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The Research of Northern Labyrinths as Navigation Network Elements

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ABSTRACT: The authors of the article consider the stone labyrinths as solar calendars. In the center of these structures there are usually already installed gnomons – vertical objects that give shade. Midday shadow points to north, and the change of its length during a year is correlated with the diameter of the arcs of the labyrinth. Points of sunrise / sunset at the equinoxes and solstices are very often fixed in the pattern of the labyrinth, as well as the beginning of the annual cycle. In general, patterns of labyrinths are of the same type, the differences reflect the regional characteristics of illumination, the differences in latitude and topography (shape of the horizon). The uniformity of the technology and the location on the waterways give an opportunity to consider stone labyrinths as ancient elements of local and regional navigation networks.

1 INTRODUCTION

Northern labyrinths can be found in England, Iceland, Norway, Denmark, Sweden, Finland, Estonia and Russia. They are located on isles, peninsulas, near harbors and in river mouths. Their picture is complicated but organized. In terms of structure, there are unispiral, bispiral, concentric and radial types. In terms of outer shape: circles, ovals, rarely squares (Yeliseyev, 1883; Vinogradov, 1927; Gurina, 1948; Kuratov, 2008; Kern, 2000).

Hypotheses about the designation of stone labyrinths can be divided into two groups: calendar and non-calendar. It should be noted that despite all the diversity of facts of non-calendar use, most part of them is often associated with time and stage of life.

Hypothesis of calendar designation of labyrinths are mainly based on the assumption of a direct projection of the trajectory of space objects on the Earth's surface (Herman Wirth, Daniel Svyatskiy) or consider pattern of labyrinth as a record of the results of direct sight of the annual variation of the Sun (Yuri Chekmenev). However, direct sight cannot explain the technology for using the labyrinth: 1) it is impossible to explain the quantitative ratios of the trajectory of a celestial object and its reflection in the stone pattern; 2) it is even more difficult to imagine the use of the pattern - with a diameter of 20-30 meters, it is impossible "to read" from the human height; 3) the problem of monitoring the trajectory of the sun is that bright light dazzles eyes, just after sunrise its movement takes off from landmarks.

The proposed concept of the labyrinth-gnomon – a tool of back sight of the sun - from the shadow set in the center of the object, opens the possibility of its use as a sundial compass and calendar (Paranin & Paranina 2009; Paranina & Paranin 2009a, 2009b, 2014, 2015, 2016; Paranina 2009, 2010, 2011ab, 2012abc, 2013, 2014, 2016). The shadow of the object is easy to observe, record, measure, and its movement reflects and a form - encodes all the movements of the sun and is consistent with the position of the elements of the structure of the labyrinth; landscape orientation on the horizon (mountains, valleys) are not necessary, on the contrary, water environment is the optimal without creating distortions of azimuths of sunrise/sunset (their normal location is on the island or cape).

Author's concept of a labyrinth-gnomon technology solves the problem of the calendar use, and is consistent with all elements of a wide range of symbolic interpretation of the signs of the labyrinth and Labrys.

The concept was proved and developed in the study of images of labyrinths on rocks of the Caucasus and Portugal (Israpilov, 2003; Hetagurov 2016; J.L. Galovart, 2012). In particular, the dates marked by the arcs of the labyrinth of North Ossetia were in line with national economic calendar (Hetagurov, 2016).

2 OBJECTS AND METHODS

The objects of study were the monuments of ancient material culture of European Russia (stone labyrinths, petroglyphs or rock carvings and etc.). From 2009 to 2013 the objects located on coast of the White Sea are investigated: in the archipelago of Kuzova, in the archipelago Solovki, in the gulf Kandalaksha, in the gulf Keretsky, in the mouth of the river Vyg and of the river Umba (Fig. 1-7)

The applied field research methods (survey, description, observation, work with maps) and Earth remote sensing, as well as methods of mathematical, conceptual modeling and mapping. Theoretical analysis is based on the theory of reflection and systemic and chorological approach, methodological statements of historical geography by V.I. Paranin (Paranin 1990, 1998; Paranina, 2012c).

Figure 1. Area of research - coast of the White Sea.

Figure 2. Labyrinth in the archipelago of Kuzova

Figure 3. Labyrinth No. 1 in the archipelago Solovki

Figure 4. Keretsky labyrinth, island Krasanaja Luda

Figure 5. Labyrinth in the gulf Kandalaksha

Figure 6. Labyrinth near the mouth of the river Umba

Instrumental labyrinths functions can be set on the basis of the correspondence between the elements of the spatial structure and the parameters of the lighting mode (altitude and azimuth of the sun). Calculating the height and installation space of the gnomon, in which the shadow end positions coincide with inner and outer diameters of the arcs of the labyrinth, made using the original equation (1) based on the trigonometric identity (H = tg α • A). Both parts of the equations give one result - the height of the gnomon and describe the relationship of the angle of incidence of sunlight and the length of the shadow of α A: left - for summer, right - for the winter. By the distance measured from the center to the extreme edges of the labyrinth (in this example - 1 m and 5.5 m), added an amendment's, allowing to clarify its position in the central addition:

$$\text{tg } 48{,}47\ (1 + x) = \text{tg } 4{,}97\ (5{,}5 + x) \qquad (1)$$

The greatest number of functions (compass, clock, calendar) perform bi-spiral labyrinths, symmetric with respect to the meridian. In other aspects, solstice, equinox, and other dates are determined by the azimuth of sunrise / sunset.

Labyrinths research algorithm includes the following steps: 1. The use of standard methods of description (measurement, comparison); 2. characteristics of the landscape (including the evolution of the climatic conditions during the Holocene geological and geomorphological features, including the dominant system in the fracturing of rocks and stretch lineaments - linear tectonic structures that are reflected in the landscape); 3. astronomical and calendar calculations of paleoastronomical azimuths of sunrise / sunsets and the moon (to account for differences of physical and astronomical horizon), the height of the gnomon of a sundial-calendar and regulations midday shade seasonal (for geographical coordinates of the property); 4. The establishment of the correlations of the spatial characteristics of the object, of the landscape and important astronomical figures recorded at this point; 5. comparison of instrumental features of object with local and regional life support tasks in different historical era (including the location of the object in the analysis of the transport communications system).

Comprehensive analysis of the purpose and use of labyrinths also includes the cultural context (neighboring archaeological sites, toponymy, linguistics, mythology, folk traditions).

3 RESULTS AND DISCUSSION

For interpretation of a northern labyrinth the gnomon - the elementary astronomical tool was used. The shadow of a gnomon codes a trajectory of movement of the Sun on a firmament. In 2009 the authors proved that drawing of a labyrinth fixes astronomically significant points: 1) the provision of a midday shadow in days of winter and summer solstice corresponds to extreme arches of spirals, 2) the ends of spirals correspond to azimuths of risings/calling, 3) the entrance to a labyrinth notes the beginning of an annual cycle (in an equinox or a solstice).

The sketch of a shadow of a gnomon in days gives the schedule similar to a pitchfork, horns, wings, a fish tail. The shadow schedule in a year fills the space whose shape form represents labris - a bilateral two-horned axe of god of light.

Figure 7. Labyrinth No. 1, the topographical plan (Skvortsov 1990).

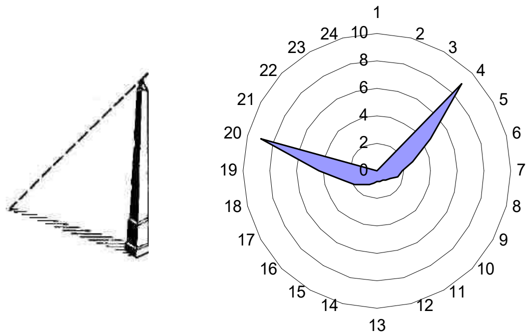

Figure 8. Gnomon and geometry of its shadows per day.

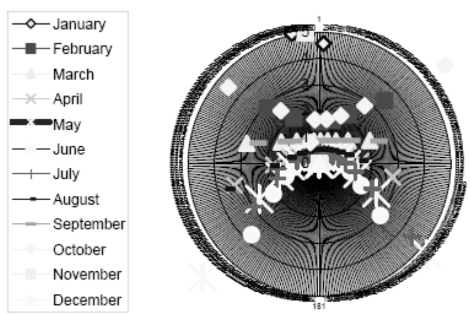

Figure 9. Geometry of shadows per year (Paranina 2010).

The basic units of the information model of the world (IMW) reveal different aspects and levels of modeling of space-time: the first basic level - the navigation, creates a spatial and conceptual framework of IMW; second modeling level - reflects semiotic, linguistic, cartographic, toponymic, mythological units that encode, duplicate and replicate vital navigational information; and the crown of the model - a tradition that serves as the selection and storage of proven information to maintain the continuity of Life, including the Renaissance. Basic processes and phenomena form the reference benchmarks of fundamental concepts, the meaning of which is priceless, and therefore sacred, and their shape is less exposed to other transformation. Structure flow, which maintained sustainability of this model throughout the history of our civilization, was a continuous practical use of sunlight to ensure the order (Paranina 2010, 2011, 2012a, 2012b, 2013, 2014).

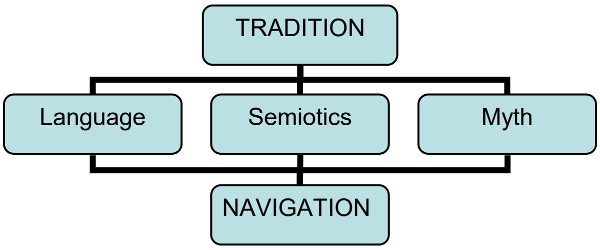

Figure 10. The structure of the information model of the world – navigation concept (Paranina 2014).

4 NORTHERN LABYRINTHS AS NAVIGATION NETWORK

Stone labyrinths are located, as a rule, on a plot of sea coast estuaries (at the source of fresh water) - it's convenient for rest and orientation, waiting for the desired date of astronomical calendar, in which marks of important phenological events of the area (cycles of fishing animals, climate and hydrological mode, lighting) can be made.

Key elements of the picture calendar are diameters of arcs and azimuths of entrance and end spirals - reflect the effect of two factors: the latitude and discrepancies of physical horizon (surface relief) with the astronomical horizon.

Polar regions differ from moderate latitudes in terms of azimuths of sunrise/sunset in the solstice that vary considerably in adjacent parallel (Table 1). If latitudes 40-50º rise at the summer solstice and shift by only 6.92º, and at latitudes of 50-60º only twice – 13.42 º, then advancing further at only 5º (60-65º) to the north - rise shifts at 17.37º, and latitudinal range of 1º 33″ (65º - 66º 33″, i.e. B. Zayatsky Island to the Arctic Circle) - to 20.03º. It is obvious that planetary space conditions of astronomical observations in the polar latitudes become the main reason for specific features of drawings.

The distorting influence of the physical horizon line on measurement of astronomical azimuths can be levelled by locating the instrument on the beach, whose calm surface coincides with the astronomical horizon, this explains the location of the labyrinth near water. This fact partly explains the abundance of labyrinths in a small area of the Big Zayatsky Island (more than 30 items on 1.25 km^2): firstly, the labyrinths are located on parts of the shore, open to different sectors of the horizon, which provides accurate measurements for different astronomical dates and various astronomical objects (objects in the light of the moon cast a shadow as well); secondly, the construction of new labyrinths is associated with the retreat of the shoreline; thirdly, arranged compactly enough, they form a local network.

An equally important reason for the construction of new labyrinths is variability of subpolar latitudes of astronomical targets not only in space but also in time - here the change in slope of the Earth's axis is most visible; being observed according to displacement of the position of the Arctic Circle at other latitudes, these changes are not as dramatic (Tab. 1). The table shows that 5,000 years ago, the azimuth of the summer solstice (SS) was significantly less than modern, therefore, the line of the Arctic Circle was located closer.

Table 1. Dynamics of astronomically significant directions in space and time

N (º)	2010			3000 BC
	WS*, 22.12	SS**, 22.06	WS, 07.01	SS, 02.08
65	160	20,03	165,31	15,46
60	142,86	37,40	144,82	35,48
50	128,41	51,82	129,55	50,71
40	121,29	58,74	122,25	57,81
30	117,39	62,74	118,20	61,97
20	115,05	64,97	115,83	64,29
10	113,85	66,19	114,50	65,56
0	113,44	66,56	114,09	65,91

*WS - winter solstice;
**SS - summer solstice.

Most labyrinths are located in the most dynamic area approximately from latitude 57° to 66° 33″, which primarily determines the differences in their pattern.

At the latitude of the Arctic Circle azimuths of solstices coincide with the meridian, and the boundaries of the astronomical seasons are in the shape of direct cross. In some cases the center corresponding to the polar day, is marked by a closed circle or spiral, as in a labyrinth in Iceland.

North of the Arctic Circle, only equinoxes can be reliably determined by azimuth of sunrise/sunset. To divide the year into periods between the polar night and polar day, you can use the azimuths of sunrise/sunset, which, depending on latitude, more or less rapidly move in the range of 0° +/- 180°. When the sun does not set over the horizon, length of midday shade - diameters of arcs - become the only way to divide time into days.

For systematic studies of the structure and evolution of the navigation network labyrinths of Northern Europe it is necessary to create a database with the indication: 1. geographical coordinates of the center points of labyrinths; 2. The true (geographic) entrance azimuths as well as directions to the point and linear drawing elements; 3. The values of the deflecting effect of the physical horizon (obtained using circular panorama); 4, age of the relief elements (coastal terraces), on which there are mazes; 5. dating maze, derived from paleoastronomical calculations.

By M. Milankovitch, tilt the Earth's axis of 41,000 years varies from 22,1º to 24,5º (Fig. 11), which leads to the boundaries of lighting and climate change. At the same time, the Arctic Circle is shifted in a range from 67º54 'to 65º30'.

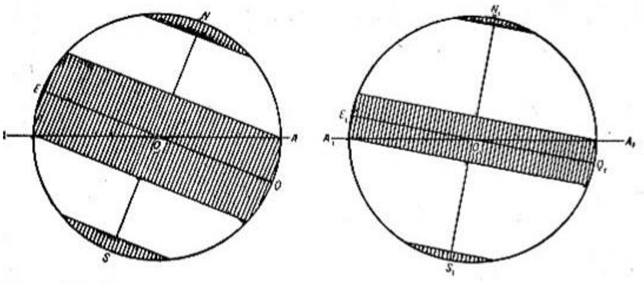

Figure 11. Scheme of change in the position of the tropics and the polar circles with the angle of inclination of the ecliptic (Kalesnik 1970).

According to the orientation of the Egyptian temples, calendars, tilt the Earth's axis could be 25,2º, which corresponds to the position of the Arctic Circle at 64º48 '. All possible positions of the northern polar circle marked on the satellite image (Fig. 12).

Figure 12. The boundaries of tilt of the Arctic Circle.

Given the dynamics of the Arctic Circle, in the area of the labyrinths of Northern Europe (. Figure 13), there are three groups of objects: 1. Transpolar - located above the possible position of the Arctic Circle; 2. Circumpolar - near the modern and the other possible positions of the Arctic Circle; 3. labyrinths of the temperate zone. It is evident that only a few objects are located in the Arctic, labyrinths of the White Sea are in the eastern area of the circumpolar group, and the largest group -labyrinths the Baltic Sea, located in the north of temperate light zone, the most populated and convenient for the solar navigation.

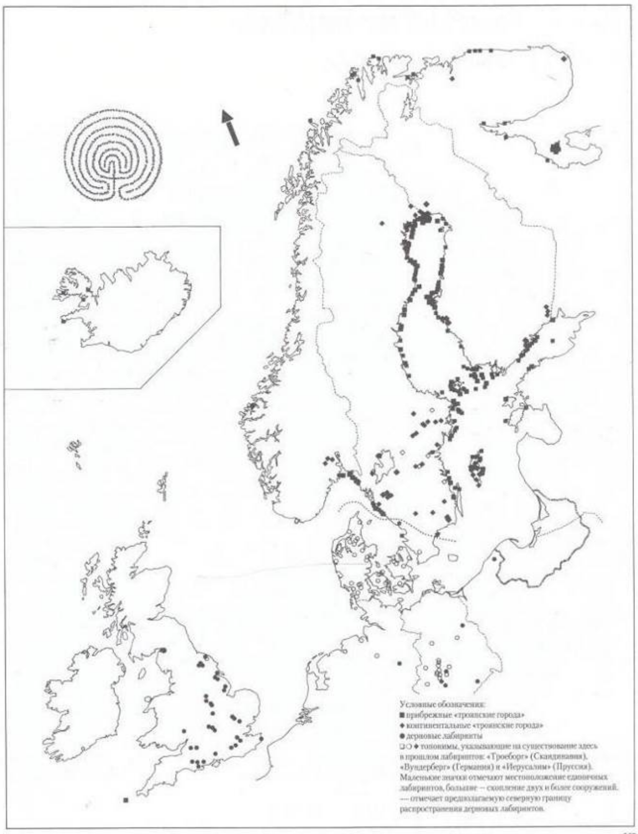

Figure 13. The area of northern labyrinths (Kern 2000)

Convenience and tradition of observing the sun in the middle latitudes of 50 to 66º N were mentioned in different sources. According to ethnographic research in Poland, the gnomon is long and widely used in rural areas (Stomma 1981). A number of the descriptions of clocks produced in XIV-XV century in Poland. In the XVII century Hevelius of Gdansk designed pocket sundial. Polish scientists read gnomonymy courses in European universities: Bologna, Budapest (Sundial ... 1990).

Experience of evolutionary geography and study about the rhythm of natural processes are of great importance for the development of research of labyrinths and other navigation instruments (Maksimov, 2000).

5 CONCLUSIONS

The simplest astronomical tools – Gnomon, allows to read pattern of northern labyrinth as a solar calendar. Phenomena of polar days and white nights contribute to development of solar navigation in the north.

Labyrinths and other megalithic sites in Northern Europe should be considered as elements of local and regional navigation networks. This approach will provide: 1. an integral understanding of the technology of solar navigation in its space and time dynamics; 2. a more precise dating of labyrinths, using astronomical criteria; 3. additional information about the rhythm of natural processes.

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