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Application of geological methods for dating of stone labyrinths on the White Sea coast

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Abstract. The geological and geomorphological methods of the investigation of the relative sea level changes during the Late Holocene jointly with traditional methods of archeology have been used for determining age of the archaeological monuments – the stone labyrinths known on the Kandalaksha coast of the White Sea.

Аннотация. Методы геологического и геоморфологического изучения перемещения береговой линии моря в позднем голоцене в комплексе с традиционными методами археологии были использованы для определения возраста археологических памятников – каменных лабиринтов, известных на Кандалакшском берегу Белого моря.

Key words: stone labyrinth, relative sea level change, White Sea, Late Holocene

Ключевые слова: каменный лабиринт, перемещение береговой линии моря, Белое море, поздний голоцен

1. Introduction

The stone labyrinths are the mysterious installations which are widely found on the European North where they are usually named "Trojan towns". All of them are constructed on Crete specimen where the main idea of a design is transformation of a square into a circle by means of a special connection of special points. The purposes of the stone labyrinths are connected with sacral or religious traditions (*Kern*, 2007). The stone labyrinths are mainly presented in Scandinavia and in the northwest of Russia (*Toivinen*, 1993).

In the Kola region stone labyrinths have local name given by inhabitants of the White Sea and Barents Sea coast – "babylons". The babylons involve not only labyrinths proper representing branching paths limited to two lines, but also the spirals showing a direction of movement along a path of a labyrinth – original the "thread of Ariadne". There are twelve stone labyrinths in the Kola region (Fig. 1). On the Kandalaksha and Tersky shores of the White Sea there are five of them: 1. the Kandalaksha labyrinth (Fig. 2) is situated on the Pitkulsky Navolok Cape (3.4 m above sea level (a.s.l.) altitude); 2. two Umba labyrinths (large and small) are located close to the Anninsky Krest Cape (altitude 6.6 m a.s.l.), 90 m away from the Udarnik fishery marked on the map; 3. two Ponoy labyrinths (large and small, with the distance of several kilometers from each other). It is necessary to note that the large labyrinth located in the former village Ponoy differs from the other one known in the Kola region, it occupies the highest hypsometric position (20 m a.s.l.) and is situated far off (about 15 km) from the present-day seacoast on a sole fragment of a terrace above the flood plain in the Ponoy River undercurrent.

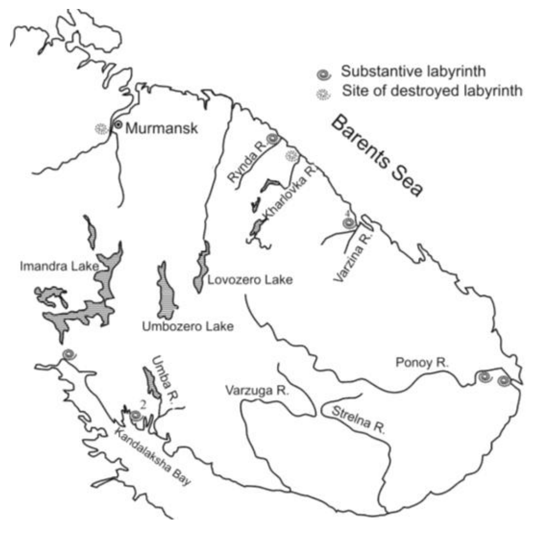

Fig. 1. Locality map showing the Murmansk region stone labyrinths sites

Several stone labyrinths are known on the Barents Sea coast (Fig. 1). One of them is located on the shore of the Vyashchina creek and four labyrinths – in a valley of the Varzina River. In addition one stone labyrinth is known to have existed in the mouth of the Kola River but it was destroyed as far back as at erection of the Kola fort. One more labyrinth situated in the valley of the Kharlovka River was ruined rather recently, in the middle of the XXth century (*Gurina*, 1982).

Fig. 2. The Kandalaksha stone labyrinth (a) and the plate indicating the age of these labyrinths estimated by archeological methods (b)

The detailed research of the stone labyrinths on the White and Barents Seas by *Gurina N.N.* (1948; 1953), *Mullo I.M.* (1966), as well as investigations in Sweden, Norway and Finland by *Kraft J.* (1977), *Kern H.* (1981; 2007), *Olsen B.* (1991) and other researchers allowed to conclude that the "Trojan towns" with very rare exceptions were constructed in the direct proximity from the ancient coastal line (a line of the high tide level) and had never been flowed by the sea. Some of labyrinths are located near other archaeological objects (primeval site, prehistoric burial places) where the quartz scrapers and drawing knifes, the shale arrowhead, the fragments of asbestine ceramics and the rare fragments of vessels decorated with an ornament have been found. The finding of these cultural artifacts attributes to the so-called "culture of Arctic Neolith (late Stone Age)", which approximately had dated back to the temporal interval of V-I millennium B.C. It allowed *Gurina N.N.* (1948; 1953), *Mullo I.M.* (1966) and others to compare age of the labyrinths known in the Kola region and located close to the primeval archeological sites just with the epoch of late Stone Age. Afterwards this age was extrapolated for all stone labyrinths available in the Kola region, and not just on those located near the primeval archeological sites. Due to works of the archeologists the age of the Kola labyrinths is already traditionally defined as the second millennium B.C., i.e. estimated as 3000-4000 years B.P. (Fig. 2b).

There is no yet a definite answer to a question concerning appointment of stone labyrinths of the Kola region, but it is well known that all of them are linked with the sea-shore and are located near the places rich with fish. On the basis that stone labyrinths had never been flowed by the sea, it is allowed to define the age of the archaeological objects, having connected them with postglacial relative sea level position. It has been noticed that the similar approach of age estimation for the Scandinavian labyrinths has allowed foreign researchers considerably correct it towards rejuvenation (*Kern*, 2007). Moreover, from the end of 1980th owing to works of the Swedish scientists of *N. Broadbent* (1987) and *R. Sjöberg* (1996) for dating of the stone labyrinths a lichenomethric method (gauging of height of lichens) came into wide and successful use. Several tens labyrinths located at the northeast coast of Sweden at the altitude from 3 to 85 m a.s.l. have been studied, and found that they were constructed at various times, since the end of the XIIIth century till our time (*Kern*, 2007).

All the labyrinths known in the Kola region at present are to some extent reconstructed and consequently the lichenomethric method of dating cannot be fully used.

2. Paleogeography of the White Sea depression during the Late Pleistocene and Holocene

Recent spatial distribution of the Kola stone labyrinths, grows out of a joint influence of mainly glacio-eustatic sea level change, glacio-isostatic and tectonic proper movements of the Earth crust. As it has been earlier established the Kola region during the Late Glacial and Holocene time had undergone the glacio-isostatic raising, and the surrounding it water areas had undergone the eustatic raising of the sea (*Corner et al.*, 2001; *Kolka et al.*, 2005; *Kolka, Korsakova*, 2005; *Yevzerov et al.*, 2007). The raisings coincided in time, but their speeds were various. It was reflected in the sedimental sequences discovered in the bottom deposits of the hollows located at the coast of the White Sea and presently occupied with lakes.

It was found that there were periglacial lakes in the Belomorian (White Sea) depression during the deglaciation where had deposited the sediments relevant to sedimental facies of the periglacial lake. The ocean level at this time was situated lower in comparison with position of the modern bottom surface of the White Sea Throat, i.e. the White Sea depression was separated from the Arctic Ocean by the "overland bridge". It should be recorded that this "overland bridge" could be used by ancient people as migratory ways.

The considerable eustatic raising of the sea level was occurred towards the end of Allerod that already had outrun of land raising. The salt sea waters began to enter into the Belomorian (White Sea) depression. The altitude of sea level was rising during approximately one thousand years (11 000-10 000 ^{14}C years) and at the very beginning of Holocene the marine conditions were already established in the Belomorian (White Sea) depressions. From this time the eustatic sea level raise began to lag behind the glacio-isostatic raise of the land surface (*Korsakova et al.*, 2004). From the proposed method the stone labyrinth age can concur with the age of the sea level position on corresponding altitude or could be younger.

3. Method

The methods for identifying the age of stone labyrinths consist in determining the time interval when the sea coast was at the same altitudes as the present stone labyrinths are. This time interval is correlated to the maximum possible age of the labyrinths located in coastal areas. Thus, there have been investigated limited areas in the immediate vicinity of the labyrinths, the bottom sediments of small lake basins located at different altitudes (from the coastal line up to the upper marine limit). Due to marine regression the sedimentation environments for each site sequentially changed and the corresponding sediments were accumulated being locked in the bottom sediment sections of the nowadays coastal small-lake depressions (Fig. 3).

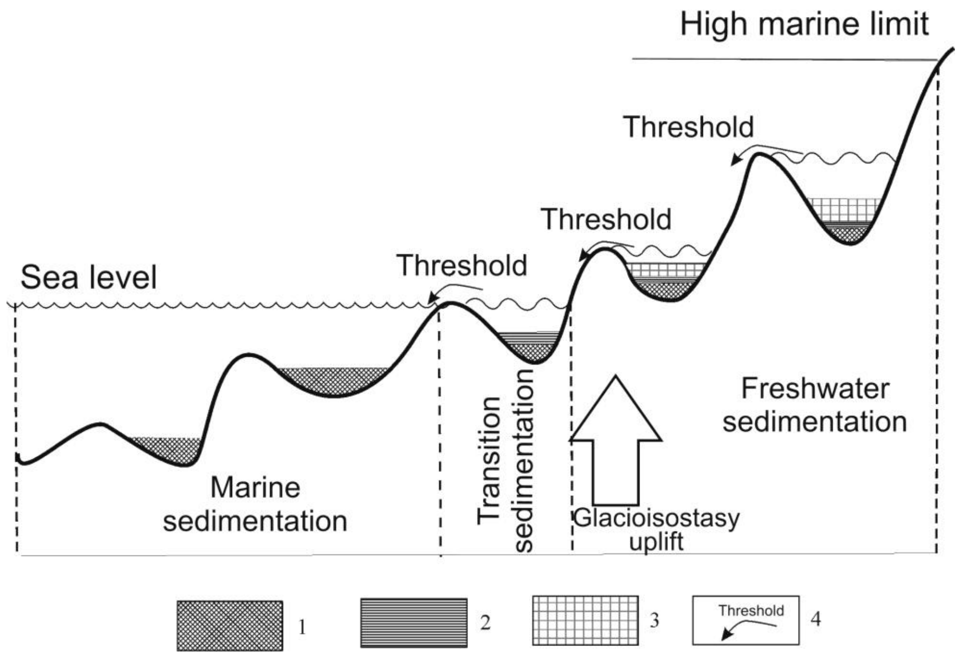

Fig. 3. Conditions of sedimentation in the depressions on the sea slope under sea regression:
1 – marine sediments (facies III); 2 – sediments of marine-lacustrine transition zone (facies IV);
3 – lacustrine sediment (facies V); 4 – threshold

Under marine environments, the main sediments were represented by silt and sand. Later, in the course of marine-lacustrine transition, the sediments were mainly marine mineral and lacustrine organic ones. At the following stage of lacustrine sedimentation, they were formed by gyttja.

The ancient shore lines are correlated to the isolation interval of the marine-lacustrine transition zone in the sequences. To identify it in the sequences, a thorough sedimentological analysis of the cores was carried out. The isolation interval was established by diatom analysis and C^{14} dated, as well the threshold was established. If there is a transition zone, the core threshold altitude is the previous sea shore level at the beginning of the sea – lake isolating phase. By using the shore displacement curves, all evidence of the marine-lacustrine transition zone in the sequences, and the threshold altitudes from different sites and C^{14} dates the plots of the change of the coastal line location in time were constructed.

On the whole, a sedimentology sequence of five lithological facies was reconstructed from deposits studies of dozens of lake depressions on the White Sea coast (*Kolka et al*., 2005). As a rule, the basal part of a complete sequence is the sediments of the periglacial lake (facies I), becoming apparent as laminated or unclearly laminated clays or varves with remains of brackish-water diatoms attributed to the periglacial lakes. It is overlaid by interstratifying sands, silts, and clays with organics and diatoms, referred to the stage of Late glacial marine ingression – a facies of the lacustrine-marine transition zone (II). Silts and sands with subfossil mollusk shells and polygaline or mezogaline (marine or brackish-water) diatoms are attributed to sediments of marine facies – III. The marine sediments are overlaid by laminated or unclearly laminated gyttja or silts including diatom complexes with marine algae in the bottom section and fresh-water ones towards the roof. This is another transitional facies (IV), accumulated under changing marine- to freshwater environments. Gyttja with dominating fresh-water diatoms crowns the complete sequence; this is a freshwater lacustrine facies (V).

As it has been mentioned above, dating of the stone labyrinths is not a mere study of the sediment interval sequences represented by marine facies (III), marine-lacustrine transition zone (IV), and lacustrine facies (V). On the basis of this examination, there emerges the position of the ancient shore line altitude corresponding to the threshold isolating the lake basin from the sea. This is the so-called termination interval, i.e. the position of the marine-lacustrine transition zone (lithological facies IV) (Fig. 4). The lithologic-stratigraphical and paleontological (diatoms analysis) studies aimed at identification of thresholds were followed by the C^{14} dating, hereby dating the relative sea level at the conformable altitudes under the changing marine-freshwater environment. The determined C^{14} ages correspond to the age of the sea shore line at certain altitude. In addition, we carried out geomorphology profiling to determine the shore fitches (terraces and beach ridges) synchronous to the ancient shore lines.

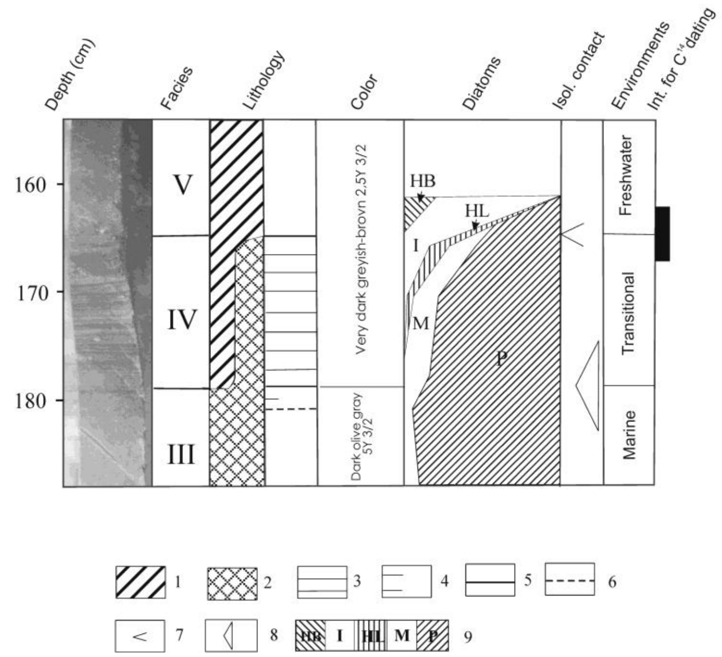

Fig. 4. Stratigraphy of the transition (facies IV) between marine (facies III) and lacustrine (facies V) sediments: 1 – gyttja; 2 – sandy mud; 3 – lamination; 4 – weak lamination; 5 – sharp contact; 6 – gradational contact; 7 – marine-freshwater diatom transition; 8 – isolation contact; 9 – diatoms: HB – halophobous; I – indifferent; HL – halofilous; M – mesohalobous; P – polihalobous

The obtained lithologic-stratigraphical and geomorphological data were used to simulate the relative sea level (RSL) curve of different sites (Fig. 5), including those without any lake depressions with the relevant succession close to the stone labyrinths. The shore displacement curves, or relative sea level curves, make it possible to establish the shore line altitude position for a particular site in coastal areas at any time through the Late Glacial-Holocene.

4. The age of the Kandalaksha labyrinth

The Kandalaksha labyrinth (N 67° 09' 46"; E 32° 23' 20") is situated on the Pitkulski Navolok Peninsula at the 3.4 m a.s.l. altitude (Figs. 1, 6). To determine the labyrinth age, we used the findings on the shore line displacement in the Late Holocene, at two proximate sites. Since there are no lake depressions close to the Kandalaksha stone labyrinth at suitable altitudes, modeling reconstruction was used, involving the sedimentology and C^{14} data from bottom sediments for both lake depressions in the Kandalaksha area (the core was taken at the site with N 67° 07' 07"; E 032° 07' 26") and the Lesozavod area (the core was taken at the site with N 66° 45' 38"; E 032° 49' 03') (Fig. 6).

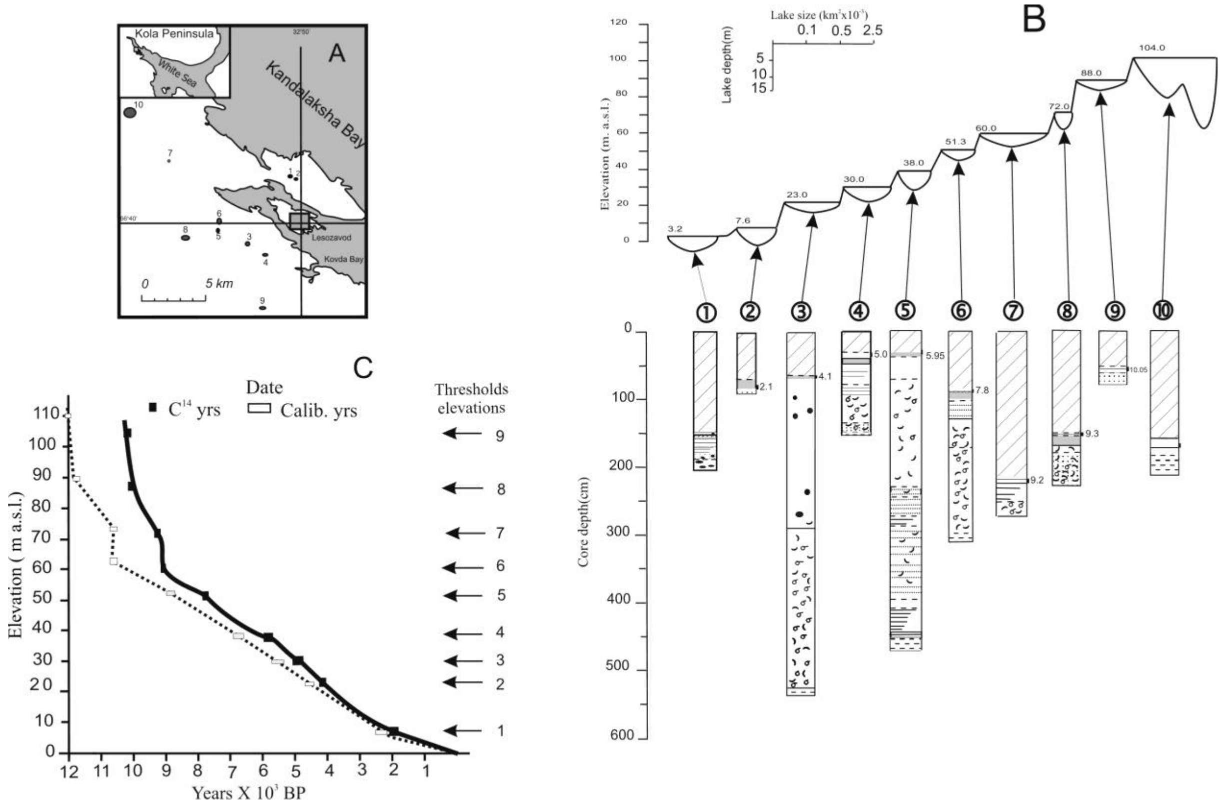

Fig. 5. Location map of the cored lake sites (A), overview of the investigated lake basins (B), relative sea-level (solid line – for C^{14} age, dashed line – for calibrated C^{14} age) curve (C) for the Lesozavod area

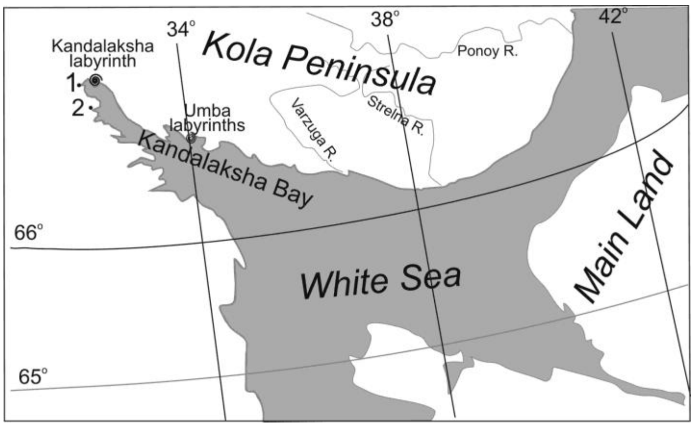

Fig. 6. Locations of the Kandalaksha labyrinth and the investigated lake bottom sediment succession used for estimation of the Kandalaksha labyrinth age: 1 – the Kandalaksha area; 2 – the Lesozavod area

Lake depression in the Kandalaksha area. The threshold is at 9 m a.s.l. altitude. The sequence of III-IV-V lithological facies was obtained from the lake. The marine sediments (facies III) are sands and unclearly laminated silts and transition zone ones (facies IV) represented by interstratifying silts (70 %) and gyttja (30 %); the lacustrine sediments (facies V) are the lacustrine gyttja (sapropel). The correct identification of each lithological facies has been confirmed by diatom studies. For accumulations in the lake basin incompletely separated from the sea, the isolation – pre-isolation interval in the core was aged as 2560±130 C^{14} yr B.P. (Table).

Lake depression in the Lesozavod area. The threshold is at 7.6 m a.s.l. altitude. Similarly to the lake depression in the Kandalaksha area, it was cored from the same lithological facies of bottom sediments, but there is not a distinct transmission zone (facies IV) here. Medium-grained not laminated marine sands (sediments of facies III) are gradually overlaid by freshwater gyttja (sediments of facies V). The basal interval of the gyttja being extremely sanded. This indicates that the sea water had intermittently penetrated into the lake basin already separated from the sea, which could occur under heavy (spring) tides, or storm surge, or pilling up of water, etc. As shown by diatom analysis of the sediments in the core, this basin had incompletely been separated from the sea in 2060±70 C^{14} yr B.P. (Table).

To simulate the relative sea level curve, the C^{14} dates have been calibrated using the radiocarbon calibration program OxCal 4.0 (*Ramsey*, 2001). As follows from the Table, the calibrated dates are given for all three 1σ, and 2σ, and 3σ standard deviations, to calibrated dates with expectancy of falling into the mentioned time interval of, respectively, 68 %, 95.4 %, and 99.7 % probability. To simplify the computation we have calculated the average calibrated dates for all three standard deviations (Table).

Table. Date for estimation of age of the Kandalaksha labyrinth

Area	Lake elevation m, above sea level	Lake depth, m	Depth of sampling interval, m from water surface	Laboratory C^{14} date (years B.P.)	Calibrated C^{14} dates (years B.P. ±σ)		
					1σ (68 %)	2σ (95.4 %)	3σ (99.7 %)
The town of Kandalaksha	9	3	3.27-3.32	2560±130	2778-2377	2927-2341	3158-2153
Mean quantity of calibrated C^{14} date (years B.P.)					2577	2634	2655.5
Raising of the Earth surface, cm/year					0.35	0.34	0.34
Estimated age of the Kandalaksha labyrinth. Labyrinth elevation 3.4 m a.s.l.					971	1000	1000
The village of Lesozavod	7.6	5.5	6.33-6.40	2060±70	2121-1946	2302-1871	2331-1819
Mean quantity of calibrated C^{14} date (years B.P.)					2034	2087	2075
Raising of the Earth surface, cm/year					0.37	0.36	0.37
Estimated age of the Kandalaksha labyrinth. Labyrinth elevation 3.4 m a.s.l.					918	944	918

A regular isostatic uplift of the Kandalaksha Bay head in the Holocene was suggested on the evidence derived from the relative sea level investigations (*Kolka et al.*, 2005; *Yevzerov et al.*, 2007), which made it possible to determine the average velocity of the land rising at 0.34-0.37 cm/yr, by using the calibrated dates for all standard deviations (Table). Knowing the average velocity of the land rising, we suggested that the shore line calibrated age at the altitude position of the Kandalaksha stone labyrinth (Fig. 7) is 918-1000 calibrated years. Hence we can infer that the age of the Kandalaksha stone labyrinth is not older than the early II millenium A.D.

5. The age of the Umba stone labyrinth

The given method was also used for dating two labyrinths located near Umba (situated at the altitude 6.6 m a.s.l.). As for the Umba labyrinths it is necessary to note a tentative age estimation because it is given after the examination of the bottom sediment sequences only from one lake. After obtaining additional data the age of the Umba labyrinths will be determined more precisely.

The bottom sediment of the lake depression located close to the large Umba labyrinth has been studied. The altitude of this lake threshold is 12 m a.s.l. The established age of the depression being isolated from the sea is 3300±70 C^{14} years (*Kolka et al.*, 2005). Average annual raising of land surface where the large Umba labyrinth is located (calculated for calendar age) has made 0.34 cm/year.

Thus, the calendar age of the sea level on the altitude 6.6 m a.s.l. equal to the altitude of this labyrinth location calculated on the basis of raising rate of land surface in this area amounts to 1941 calendar years. It means, that the Umba labyrinths were constructed not earlier of the beginning of the first millenium A.D. The peculiarity of the large Umba labyrinth is that it was originally built on a bare rock, and when it was discovered by N.N. Gurina the 30 cm thick soil between its stones was formed. The approximate age of this soil was estimated as more than 1000 years (*Gurina*, 1948; 1953; *Kern*, 2007). In any case the large Umba labyrinth, and quite possible the small one situated near, have more ancient age than the Kandalaksha labyrinth.

All stone labyrinths located on the White Sea coast of the Kola Peninsula and have been dated by the geological methods are much more young than it was supposed on the basis of archaeological data spoken above.

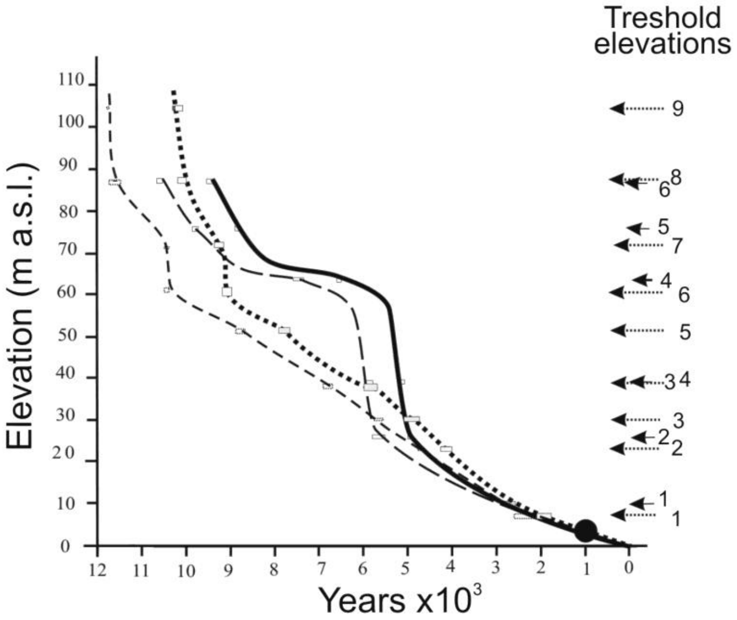

Fig. 7. Position of the Kandalaksha labyrinth (filled in circle) on the relative sea level curves of the Kandalaksha Bay head. The solid line – for C^{14} age of Kandalaksha town area, the dotted line – for C^{14} age of Lesozavod settlement area, the dashed lines – for calibrated C^{14} age

6. Conclusion

The geological and geomorphological methods for studying the Late Holocene relative sea level change in complex with the traditional archaeological methods can be used for dating the archaeological monuments known at the coast of the Kola Peninsula.

The researches spent in two areas of the coast – Kandalaksha and Umba – have shown that having connected position of the coastal line of the sea with position of stone labyrinths, the greatest possible age of these archaeological objects can be established as it is known that they were never flooded by the sea. The age of the Kandalaksha stone labyrinth cannot be more than 1000 calendar years, and the Umba labyrinth – no more than 1940 (according to preliminary data). The age of the Ponoy labyrinths located far from the modern coast, has not been studied yet by the proposed geological methods.

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