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Cross-disciplinary Researches of Objects of Ancient Heritage on the Example of Stone Labyrinths and Petroglyph

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ABSTRACT: As an example of cross-disciplinary researches of objects of ancient heritage, labyrinths – stone constructions and petroglyphs are considered. The researches conducted by authors with application of a gnomon of solar clocks calendars open purpose of parts of labyrinths as markers of a geographical space-time. Results of the analysis of conditions of solar navigation are given in different latitudes which is considered by authors as a methodological basis of researches in culture geography. On the basis of instrumental function of objects the correct explanation of the contradictory symbolical interpretation which collected in humanitarian researches is received. Possibilities of cross-disciplinary researches with use of archaeological, historical, ethnographic data and the navigation concept of informational model operation of the world are shown.

1 INTRODUCTION

1.1 *Geography of culture*

Geography of culture considers the objects of natural and cultural heritage as elements of geo-cultural space (Streletsky, 2005). Culture is understood as a form of geographic adaptation, in which a person does not only adapt to the environment, but also creates it. This explains the need to study two areas of cooperation between human and nature, "the landscape in culture" and "culture in the landscape." Subject of the research is the rational content of the culture associated with the life-support processes. In contrast to the humanities, applied field and quantitative methods, unlike astro-archeology and paleoastronomy, objects are seen as elements of the territorial system, in general, studies are complex.

1.2 *The methodology of research*

Our interdisciplinary research of ancient heritage objects is based on the methodology of the natural sciences, system approach and the doctrine of geosystems by V.B. Sochava. First of all, the following theoretical principles are effective: 1. The concept of geo-system structure as its spatial and temporal organization (according to Isachenko A.G.); 2. The idea of the constructive role of super-systems (according to Dyakonov K.N.); 3. The flow system as the basis of stability (according to Armando A.D.); 4. The flow of the structure-function (according to Viktorov A.S.); 5. The territorial networks (according to Rodoman B.B.).

The studies of V.I. Paranin on historical geography play a special role in the research of ancient heritage objects, including his conclusions: 1. names labeling of elements of territorial systems based on the orientation of the sun; 2. mapping models of geospace rhythm of natural processes (such as the 1850 summer humidification cycle); 3. the role of transport

communications as flows of matter, energy and information, forming geocultural space (Paranin, 1990, 1998). The navigation concept and the system of methods, developed by the authors, provide for detection of measured quantitative correspondences in hierarchically structured system of "cultural object - enclosing space: informational, geocultural, landscape and geographical and spatial" (Paranina, 2010, 2011, Paranina & Paranin, 2015). In this article, as an example of interdisciplinary research of objects of ancient heritage, the labyrinths – stone structures and petroglyphs – are considered (Fig. 1).

2 OBJECTS AND METHODS

2.1 *Variety of forms and scientific approaches*

Labyrinths are found on all continents except Antarctica. Age of images reaches tens of thousands of years, as a sign of honor in all cultures – it correlated with light and shadow, birth and rebirth, all the stages of human life (Eliseev, 1883, Kern, 2007). Note that all of these meanings combine the concept of "time".

The diversity of opinions on the designation of labyrinths can be divided into groups: mystical (fishing and household magic), household (fish traps) and calendar. The latter differ in the choice of the astronomical orientation (sun, planets) and technology (direct projection, direct sight). The authors, in the course of independent studies conducted in different regions of Russia, developed a calendar model of interpretation, based on the backsight (in the shade) by labyrinths-gnomons (Paranin & Paranina, 2009, Hetagurov, 2016).

2.2 *Stone labyrinths and petroglyphs*

On the territory of Russia authors investigated: the labyrinths of the White Sea – the Solovetsky archipelago (Bolshoy Zayatsky island) and archipelago Kuzova (island Oleshin) and others and labyrinths of the Caucasus.

Northern labyrinths are located mainly on the coast – capes and terraces, and represent one or two spirals with a diameter of 30 m, built of rough stone the size to 30 cm. The image of stone labyrinth from a human height cannot be read. In the bi-spiral labyrinth radial elements oriented to the horizon are located: the entrance and rays are perpendicular to it, radiating from the center. A vertically placed single stone or stone addition can be placed in the center, crafted balls and plates can be seen as well.

Caucasian labyrinths are presented, mainly by drawings, engraved on large slabs, included, as a rule, in the facades of medieval buildings – houses and temples. There are drawings of labyrinths on the monuments set on the ancient tombs and on the roads, on household items, the greatest number of them is described in Dagestan (Khan-Magomedov, 2000) The most detailed study was carried out for Mahcheskiy labyrinth of Digora Gorge in North Ossetia-Alania. Archaeologists and anthropologists note the autochthony of this object and similarity of drawing to samples of ancient art and the plans of the northern labyrinths (Miller. 1925, Krupnov, 1951).

a

b

c

d

Figure 1. Always supply original photographs. Northern labyrinths. a - Bolshoy Zayatsky island (d = 10 m); b - island Oleshin (d = 25 m). Mahchesky labyrinth: c - in Vladikavkaz Museum; d - in Digora Gorge (Paranin & Paranina, 2009, Hetagurov, 2016)

2.3 *The method of calculating the height and the installation of the gnomon*

The method of calculating the height and the installation of the gnomon (Paranina, 2010), in which the extreme shadows provisions coincide with the diameters of the inner and outer edges of the labyrinth, or another rhythmically constructed structure (including speed), focused on the geographical meridian, is the solution for the equation based on the trigonometric identity ($H = tg\ \alpha \cdot A$). Both parts of the equation give one result – the height of the gnomon – and describe the relationship of the angle of incidence of sun beam α and the length of the shadow of A: left – for summer, right – for the winter. The adjustment x was added to the distance measured from the central addition to the extreme edges of the labyrinth (in this example - 1 m and 5.5 m), allowing to specify its the location:

$$tg\ 48.47\ (1 + x) = tg\ 4.97\ (5.5 + x) \quad (1)$$

The solution of this equation makes it possible to determine all basic dimensions as a result of calculating the adjustment for the distances x arbitrarily selected to the center:

$1.13\ (1 + x) = 0.09\ (5.5 + x)$
$1.13 + 1.13\ x = 0.5 + 0.09\ x$
$1.13\ x - 0.09\ x = 0.5 - 1.13$
$1.04\ x = -0.63$
$x = -0.63 / 1.04$
$x = -0.61$

Adjustment of the distance to the center is based on the determination of the length of the shadows in different seasons (m):

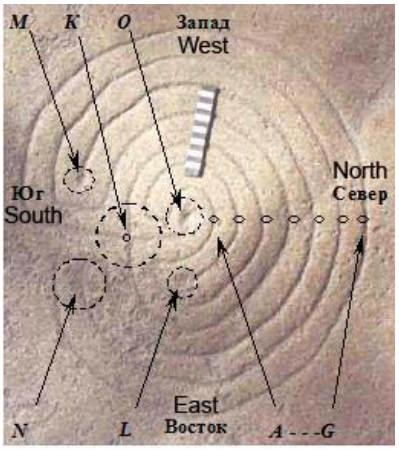
$1 + x = 1 - 0.61 = 0.39$
$5{,}5 + x = 5.5 - 0.61 = 4.89$

The final solution of the equation (1) gives the height of the gnomon (m):

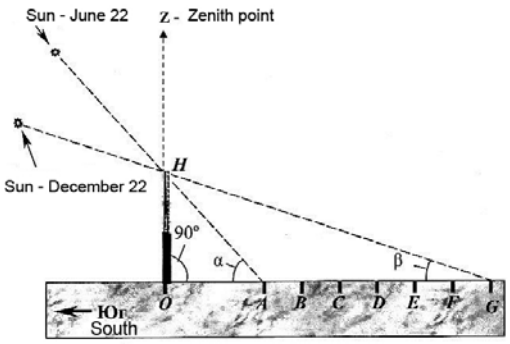
$1.13 \cdot 0.39 = 0.09 \cdot 4.89$
$0.44 = 0.44$

2.4 *The method of calculating the calendar by the example of Mahcheskiy labyrinth*

The method of calculating the calendar by the example of Mahcheskiy labyrinth (Hetagurov, 2016). To determine the possibility of using the labyrinth as a calendar it is necessary to find the specific points and lines. In the center of the labyrinth a recess is clearly visible – the installation point of gnomon indicated on the diagram D (Fig. 5a). Midday shade intersection points from the vertical pointer (gnomon) with radial labyrinth lines are A, B, C, D, E, F, G.



a



b

Figure 5. Elements of Mahcheskiy labyrinth – solar calendar: a - in the plan; b - in the profile (Hetagurov, 2016).

We orient the cross (X) on the stone by the cardinal points so that the points A-G are located along the south line South-North. By the time of crossing the south shadow of the gnomon OH radial lines A, B, C, D, E, F, G of the labyrinth, we define the corresponding date of the year.

Figure 5 B shows the same position of the sun: α - the height of the sun above the horizon at the summer solstice on June 22, β - the height of the sun above the horizon at the winter solstice on 22 December. From spherical astronomy we know that the height of the sun above the horizon during the solstices is:

$$\alpha = 90° - \varphi + \sigma \quad (2)$$
$$\beta = 90° - \varphi - \sigma \quad (3)$$

where φ is latitude of calendar setting point (for village Mahchesk φ = 42.66 °), and σ = ± 23.44 ° - declination of the Sun during days of solstice.

Since triangles OHA and OHG and rectangular, then:

$$tg\ \alpha = OH/OA \quad (4)$$
$$tg\ \beta = OH/OG \quad (5)$$

from which:

$$OA = OH/tg\ \alpha \quad (6)$$
$$OG = OH/tg\ \beta \quad (7)$$

According to the formulas (1) and (2) we calculate:

$\alpha = 90° - 42,66° + 23,44° = 70,78°$
$\beta = 90° - 42,66° - 23,44° = 23,9°$

from which:

$tq\ \alpha = 2,88$
$tg\ \beta = 0,44$

Having measured length OA = 4.2 cm on the labyrinth, using the formula (6) we define the length of the OH index:

$OH = AO \times tg\ \alpha = 4.2 \times 2.88 \approx 12$ cm.

Based on the properties of a right triangle and astronomical data, if the measured length of the shadow OG is equal to the length OG defined by the formula (7), we can say that the labyrinth could be used as a solar calendar that defines the days of the solstices.

According to the formula (6) we calculate: OG = OH / tg β = 12 / 0.44 = 27.27 cm, which is equal to the measured item.

2.5 *A comparison with ethnographic data*

A comparison with ethnographic data shows that the intersection of the date of the midday shadow semicircles corresponds to the folk calendar and sheep production cycle of Ossetian herdsmen. Thus, the intersection of a midday shade to line the helix at point D provides day 21 of February, which is the best for the start of lambing sheep and goats in the climatic conditions of the mountain Ossetia. Lambs born during these dates by the beginning of the grazing season (first decade of May) reach the age when they can eat green fodder using pastures in full. Accordingly, by the autumn lambs are growing well, it gives sufficient wool clip, full and meat carcass and left in the race – enters into hibernation more robust and large (Nikolaev, 1973). Lambs born at an inopportune time, are certainly subject to slaughter for skins – krimmer. The optimal start date of mating sheep and goats – 23 September. This day noon shadow of the pointer intersects the semicircle at point C. Using this date for mating, lambing can be obtained during the most favorable for the preservation of offspring and maximize production from the sheep - the main occupation of the Caucasus mountaineers since the Neolithic era. Calendar labyrinth yields and other important dates: the beginning of shearing (Falvara) and the transition from grazing on stabling (Dzhiorguba).

Different segments of the length of time between the arcs of the labyrinth is consistent with the descriptions of the Ossetian calendar. So, at the beginning of the XIX century, Julius Klaproth described the calendar of Ossetians-Digors, consisting of ten months in which there were "twin months" - "Maruja Dua Mai" and "Ruh dua mai" (two months Maruja and two months Rukh) (Kaloev, 1967, p. 163). Later, in 1882, V.F. Miller, in "Ossetian etudes" showed calendar of Ossetians-Digors, where the duration of the month "Komahsan" was determined from the middle to the end of January and the month "Geuargoba" followed by unnamed period continued for about two weeks (Miller, 1882, p. 263-264). Thus, in the Ossetian calendar months were not 30-31 days long, but 14-15 and 59-60 days – multiple of the moon phases. Calculations of calendar dates for Mahcheskiy labyrinth and their comparison with ethnographic data show that the labyrinth could be used as a solar calendar up to the XVIII-XIX centuries (Hetagurov, 2016).

3 DISCUSSION OF RESULTS

3.1 *Labyrinths – solar calendars in Eastern and Southern Europe*

Calendar function was proved for Mastischenskiy labyrinth, found by archaeologists of the Voronezh State University during the excavation of a Bronze Age settlement on the high chalk headland (60 m above the water level in the river Don) between the villages Divnogorie and Kostenko. Azimuth measured from the center of the labyrinth mound, through established therein granite slabs, corresponds to the directions of sunrise / sunset in the days of the equinoxes and solstices (Chekmenev, 2001). We calculated the height of the gnomon using the formula (1) as 3.5 m (2 primaries fathoms) (Paranina, 2012).

Calendar use of Mogor labyrinth carved on rocks Marina (Galicia, Portugal), has been studied by mathematics teacher Jose Luis Galovart, who proved that the central point of the drawings at the equinoxes binds the shadows of the objects, which were set during these equinox days (Historia y arqueología…).

3.2 *Structure of solar calendars: regional features*

Calculations of solar calendars structure at different latitudes reveal the regional characteristics of solar navigation.

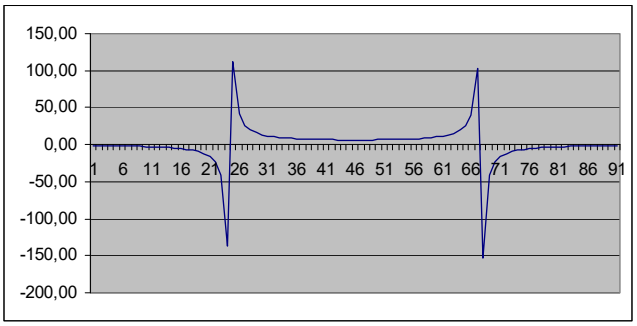
Calculations of midday shade length for the gnomon, 1 m high show that the optimum conditions for creating labyrinth calendar is the temperate zone, where the shadow throughout the year crosses all arcs twice. In the cold zone the polar night period is not applicable, and in the hot zone – midday shadow disappears 2 times a year (since the sun is at its zenith), and the shadow "passes" some parts 4 times (Paranina, 2010).

By the ratio of the height of the gnomon (e.g., 1 m) and the length of its shadow several types of labyrinth pattern and solar calendars can be distinguished: 1. Type "ankh" – in the conditions of a polar day central part is highlighted as a closed ring structure (labyrinth of Iceland) 2. "labyrinth-11" in the polar latitudes, does not have an arc for midday shade fixing in the winter solstice, as this shadow is much larger than the size of the labyrinth; 3. at latitude 50-60 ° shadows of all months of the year are placed in a circle of a relatively small diameter, a 7-arc "classic" labyrinth is a convenient here; 4. at latitudes 40-30 ° radius of the outer circle is two times larger than the height of the gnomon – a type of “staff” (≈ 2 m); 5. Tropical calendar sizes shadows are placed on the

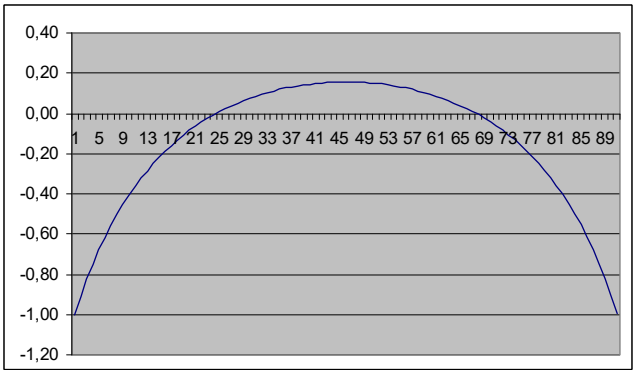
gnomon - a type of "rod", "scepter" (e.g., hex rod of dervishes) (Paranina, 2010. 2016).

The ratio of the length of a midday shade in winter and summer solstices (the longest and the shortest) ranges from 1x6,4 to more than 1000 times (Fig. 6 A).

The ratio of the lengths of shadows in the winter and summer solstice was proposed by A.T. Hetagurov as an indicator of the calendar function of cultural heritage objects, built on the basis of back sight technology. A diagram for the temperate latitudes (Fig. 6b) may be the key to geographic, astro-archaeological and local history research.



a



b

Figure 6. The ratio of the lengths of the shadows in the winter (A) and the summer (B) solstices: a - A / B; b - B / A.

Archaic measures of length have the ratio of 1:7 : foot (about 30 cm) and standard staff (6-7 feet), which may be measured by the depth under the keel, the choice of the waterway (remember the wish of "seven feet under the keel"). Length of seven feet is just average whip of the shepherd and the rider (the longest - 8 feet), and the length of his whip ranges from 30-35 cm up to 45 and 70 cm (feet and fathoms). In ancient times, a ratio of the size of objects indispensable in the steppe landscapes (which dominate in these latitudes), could be a template and a tool for creation of the solar calendar, like tables of Ancient Babylon, in which, for the seven "climates" of the northern hemisphere, for different seasons of the year human height ratio and the length of their shadow measured by feet were calculated. Interestingly, latitudes, where the calendar ratio of the length of shadows calendar is equal to 1:7, coincide with the two out of seven abovementioned boundaries of Ancient Babylon climates, calculated according to the formula (90º / 7)n: 0º, 12.9º; 25.7º; 38.6º; 51.4º; 64.3º; 77.1º.

Dynamics of landmarks of solar navigation near the Arctic Circle and the tropics explains the high level of development of astronomy in antiquity, noticed for regions located at these latitudes (Stafeev & Tomilin, 2006). Different sources indicate on the preservation of the traditions of orientation on the Sun in Europe. For example, the tradition of installing the gnomon in the yard near the house until the end of the twentieth century is mentioned in the ethnographic works of M. Stomma for Poland (Stomma, 1981). Studies of the Pulkovo Observatory recorded a strong tradition in the steppe regions of Asia, the Caucasus, the Baltic States and Karelia (Sundial and calendar system of peoples…, 1985). We have recorded messages of respondents from Karelia about vertical installation of a stick on a lined wet sand (by fishermen), about stringing of strings on carved frames of windows, facing south, about the use of palm. In Leningrad and Ryazan regions people recall the tradition of measuring their shadow by feet, in the Ryazan, the use of whip as the gnomon of a sundial by shepherds is also recalled.

3.3 *Evolution of the geographical space*

Studies of ancient navigational tools take into account the regional and global models developed in astronomy, physical geography and evolutionary geography. It is known that the position of the polar circles and the tropics, as well as natural and climatic conditions of region (especially polar) affects the Earth's axis tilt change from 22.1 to 24.5º: by reducing the inclination, border of moderate light zone are expanding, with an increase – are narrowing. In view of the possible positions of the polar circle, we divide stone labyrinths of Northern Europe by polar, circumpolar and temperate zone objects. Features of light conditions largely explain the differences in the structure of objects (figure of objects) (Paranina & Paranin, 2015).

4 CONCLUSIONS

Interdisciplinary studies of ancient heritage sites in the geography of culture enhance the possibility of objective understanding of their primary management purpose, a symbolic interpretation of the structure and functions of geo-cultural space. For further detailed studies it is necessary to create a database of objects structure and accommodating landscape.

Studies conducted by the authors using the gnomon of a sundial-calendar, open the designation of labyrinths as markers of geographic space-time, and explain the contradictory diversity of symbolic interpretations on the basis of the instrumental functioning sites.

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