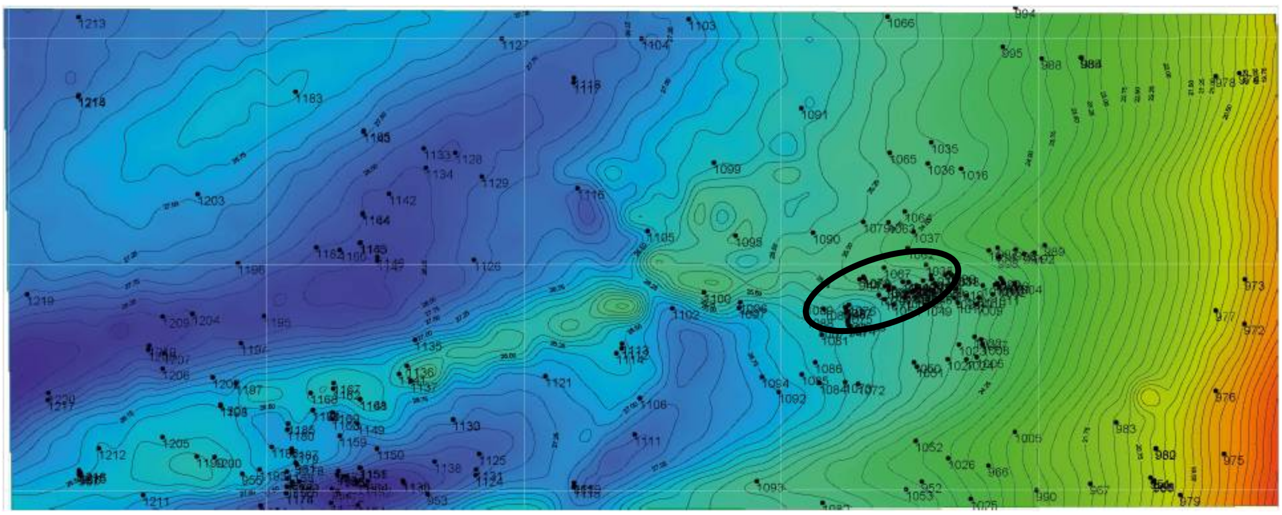

**Fig. 3 Explored Baltic Sea bed section and main investigated underwater relict tree group RF-I-A, RF-I-B, RF-I-C location [15].**

**Fig. 4 RF-I-C-1 tree group, a pine stump.**

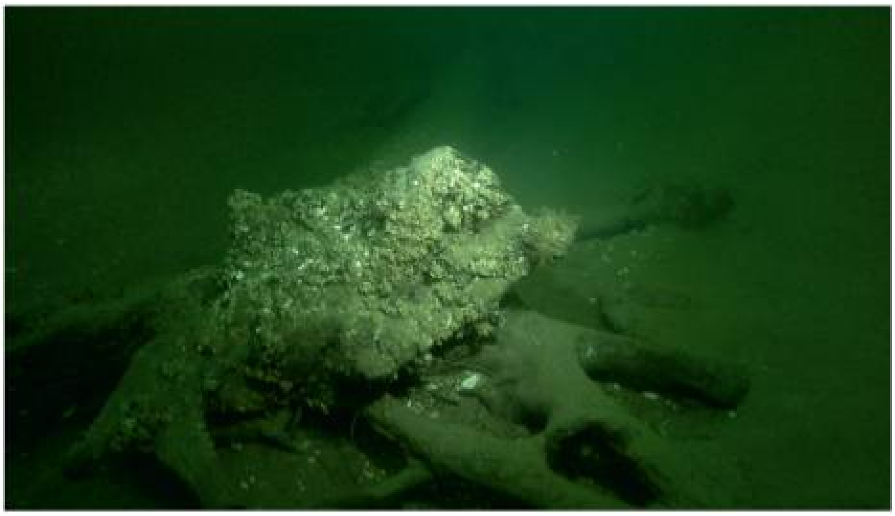

**Fig. 5 RF-I-B-1 tree group, a pine tree trunk.**

**Fig. 6 RF-I-B-1 tree group, sawn-off pine tree trunk.**

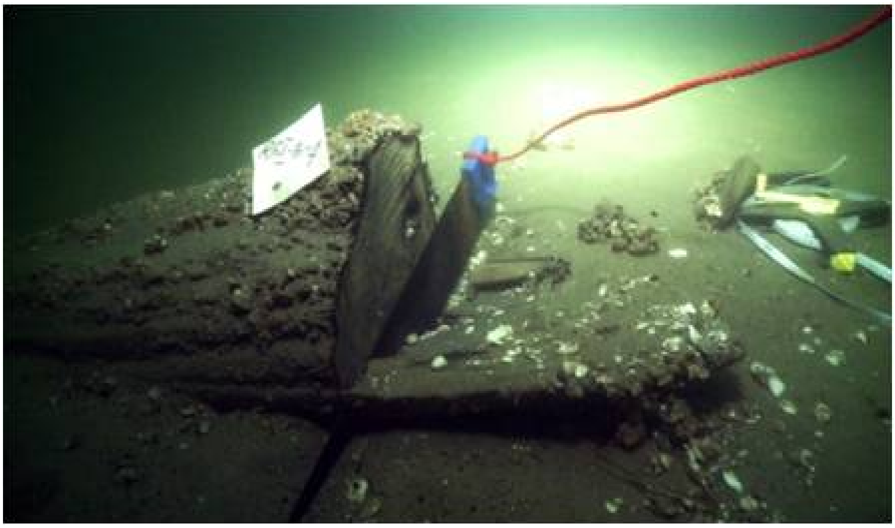

**Fig. 7 RF-I-B-4 tree group, sawn-off pine tree trunk.**

layer of salty sand. The deeper layer was composed of clay.

A fragment of peat was discovered near the roots.

Group of trees RF-I-E was situated considerably further, 6.5 km west of the groups RF-I-B and RF-I-C. The depth at that point was 29-30 m.

In the central part of the investigated area, peat layers were discovered in situ (RF-I-P-1A, B). Peat deposits were detected at a depth of 29 m. They looked as the upper ridge of a large peat bed. The 20-35 cm thick peat layer was overlying a sand layer. A trunk (about 30 cm in diameter) with branches was found lying near the peat layer.

Twelve samples from the sea bed have been dated[10].

The greatest number of relict forest stumps and trunks, including the dated ones, were discovered at a depth of 25-29 m; yet they were unevenly distributed. The dates of samples taken within one group were comparable. The groups of trees spaced by greater distances were distributed at different depths. The difference in their dates is also more noticeable. RF-I-C trees dates are 8700-8675 cal. BC and 10440-10230 cal. BP. Peat found next to this group is dated 8840-8570 cal. BC. Trees from group RF-I-B were lying very close to each other, and they were dated back to the same time as trees from group RF-I-C: 8820-8550 cal. BC, 9135-8970 cal. BC, 9255-9125 cal. BC. Group of trees RF-I-E were situated considerably further to the groups RF-I-B and RF-I-C. One of the few pines from this group (RF-I-E-1) is dated to 9355-9130 cal. BC (Table 1).

### 3.2 Dates of Relict Trees and Peat

Samples fit for tree ring analysis could be sawed off from almost all trunks of greater diameter[11]. The aim of dendrochronological analysis was to determine the correlation of samples and to frame the relative chronological scale[12]. In 2011 and 2012, seven *Pinus sylvestris* trunk test samples from the sea-bed were sawed off for dendrochronological research. Five test pieces were suitable for tree-ring measurement. The explored underwater relict pine forest was relatively young: four pine ring measurements showed that biological age of relict pines were 103, 117, 121 and 138 years. According to the data, the relict forest on the Baltic Sea (RF-I) bed was 139 years old[13].

[10] Dating was implemented at the Radioisotope Research Laboratory, Nature Research Centre of the Institute of Geology and Geography, Vilnius, Lithuania. Protocols of $^{14}C$ dating: RTL-119, RTL-163 and RTL-164.

[11] Trees are in diameter: 10-15, 18, 28, 28, 38, 30, 30, 39, 40, 40, 45 and 57 cm.

[12] The cross-sections of trunks were dendrochronologically analysed by Dr. Mindaugas Brazauskas (Institute of Baltic Sea Region History and Archaeology, Klaipėda University).

[13] The measured width of growth rings were statistically correlated using “PAST 32” software.

**Table 1 Dating of wood and peat samples by radiocarbon method ($^{14}C$).**

| Index and sample number | Sample | Age $^{14}C$ BP | Age cal. BC |
|---|---|---|---|
| Vs-2019 | RF-I-C-1, pine | 9180 | 8391 ± 143 BC |
| Vs-2018 | (RF-I-B), pine | 9170 | 8437 ± 120 BC |
| Vs-2020 | (RF-I-B), peat | 7480 | 6340 BC |
| Vs-2254 | RF-I-B-5, pine | 9555 | 9135-8970 BC |
| Vs-2255 | RFI-C-3, pine | 9300 | 8700-8675 BC |
| Vs-2256 | RFI-C-3, peat | 9435 | 8840-8570 BC |
| Vs-2257 | RF-I-E-1, pine | 9770 | 9355-9130 BC |
| Vs-2272 | RF-I-B-2, pine | 9685 | 9255-9125 BC |
| Vs-2273 | RF-I-B-4, pine | 9410 | 8820-8550 BC |
| Vs-2275 | RF-I-P (RF-I-X), peat | 7970 | 7045-6445 BC |
| Vs-1372 | RF-I-A, pine | 9160 | 8090 BC |

Synchronization of wood samples showed that they ceased to grow at different times; trees withered within an interval of 32 years.

## 4. Natural Environment

The Baltic Sea bed in the area of the underwater Curonian Plateau (studied in 2010-2014) is sandy, rather smooth and sloping westwards. 2-3 m high underwater hills and troughs were found over the whole study area at a greater depth (30 m) extending northeast-southwest (Fig. 8). In this area, three narrow (100-200 m wide and 1.5-2 km long) troughs at a depth of 29-30 m were discovered. One of the troughs contained peat beds in situ. Sea-bed around these troughs is higher: at a depth of 27-24 m.

A flat sandy surfaces, hills and troughs were all overgrown with pine forest. A sloping (about 1 m in height) terrace was found near the trees from group RF-I-A. Its slope is composed of till sediments and surrounded by small boulders.

Forest relicts were altogether absent in the western periphery of the study area at a depth of 29 m and deeper. Along the 29 m isobath (at this depth tree stump RF-I-E-1 was discovered), the coastline of the forest was reconstructed before the submergence at the western edge of the area. The ancient coastline was highly broken by capes and washlands extending far into the land (Fig. 9). The ancient coasts are marked by small terraces on the sea-bed which were detected with side-scan sonar at 29-30 m depth.

In the westernmost edge of the surveyed area, 15 km to 15.5 km from the coast, an ancient coast structure was discovered. A depth of 37-39 m sonar showed a very unusual underwater terrain (Fig. 10). This probably was a washed off ancient coast remains [14]. These bottom forms could have been generated by the rising waters of Ancylus Lake. Degraded remains of terraces were detected at the depth of 39 m and further to the west, deeper into the sea, at a depth of 43 m, a low continuous underwater terrace was also found that was extending to north-south.

At depths of 44 m and 47 m, underwater ridges, small terraces and presumed disrupted coast structures were observed. Supposedly, they are relicts of an ancient coastal terrace from the Yoldia Sea.

The dates of relict forest fossils and peat in situ (Table 1) serve as an evidence that discovered underwater landscape with small lagoons and relict forests have developed at different times. So far known $^{14}C$ dates of the relict pines are within the 9355-9130—8391 ± 143 cal. BC interval. The peat found in situ at a depth of 29 m (RF-I-P-1A, B) (Fig. 10) is dated to 7045-6445 cal. BC. The date of peat

[14]During the first stage of Ancylus Lake, the presumable water level was 33-37 m b.s.l. [14].

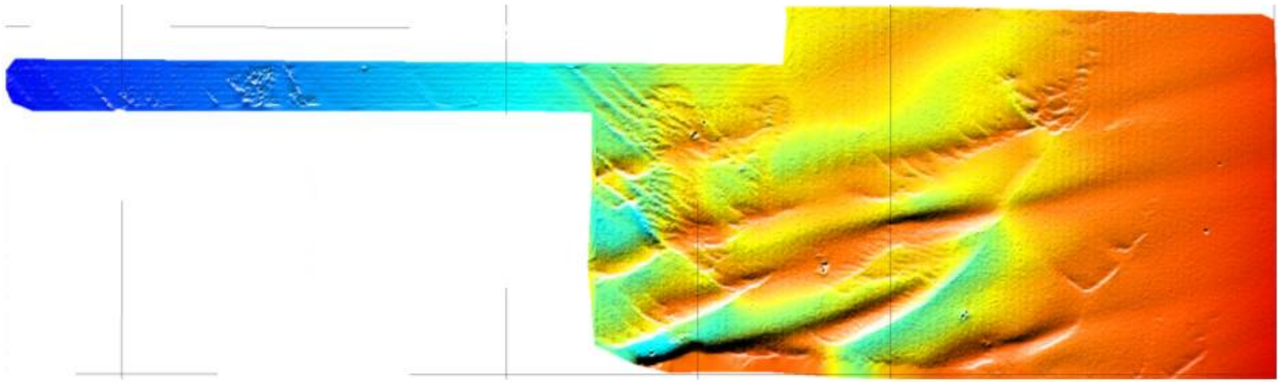

**Fig. 8 Sea bed in the area [15].**

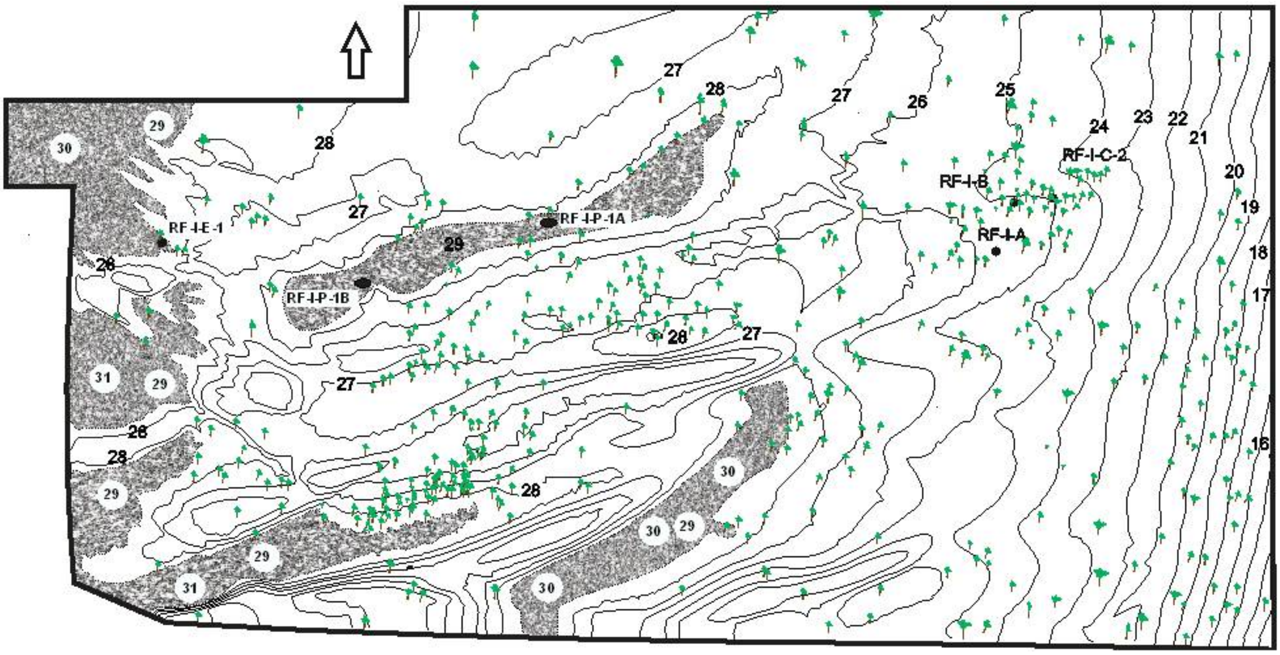


**Fig. 9 The relict pine forest and the Baltic Sea ancient coasts in the explored area.**

fragment discovered in group RF-1-B is similar—6340 cal. BC (Table 1). The interval of these dates, 7045-6340 cal. BC, implies that it has formed long after the existence of the pine forest.

Relict forest in the reference area grew on flat morainic sand-covered hills at the end of Yoldia Sea stage—the beginning of the Ancylus Lake transgression within approximate 9355-8090 BC time interval. The Yoldia Seacoast extended 5-5.5 km west of this drowned forest. At that time, coast also had small closed fresh water bodies, where active sedimentation and peat formation took place. The peat sample discovered at a depth of 45 m was dated 9000 BP [11]. Possibly, the peat fragment found near the roots of the relict tree RF-1-C-3 was brought by the rising waters. It is date to 8840-8570 BC (Table 1).

The rising water during Ancylus Lake transgression flooded small hills overgrown with pines and the troughs between them. The relict trees were discovered at depths of 24-29 m. At lower depths, they were absent. This could be taken as a sure evidence that the water level during the Ancylus Lake transgression was above 24 m of the present sea level. Otherwise, the relict pine stumps and trunks would not have been preserved. 7045-6340 cal. BC (when peat layer was deposited), the water level must have stayed

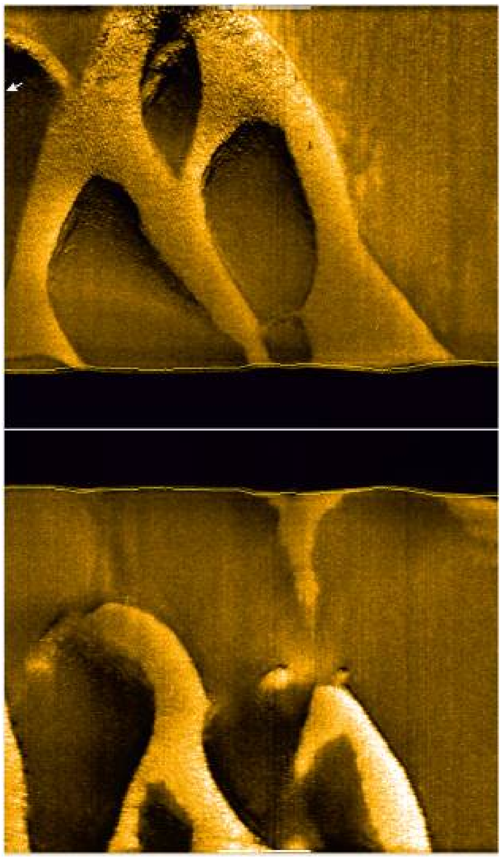

**Fig. 10 The Baltic Sea coast formations in the depth of 37-39 m [15].**

at a level of about 23 m b.s.l. for a long time. It is likely that at that time the coast of a nearly freshwater Ancylus Lake [16] was situated in this area. Sedimentation took place in the littoral zone and small bottom troughs. Peat bed of more than 35 cm in thickness formed in the areas such as RF-I-P-1B. It is assumed that at the time of peat bed formation (7045-6445 cal. BC), this trough might have been 4 m below the coastline (Fig. 11).

Peat also was deposited in shallower places close to the coasts of the ancient lake. The peat fragment found at a depth of 25 m was dated to 6340 cal. BC. Sediments with freshwater diatoms, which could have inhabited the Ancylus Lake, were detected at 12-24 m b.s.l. [17-19]. The conditions in the lagoons of the ancient coast were favourable for peat formation. This is obvious from the composition of peat sample taken from RF-I-P A. Palynological analysis revealed the composition of Pre-Boreal vegetation whereas macro-botanical examination showed the presence of hydrophytic species including buckbeans (Latin—*Menyanthestrifoliate*).

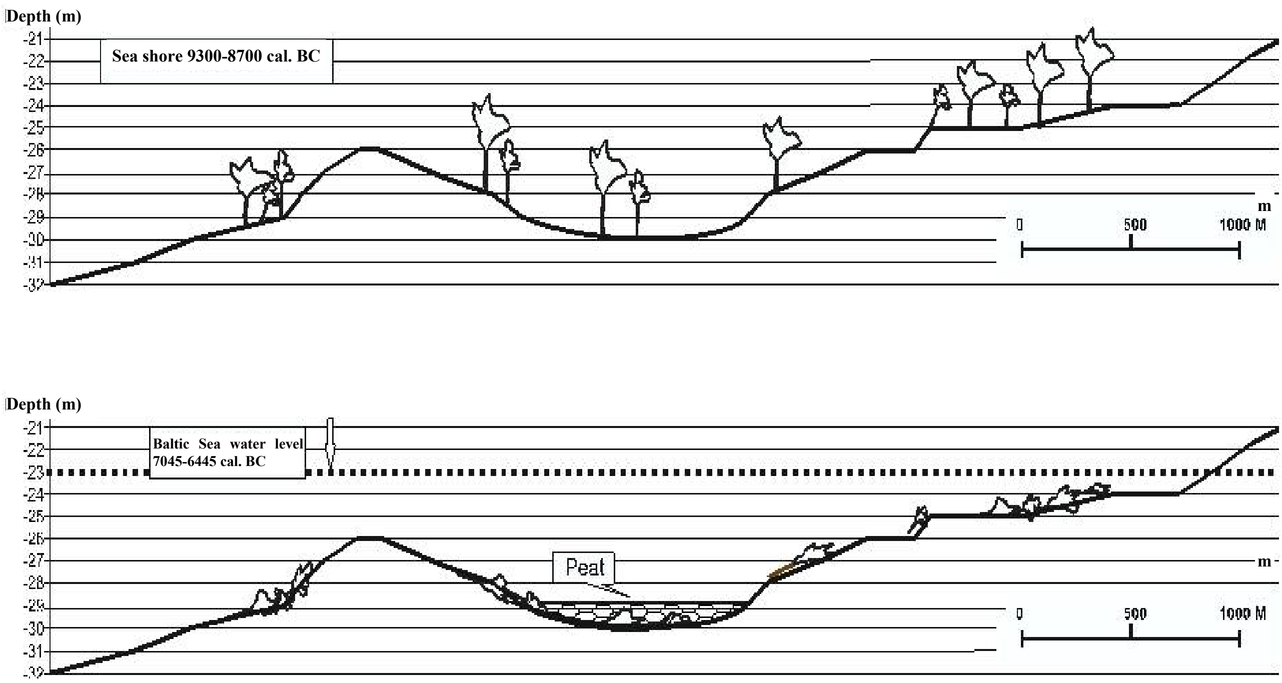


**Fig. 11 The Baltic Sea coast in the explored area (Yoldia Sea to Ancylus Lake transgression).**

At the beginning of Pre-Boreal, the coast was overgrown with birches and small pine groves.

Meanwhile, at the end of Pre-Boreal, pine groves expanded and birches became sparser [20]. A sparse pine forest grew not too far from the sea, in a sandy and partlyclayey soil. Alders, somewhere even nut-trees, and dwarf scrubs could have grown near the lagoons, traces of which were detected under water. According to the data of palaeobotanical and isotopic analysis of sediments (Fig. 12), the spores-pollen spectrum is characterized by a marked pollen count of pinus and deciduous trees (*Corylus*, *Quercus*, *Alnus*). Pollen of broad-leaved trees—lime (*Tilia*), oaks (*Quercus*) and elm (*Ulmus*)—also were detected in the sediments. Spruce (*Picea*) pollen was only found in a few specimens. The content of grass pollen in sediments is not very high, however, representatives of the sedge and grass families (*Cyperaceae* and *Poaceae*) are dominant. It is obvious that the area at the time of sedimentation had enough water. However, the climate was relatively cool what is proved by an identified club spikemosses (Latin-*Selaginelaselaginoides* L.). Palaeobotanical data suggest that sedimentation took place at the beginning of Holocene, the end of Pre-Boreal and Boreal. It was related to the Yoldia Sea period or, more precisely, with the transition period from Yoldia Sea to Ancylus Lake [21]. It is obvious that the vegetation cover in the territory was rather rich and the landscape was rather open. The grass cover near the coastal lagoons formed the peat layer preserved till nowadays.

After determining the Yoldia Sea-Ancylus Lake coastal strip, which existed for about 1,000 years (approximately 9300-8400 year BC), the questions arise whether it could have been settled or if the natural environment suited the people. It is also interesting whether it is promising to seek for some material evidence about human habitation and economic activity.

The living conditions on the Yoldia Sea coast were considerably better than in the areas by the recent coast. Further away from the Yoldia Sea coast, sources of food and raw material were fewer than in the coastal strip. The coast with lagoons, bays and influents were a favourable area for human habitation. It was abundant in marine resources (especially seals and high species diversity of fish), coastal forest fauna and coastal migratory birds. This allowed developing effective subsistence economy. It is assumed that the

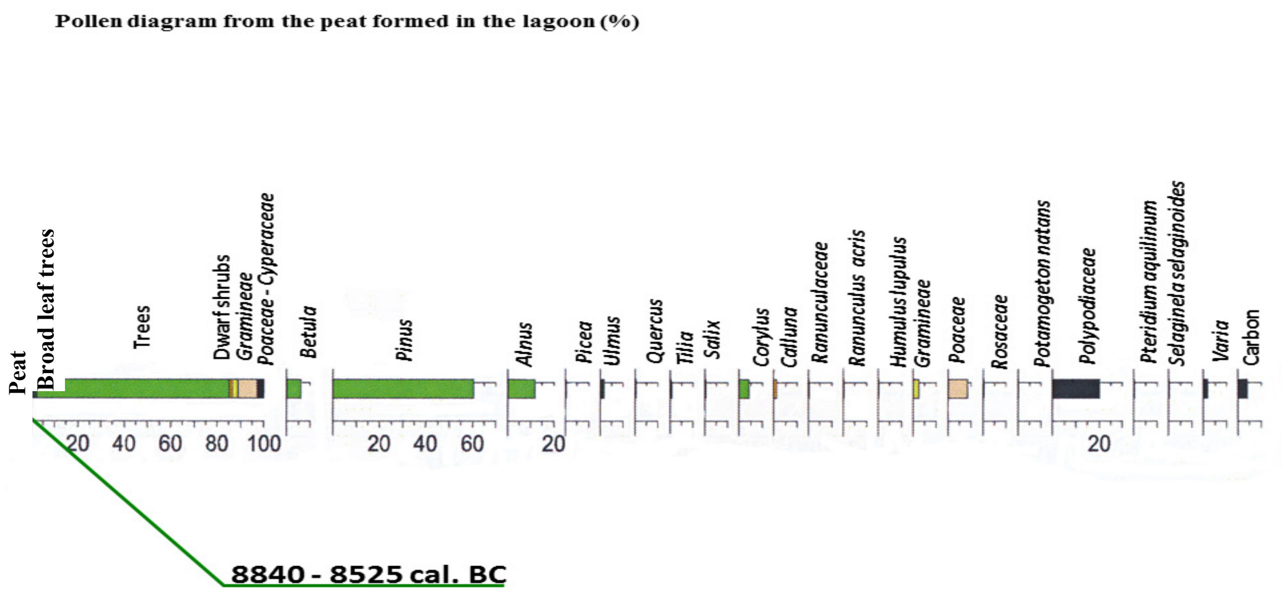


**Fig. 12 Pollen diagram from the peat formed in 8840-8525 cal. BC [15].**

population of the former Baltic Ice Lake coasts moved to the newly formed Yoldia Sea coastline with abundant fauna as a source of human survival.

Therefore, in the current coast, which partly coincides with the Baltic Glacial Lake shores in the Early and Middle Mesolithic, the settlements are difficult to detect (Fig. 13). Settlements must have been concentrated on the Yoldia Sea coasts, which now are on the Baltic Sea bottom. Only the Late Mesolithic settlements are known in the recent continental Lithuanian Baltic Sea coast. In 2009-2011, three of them were identified: Palanga, Šilmežiai and Būtingė.

For a long time, nobody assumed that remains of pre-historic settlements might be preserved on the sea bed. A similar ecological and economic situation existed in the territory of south-eastern part of the Baltic Sea in the Early Neolithic period. The Early Neolithic settlements are not known in the recent coastal strip [22, 23]. When the water level between the 1st and the 2nd phases of Litorina Sea subsided [12, 24], the Early Neolithic population must have inhabited the territories in closer proximity to the relict sea coast. Later, their settlements must have been submerged. The traces of the Early Neolithic settlements should be sought at a depth of 10-14 m.

## 5. Results and Discussion

The research results provided new data about the relict Baltic coasts, sea-level fluctuations in the Early Holocene, coast all and scape reconstruction and coastal settlements. On the other hand, the interpretation of the data is ambiguous, and leaves a number of questions. Not all of them can be answered today.

The relict pine forest survival in the sea-bed at a depth of 25-30 m is an exceptional phenomenon. Massively surviving relict forest stumps and trunks

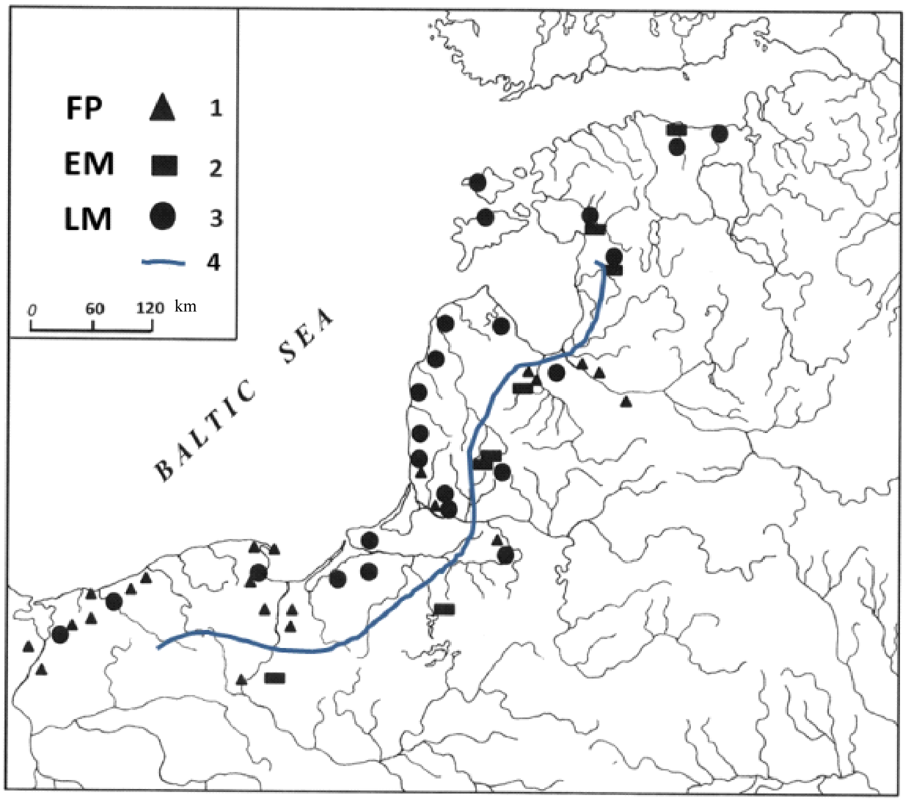


**Fig. 13 (1) Spread of Final Palaeolithic; (2) Early Mesolithic; (3) Late Mesolithic sites; (4) east Baltic area that does not contain any Early Mesolithic sites.**

(even amounting up to 200 at the explored spot alone) are not yet known anywhere else except in the Lithuanian waters. Considering the issue of relict forest survival, one should bear in mind that the investigations were only carried out in a relatively small underwater area, in the northern part of the Curonian Plateau. What options do we have for the future research?

In the context of relict forest submergence investigation, the orientation of the tree trunks discovered on the sea-bed should be kept in mind. They are lying in situ, as if after the fall they did not float in the water. The implication is that between the event when the forest was torn away and the full submergence of the area there was a certain time span: too short for pines to rot away and long enough to make them saturated with water and too heavy to float. This is in accordance with the recorded fast transgression process of the Ancylus Lake in the southern area of the Baltic Basin and with the calculated sporadically intensifying water-level rise by 5-10 m within 100 years span [25].

During this transgression, the water level might have markedly risen. According to the Lithuanian researchers, the water level of the Yoldia Sea and Ancylus Lake near the Lithuanian coasts had to be 8.8-9.5 m b.s.l. [18-20], or 4 m b.s.l. [12, 26, 27]. During the following regression, the water level stabilised at about 23 m b.s.l.. The peat layer formed in RF-I-P-1B, which according to contemporary measurements reached 35 cm in thickness, shows that 7045-6340 cal. BC the water level persisted at about 23 m b.s.l. for 300-400 years. These data are in good correlation with results from investigation of German coasts. Around 6700 cal. BC, the water level in the southern Baltic area was 22-23 m b.s.l. and later, 6700-6100 cal. BC, rapidly rose [25]. According to the Polish coasts data obtained, during the Ancylus Lake stage, the water level in the eastern Baltic region had reached 26-28 m b.s.l. [14]. The Lithuanian geologists presume that there had been the 2nd Ancylus Lake regression during which 9310 ± 20-8870 ± 40 BP (8300-8000 $^{14}$C year BP) the water level in the Baltic Sea fell to a depth of 41.3-39.9 m [9, 10].

According to the data obtained in RF-I, at the end of Anclyus Lake stage, the water level in the eastern Baltic region had not fallen below 24 m b.s.l.[15]. These data are fairly accurate because the palaeo-environment of the submerged micro-region was explored from up-close and the samples were taken from concrete relict trees and peat in situ. For $^{14}$C dating, the samples of tree stumps, trunks and peat were taken from a comparatively small area (4 × 0.5 km). Six samples of relict pines (groups RF-I-A, RF-I-B, and RF-I-C) were taken from an area sized 450 × 130 m. The explored underwater landscapes are in the zone of very small glacio-isostatic land transformations [26]; therefore, the obtained results may serve as benchmarks for future investigations of the Baltic Sea water level fluctuations.

How long did this forest grow? After the $^{14}$C dates, it follows that the pines were able to grow in this place for almost a thousand years. But so far explored under water pine forest was a relatively young one. Only the remains of a single fully rotten big stump have been recovered (a root ring about 2 m in diameter around an empty centre). More detailed information about the age of the underwater Curonian Plateau forest could be gained by more accurate $^{14}$C dates and dendrochronological relict pine dates.

Is it possible to achieve greater accuracy in dating the forest by dendrochronological method? Currently, the derivative relative age scale of relict pine forest RF-I embraces only 139 years. Further investigations are expected to considerably extend this scale. Perhaps it will be possible to contemporize it with the absolute dates embracing the whole Holocene [28].

Does the coastal formations detected 15 km to 15.5

[15]Differences in water level calculations could be due to the earth's crust Lzostate of sink in the eastern and southern coast of the Baltic Sea [26].

km from the coast at depths 37-47 m mark the oldest coastline of the maximally sunken Baltic Sea? The available data support the presumption that Yoldia Sea[16] water level has dropped 50 m beneath the present Baltic Sea water level. However, more precise dates of the samples from the coast are not available yet.

The Holocene water level fluctuations in the eastern Baltic Sea seem to have been less dynamic than in the western part of the sea [25], entailed no conspicuous coastal transformations and did not substantially change the landscape. The flat east Baltic coasts would get exposed during regressions to be gradually submerged again during transgressions. The transgression waters intensively abraded the coastal cliffs yet almost did not affect the lower areas. Therefore, the remains of relict forests also exist in other underwater areas. The dates of isolated stumps found at Klaipėda-1.3 km from the shore (RF-III) at a depth of 11 m, and 3 km from the shore (RF-II) at a depth of 14.5 m are dated to 7612 ± 66 cal. BC and 5831 ± 120 cal. BC (7770-120 BP), respectively [13]. These are the remains of forests growing on the coasts, which later submerged considerably within the region explored in 2010-2014.

This also may serve as a background for search of submerged cultural Early Mesolithic and Early Neolithic landscapes. The remains of relict forests in the recent coastal areas might have been preserved under the sediments even when the water subsided. In the 19th century, relict stumps in RF-III were observed under the water very close to the shore [30].

Fossil trees have not yet been found at depths 30-43 m. Why is it that trees failed to preserve at these depths though they preserved on the coast further from the Ancylus Lake? This could mean that 10,000 years ago either the 3-4 km wide coastal strip was not overgrown with forest or fossil trees or was destroyed by unevenly rising water during the Ancylus Lake transgression. In the initial stage of Ancylus Lake transgression, the water rise could have been slow; waves eroded the coast, destroying the primal landscape. Later the transgression gained speed and in short time inundated the forests and wetlands of coastal plains conserving its remains, which were detected during the present investigation.

The absolute dates of water levelare problematic, since the dates of geological layers, even little remote from each other, are quite different. Significantly lower scatter of dates could be achieved if dated not geological but cultural layers and relict forest trees. If one is to compare the data of submerged trees, cultural layers and artefacts, the scattering of dates are to a lesser degree. A benchmark can be data from the submerged forests because it is the key in determining Baltic Sea water level fluctuation from the Yoldia Sea-Ancylus Lake period (Fig. 14).

Analysing the map of the eastern Late Palaeolithic and Mesolithic settlements on Baltic Sea coasts, one may get an impression that in Early Mesolithic recent coastal sector between the Gulf of Riga and Vistula River was not populated. The known Early Mesolithic sites in the territory of Lithuania are located 50-80 km east of the recent Baltic Sea coast. In the territory of Latvia, they are located between the Daugava and Lielupe rivers about 25 km away from the recent coast. The Early Mesolithic settlements are not known in the Kaliningrad Region (Russia) and in the zone of Gdańsk Bay in Poland [31]. Meanwhile, the Middle and Late Mesolithic settlements are known not far from the recent Baltic Sea coasts [32-35]. This is indicative in the coastal zone which was 20-24 m below the present sea level in Early Mesolithic sites.

The composition of relict forest and riparian vegetation at depths 25-30 m confirms that the Boreal to Boreal) at the time of the former Baltic coastal water basin were favourable for habitation and successful farming in Early Mesolithic Kunda natural conditions (climatic conditions from Pre-Pulli) cultural communities. Search for the traces of people

[16]According to the varve data, the Yoldia Sea turned into saline water body in one year 10430 BP [29].

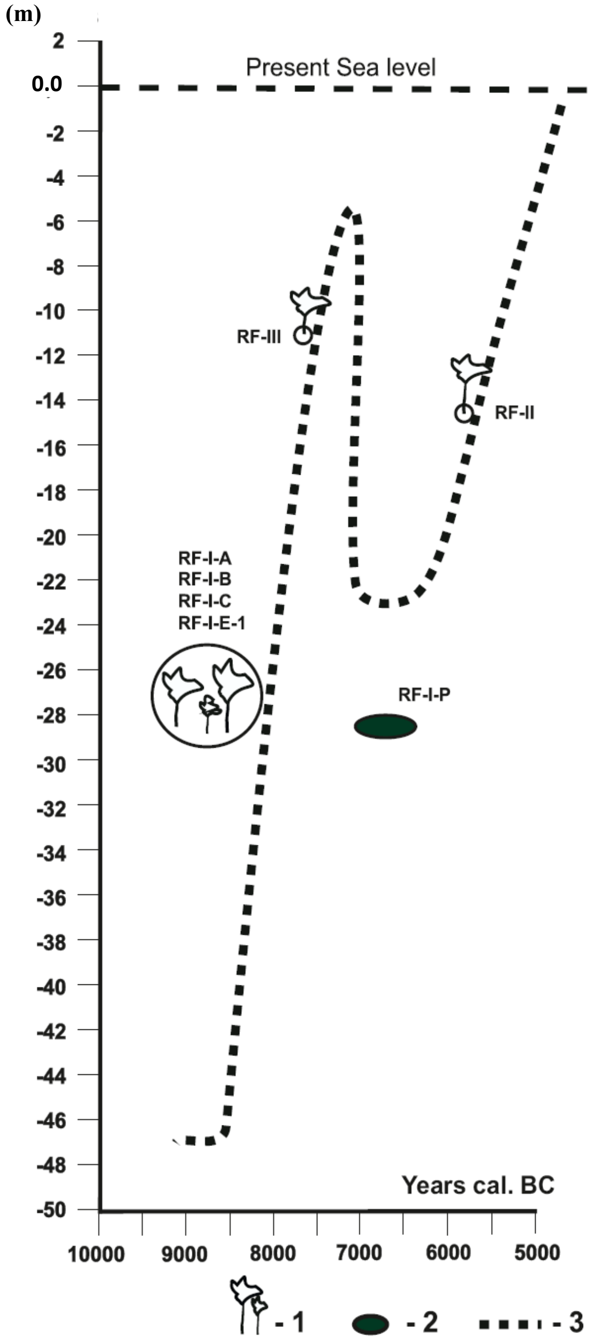


**Fig. 14 The Baltic Sea water level fluctuation (Yoldia Sea to Ancylus Lake transgression): 1—relict trees; 2—peat; 3—Baltic Sea water level fluctuation curve.**

that were living in the now flooded landscape of the Yoldia-Ancylus period should be one of the most important objectives for future research. Obtained data are very important in making palaeo-geographical findings and planning future marine geology and underwater archaeological research.

## 6. Conclusions

The data of underwater exploration from the Curonian Plateau allowed localising coasts of the Baltic Sea during the Yoldia Sea and Ancylus Lake formation stages, specifying their chronology, reconstructing the coastal landscape and discussing the possible living conditions in the Early Mesolithic period. The benchmark dates of the Baltic Sea water fluctuations in Holocene were determined and the development of dendrochronological scale of Early Holocene pine was undertaken.

During the exploration of Baltic Sea ancient coasts in the Yoldia Sea and Ancylus Lake phases, stumps and trunks dated to 9300-8700 cal. BC of relict pine forest growing on the ancient later submerged coast were discovered at a depth of 24-30 m. 7045-6340 cal. BC, the Baltic Sea water level fell down to 23 m b.s.l. and persisted for 300-400 years. At that time, peat beds were deposited in these coastal lagoons. The data obtained by exploring well preserved underwater relict forest on the ancient Yoldia Sea coastal zone showed that it was predominated by pines (*Pinussylvestris*). The ancient coast had freshwater lagoons and, according to palynological investigations, was a favourable habitat for hydrophytic plant species. The ancient Yoldia Sea natural coastal landscape and climate conditions in the transitional time span between Pre-Boreal and Boreal offered favourable living conditions for Early Mesolithic communities.

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## References

[1] Andrén, E., Andrén, T., and Sohlenius, G. 2000. "The

Holocene History of the Southwestern Baltic Sea as Reflected in a Sediment Core from the Bornholm Basin." *Boreas* 29: 233-50.

[2] Jensen, J. B., Petersen, K. S., Konradi, P., Kuijpers, A., Bennike, O., Lemke, W., and Endler, R. 2002. "Neotectonics, Sea-Level Changes and Biological Evolution in the Fennoscandian Border Zone of the Southern Kattegat Sea." *Boreas* 31: 133-50.

[3] Andrén, E. 1999. "Holocene Environmental Changes Recorded by Diatom Stratigraphy in the Southern Baltic Sea." *Meddelanden fran Stocholms Universitets Institution för Geologi och Geokemi* 302: 1-22.

[4] Gudelis, V. 1955. "The Main Stages of Lithuanian SSR Baltic Coast Geological Evolution in the Late Glaciale and Holocene." Vilnius V. Kapsukas State University of Science Works, VII, Biology, Geology and Geography of Sciences Series III, 119-39.

[5] Kabailienė, M., and Rimantienė, R., 1996. "Holocene Changes in the Palaeoecological Conditions of the Lithuanian Coast around the Šventoji Settlement, Landscapes and Life." *PACT* 50: 185-95.

[6] Raukas, A. 1995. "Evolution of the Yoldia Sea in the Eastern Baltic." *Quaternary International* 27: 99-102.

[7] Schoning, K. 2001. "The Brakish Baltic Sea Yoldia Stage—Palaeoenvironmental Implications from Marine Benthic Fauna and Stable Oxygen Isotopes." *Boreas* 30: 290-8.

[8] Lampe, R. 2002. "Post-glacial Water-Level Variability along the South Baltic Coast—A Short Overview. Holocene Evolution of the South-Western Baltic Coast-Geological, Archaeological and Paleo-environmental Aspects." In *Field meeting of INQUA Subcommission V, September 22-27. Greifswalder Geographische Arbeiten,* edited by Lampe, R. Greifswald: Ernst-Moritz-Arndt-Universität Greifswald.

[9] Gelumbauskaitė, L. Ž. 2010. "Palaeo-Nemunas Delta History during the Holocene Time." *Baltica* 23 (2): 109-16.

[10] Gelumbauskaitė, L. Ž., and Šečkus, J. 2005. "Late Glacial-Holocene History in Curonian Lagoon (Lithuanian Sector)." *Baltica* 18 (2): 77-82.

[11] Gelumbauskaitė, L. Ž. 2009. "Character of Sea Level Changes in the Subsiding South-Eastern Baltic Sea during Late Quaternary." *Baltica* 22 (1): 23-36.

[12] Šečkus, J. 2009. "Study of the South-Eastern Baltic Sea Development Applying Geological Modeling Methods." Ph.D. thesis, The Vilnius University.

[13] Bitinas, A., Žulkus, V., Mažeika, J., Petrošius, R., and Kisielienė, D. 2003. "Tree Remnants on the Bottom of the Baltic Sea: The First Results of Investigations." *Geologija* 43: 43-6.

[14] Miotk-Szpiganowicz, G., Uscinowicz, S., and Przezdziecki, P. 2010. "Relicts of Terrestrial Deposits on the Southern Baltic Sea-Bed." *The Baltic Sea Geology* 10: 80-2.

[15] Žulkus, V., and Girininkas, A. 2012. *The Coasts of the Baltic Sea 10,000 Years Ago.* Vilnius: Research Council of Lithuania.

[16] Emelyanov, E. M., and Vaikutienė, G. 2013. "Holocene Environmental Changes during Transition Ancylus-Litorina Stages in the Gdansk Basin, South-Eastern Baltic Sea." *Baltica* 26 (1): 71-82.

[17] Bitinas, A. 2000. *The Second Level of the Quaternary Geological Mapping (1:50,000 Scale) in the Šilutė District*. GS project report, Vilnius.

[18] Kabailienė, M. 1959. "Lithuania and the Southern Latvia Baltic Coast Evolution in Late Glacial and Holocene: Diatom Flora Studies." *Geology, Geography* 2: 175-213.

[19] Kabailienė, M., Vaikutienė, G., Damušytė, A., and Rudnickaitė, E. 2009. "Post-glacial Stratigraphy and Paleo Environment of the Northern Part of the Curonian Spit, Western Lithuania." *Quaternary International* 207: 69-79.

[20] Kabailienė, M. 2006. *Development of Natural Environment in the Lithuania over 14,000 Years.* Vilnius: Vilnius University Press.

[21] Stančikaitė, M. 2004. "Late Glacial and Holocene Palaeo Environment in Lithuania." *Lithuanian Archaeology* 26: 135-48.

[22] Rimantienė, R. 2005. *Stone Age Fishermen at the Seaside Lagoon.* Vilnius: Nacional Museum of Lithuania.

[23] Bērziņš, V. 2008. Sārnate: *Living by a Coastal Lake during the East Baltic Neolithic.* Oulu: Oulu University Press.

[24] Damušytė, A. 2011. "Post-glacial Geological History of the Lithuanian Coastal Area." Ph.D. thesis, The Vilnius University.

[25] Schmölcke, U., Endtmann, E., Kloss, S., Meyer, M., Michaelis, D., Rickert, B. H., and Rössler, D. 2006. "Changes of Sea Level, Landscape and Culture: A Review of the South-Western Baltic Area between 8800 and 4000 BC." *Palaeogeography, Palaeoclimatology, Palaeoecology* 240: 423-38.

[26] Rosentau, A., Hang, T., and Kalm, V. 2007. "Water-Level Changes and Palaeogeography of Proglacial Lakes in Eastern Estonia: Synthesis of Data from the Saadjārve Drumlin Field Area." *Estonian Journal of Earth Sciences* 56 (2): 85-100.

[27] Gelumbauskaite, L. Ž. 2002. "Holocene History on the Npart of the Kuršių Marios (Curonian) Lagoon." *Baltica* 15: 3-12.

[28] Friedrich, M., Remmele, S., Kromer, B., Hofmann, J., Spurk, M., Kaiser, K. F., Orcel, Ch., and Küppers, M.

2004. “The 12,460-Year Hohenheim Oak and Pine Tree-Ring Chronology from Central Europe—A Unique Annual Record for Radio Carbon Calibration and Paleoenvironment Reconstructions.” *Radiocarbon* 46 (3): 1111-22.

[29] Mörner, N. A., and Dawson, S. 2011. “Traces of Tsunami Events in off- and on-Shore Environments, Case Studies in the Maldives, Scotland and Sweden.” *Paleogeophysics & Geodynamics* 12: 371-88.

[30] Bezzenberger, A. 1889. *Curonian Spit and Its Inhabitants.* Stuttgart: Engelhorn.

[31] Girininkas, A. 2009. *Lithuanian Archaeology. Stone Age.* Vilnius: Versus Aureus.

[32] Kozłowski, S. K. 1989. “Mezolit.” In *Prehistory Poland, vol. 1, From Palaeolithic till La Tene,* edited by Kmieciński, J. Warsaw-Lodze: Government Printing Office.

[33] Grigaliūnas, M. 2013. “The First Palaeolithic and Mesolithic Settlements in Aukštumala, Šilutė District, the Nemunas River Delta.” *Archaeologia Baltica* 20: 175.

[34] Bērziņš, V. 2004. “Excavations at Vendzavas Mesolithic Settlement Site and Burial.” In *Archaeological Investigations in Latvia 2002-2003,* edited by Ose, I. Riga: Latvia University Press.

[35] Bērziņš, V. 2004. “Arheoloģiska apzināšana Ventspils rajona Užavas pagastā.” In *Arheologu pētījumi Latvijā 2002. un 2003,* edited by Ose, I. Riga: Latvia University Press.