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INFORMATION CONCERNING BUILDINGS CONSTRUCTION TECHNIQUES OF GETO-DACS IN THE 1ST MILLENNIUM B.C.

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ABSTRACT

Spread according to an amazing plan of defense, at the foot of stately heights, at the blunted peaks or on their oblong ridges, the Dacian fortifications and the villages of some blooming communities are proof of an extraordinary technique of space planning and of setting up of construction works, proved by their variety, richness and monumental character. Raised of large and average-size limestone blocks, these fortified areas impress not only by the chosen position, by the extraordinary building techniques, in accordance with the most up-to-date principles of strength, equilibrium and waterproofing, but also by iron processing workshops and time measuring devices. This type of buildings implies today, as it did then, specialists in designing, skillful workers for the execution, but more especially experience in construction works. The discovered fortifications and walls totalize at each of the cities about 200,000 m^3 of stone, which indicates vast building rock mining, opening-up and rock stripping, splitting of the blocks out of the mother-rock, shaping workshops, efficient ways of transport and an advanced organization of the "building site".

1 INTRODUCTION

Perhaps none of the lands of ancient Dacia (the name of the intra and extra-Carpathian territory in the first Millennium B.C.) contains more traces and more important monuments than the Sureanu Mountains, in the Meridional Carpathians [1]. A large part of the settlements and fortifications in the Sureanu Mountains are set round Sarmizegetusa Regia, the capital city of Dacia of the 1st millennium B.C. Among them, there are the walled cities of Blidaru, Costesti, Fetele Albe, Piatra Rosie –

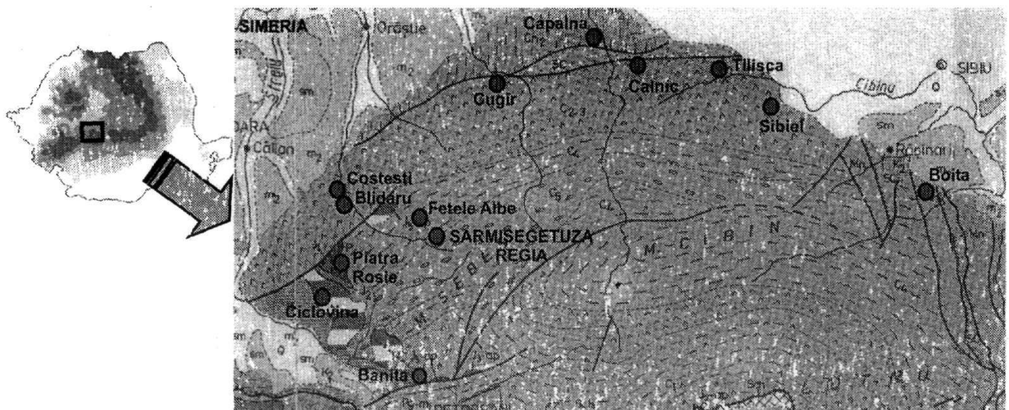


Figure 1. Location of the Dacian fortified cities from the Sureanu Mountains, in the Meridionali Carpathian

located on the Gradistei Hills or in their neighborhood, besides other numerous cities that surround the mountainous massif of Cibin (Fig.1), covering almost all possible ways of communication.

Setting up Sarmizegetusa Regia on the Gradistei Hill in the Sureanu Mountains could not have been determined by economic reasons. The remote place, far away from the great commercial roads, the high altitudes (1000 m inside the fortified city), the unstable mountain climate, the inhospitable ridge consisting of micaschists that are not suited for natural terraces, the absence of the agricultural or even grazing lands mean a choice of a military – strategic character, making use of the advantage of a place that is difficult to be approached.

The civilian Dacian constructions were set up using a great number of materials, a large part of them perished over the millenniums of history, so that the unprofessional eye cannot recognize their aspect and number. Others, such as the edifices integrally or partially built of stone or the military cities provided with massive walls, as nowhere else in the world, have been fairly preserved. The ruins themselves are impressive, letting us imagine what they looked like in their blooming period.

2 GENERAL CONDITIONS

The communal, popular, military and religious buildings indicate the material level of the community, even the number of the population, the specific features and specializations of its members, their degree of adapting and creativity depending on the environment conditions. All this is proved by the traces found in the mentioned areas, represented by stone foundations, remnants of walls or buildings, the usual archaeological inventory: ceramics of various sizes and uses, metal ware from arms to tools, ornaments, religious or household objects, treasures in coins, cranial trepanning kit (found near the Great Sanctuary at Sarmizegetusa Regia) [3].

The Dacian walled cities are the most important buildings outside the Roman Empire, comparable with those of the imperial civilization. These cities are distinguished by the:

- ample offset works, specifically strengthened more by tree planting, the offset filling material reaching hundreds of cubic meters; these terraces were fitted out by infrastructure works in five successive layers;
- circumvolution or surrounding works, to make the access to the walls of the city much more difficult;
- subdivide them into asymmetrical "patios" where for a stranger the orientation was very difficult and the danger very great;
- presence of a wall adjacent to the entrances determining the division of attacking people into two parts; the two ends of the wall facilitated the closure of these between defensive armies;
- abundance of iron building material;
- spacious underground water and dwelling facilities also fitted out with several exits.

3 MILITARY AND CIVIL CONSTRUCTIONS

In the neighborhood of the Dacian cities, more especially in the capital city, grand fortification works were found, unitary as far as the conception of the location is concerned, but with differentiated constructive elements, ingeniously adapted to the place [2].

A characteristic of the Dacian cities is the "Dacian wall" (Fig. 2), called in archaeology "murrus Dacicus". The main characteristic of the wall is the way it is built, namely of two parallel walls (Fig. 3) between which there is a filling material called emplecton, of stone with clay or with slag.

The slag has the property of hardening in time, being able to reach the strength of the concrete. Although the Dacians had a vast iron and steel working activity resulting in large quantities of slag, the expected quantities of slag are not found in the adjacent area of iron mining and processing furnaces and kilns.

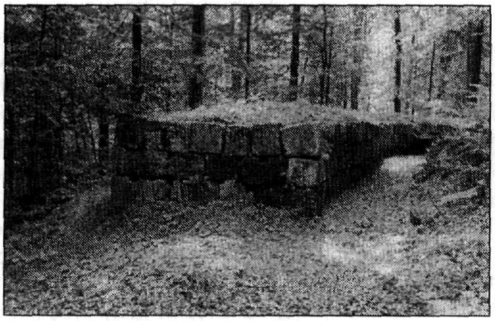


Figure 2. Part of wall around old capital of Dacia, Sarmizegetusa Regia

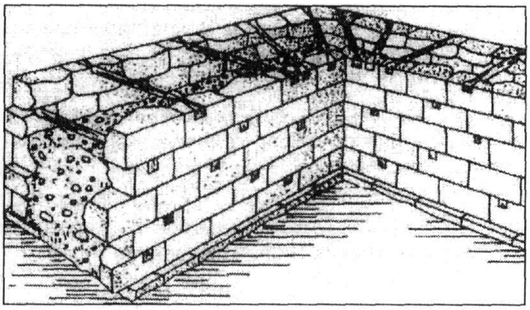


Figure 3. Archaeological sketch graph of reconstituting the Dacian wall from Sarmizegetusa Regia

Taking into consideration the climate in these areas, it was normal that the walls were very thick. With the "murrus dacicus" type city walls [3], the filling material also plays the part of what we call today a "thermal bridge". The fillings prevent the transfer of heat, but more especially of heat from the outside to the inside of the premises. The thickness of these walls is proportional with the dimensions of the rest of the building. Likely for the pyramids, this type of constructions without mortar favour the production of the phenomenon of piezoelectricity.

The Dacian wall has no mortar between its stone blocks. The blocks have fixing grooves of trapezoid section, the so-called dovetail (Fig.4), with the narrow part on the inside, where the girder poles of the same shape are introduced. The girder poles are kept in the wall and, in turn, supported the wall. This type of wall is extremely appropriate to the mountain areas where excavation for foundation is difficult due to the thin soil layer (sometimes absent) above the bedrock. Depending on both the land and the strategy conditions, the wall was 2.3 to 5 m wide. It is possible that certain war machines, of a considerable weight, were located on these walls.

The walls of the Dacian cities are whole made of limestone blocks, of which the oolithic limestones (Fig. 5) are predominant. The colour of these limestones is cream-yellowish. The exposed surfaces are sometimes degraded by the dissolution of the calcium carbonate. Sometimes they get a reddish or blackish color a consequence of the interaction with the waters and substances from the soil that covers them.

The physical degradation changed the colour of the exposed surface of the block (which turns dark cream and slightly reddish by the oxidation of the carbonic ooids and sometimes blackish because of the soil organic matter, the decomposition of the leaves etc.). All blocks are covered with green vegetal films. The blocks are not friable, probably because of the siliceous nuclei of the

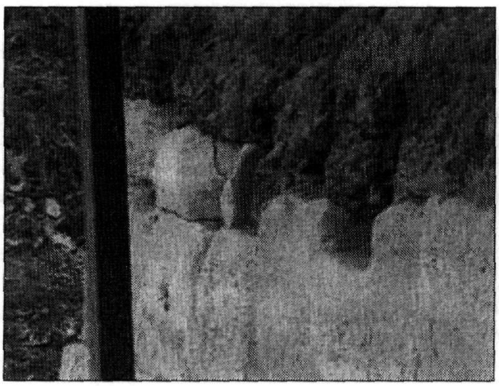


Figure 4. Fixing trapezoid grooves at Tilisca fortified city

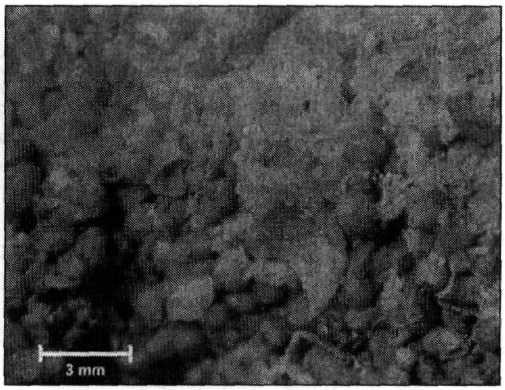


Figure 5. Photomicrograph of thin section of oolithic limestone block from Dacian fortified city walls

ooliths that make up the limestones. The colour of the blocks of fossil – bearing limestone varies from cream to yellowish – reddish. The surface of the massive limestones has a darker color (dirty-white to blackish), but the physical degradation did not led to breaking of the carbonatic material. Only superficial processes of secondary dissolution and cementation have taken place. These limestones are compact, despite the time elapsed since the walls were built and the severe weather conditions prevailing in these mountain areas.

The blocks consist of a variety of limestones which was brought from a distance of 50 km to 150 km away from the area where these edifices were raised. They were primarily processed at the place where they were quarried; subsequently they were transported and processed to obtain grooves and simple, double or triple joints (Fig.6) when the walls were built. The absence of large-sized fragments of blocks is a decisive argument for what we stated above (the small fragments and the resulting dust being certainly a part of the emplecton), besides the logic of saving the effort required for carrying these blocks to the city (it is more difficult to transport an unfinished raw stone block than smaller-sized blocks).

Figure 6. Triple joining at a block from the walls of Sarmizegetuse Region

The direction of the outer walls of the cities is predominantly N-S/E-W on some of the sides, with maximum 2-5^{o} deviation. As the exterior outline is not always rectangular (because of subsequent building of walls for strengthening purposes or change of the purpose of the rooms), there are walls, usually smaller in length, which do not have this direction.

The main constructive characteristics, determined by macroscopic study, are the following:

- The blocks present surfaces with an advanced processing degree, namely cutting and primary grinding, as the surfaces are uniform and straight; besides chamfering of the blocks and obtaining of the angular edges, confirms the application of advanced building rules complying with several rules of durability and functionality of a construction: solid geological bedrock (gneisses and micaschists) with minor or absent ruptural tectonics; use of blocks of such dimensions as to assure the solidity of the construction by their weight; making of some joining edges between the blocks, both at the corners and on the entire length of the walls (angles, inclination of the sizes of the blocks as to the vertical); draining of the waters from the premises of the construction (making of pipes, discharge grooves at an angle that should not diminish the impact force, the erosion and entraining of the blocks, one against the other); optimum wall height / thickness ratio; ornamental effect (type of rock used, limestone shape of the construction);
- The surfaces of some blocks are slightly inclined; the angle between some of the surfaces are sensibly larger , smaller from 90^{o}, respectively the vertical sides of the blocks make an angle of 5-10^{o} with the upper and lower sides. This type of shaping favours the increase of the band between the stone blocks required when the blocks are not bound together with mortar. The "pair" blocks at which the angles of each block are slightly different than 90^{o}, but at both blocks

are 180°, require at the contact surfaces, a special processing and a rigorous organization of the building – site for a proper location within the construction;

- The limestone blocks have dimensions that vary as follows: length (L)=0.5 m; width (W)=0.5 m; height (H)=0.5 m and very seldom 0.3 m.
- The structure of the walls includes stones of up to 0.8-1 t, whose location on the mountains requires lifting installations. Following archaeological studies, special pulleys were identified, of welded plates supporting weight – forces much higher than the monoblock pulleys. Taking into consideration the tree – covered mountain slopes we are entitled to suppose that the pulleys were fixed to supports resting on trees. The pulleys reduce, depending on their number (n), twice (2n) the weight that is lifted. Thus, with 4 pulleys, the weight is 8 times reduced. The Dacians fully justified the physical aptitudes required for carrying out such activities. In addition, the archaeological surveys identified the presence, within the space of the Dacian cities, of some rock bars (at present defined as machine parts shaped as a straight toothed wheel, used to transform a rotation movement into a translation movement and reversely).
- Many of blocks are cut to specific joining shapes (in steps), usually 2-3 angle cuts within the same block (Fig.6), witch determines the increase of the compression strength, supporting a bigger weight above it respectively and enabling the building of a very high construction with solid roofs and none wood, as this is very vulnerable to fire. As far as possible, a fire protection was taken into consideration, because the fire was one of the permanent attacking "arms" throughout the entire history.

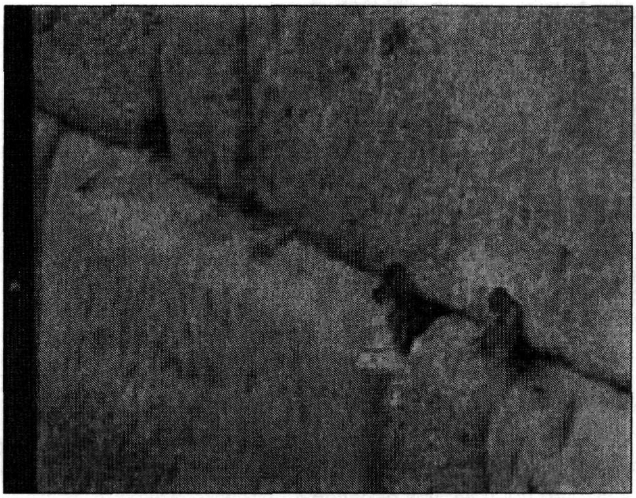


Figure 7. Exemplification of the chamfering technique used limestone blocks at Tilisca city

Almost all the blocks are chamfered (Fig.7) at the edge of the exposed surface. An additional angle to the edges is made by cutting, presenting both a high aesthetic characteristic and a better way for water discharge along the surface of the wall; all the cities in the Sureanu Mountains or adjacent to these present this constructive specific characteristic.

Sometimes "bricks" of gneisses and micaschists with thicknesses of up to 20 cm were placed over the limestone blocks, enabling waters flowing down between them; especially when the hydrostatic level is more on the surface, water must have flown more often and more abundantly during rainy periods and after snow melting, determining the adoption of some additional wall protection measures.

Almost 70% of the blocks have trapezoid shaped holes cut for water flowing, mostly disposed at an angle of 45° as to the sides of the block; a similar feature can be found on the other sides, too, but in a smaller number. This type of constructions (Fig.8) lead nowadays specialists in designing, skilled workers in the execution, but more especially experience in construction. The discovered fortifications and walls totalize abt. 200,000 m^3 of stone, at each of the cities of the Luncanilor plateau.

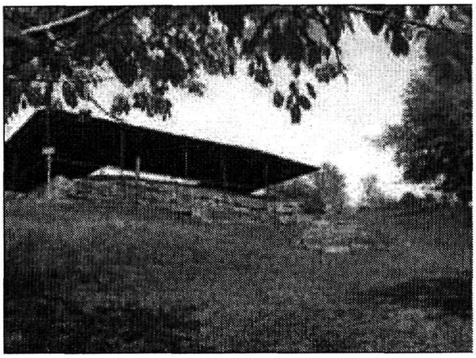


Figure 8. Partial buildings from Costesti civil and fortified city

Figure 9. Paved road on the blocks of the exterior walls in Dacian walled city

This fact indicates vast mining of building rocks, stripping and derocking, detachment of the blocks from the parent – rock, shaping workshops, efficient ways of transport and an advanced organization of the "building – site" [4].

The Dacians civil constructions are adapted to the conditions specific to the geographic and climatic areas of the ancient Dacia, offering good protection to the people and the domestic animals during hard winters. The dwellings had several shapes and levels. Concentric dwellings were identified, polygonal, octagonal or round in shape, to reduce heat losses through corners; the walls were about 50 cm thick, the roofs were also extremely solid to provide a proper thermal insulation, resistant to load due to rainfalls and snow. The constructions thus built, with an appropriate partition of the interior spaces, offered a real comfort.

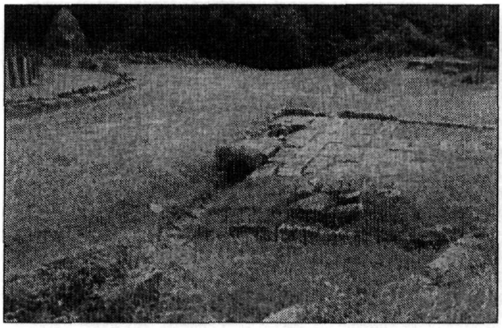
The vast spaces destined to the storage of food for both people and animals indicate the high economic level of the households. Ceramic terra - cotta pipes, supported and earth insulated by wooden troughs, were used for water catching from the springs and directing it to the households. The water was filtered and stored in simple cisterns, sometimes lined with wood. There were also pipes dug up in the rock or consisting of beautifully shaped stone blocks as well as storage cisterns of stone slabs and mortar.

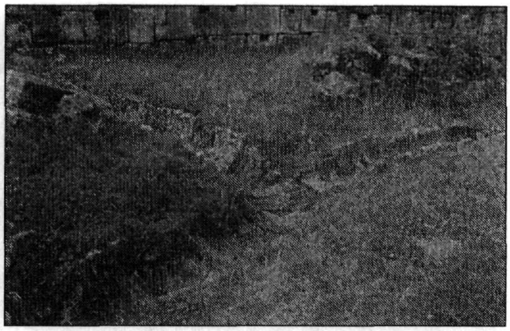
The spaces of the households used to communicate by means of paved roads (Fig.9), some of them covered ones. At some of the former dwellings, monumental staircases, special arrangements, rain water draining pipes, land planning and fortifications, all aiming for preventing land slides were identified. All these incontestably indicate economic prosperity and a high level of civilization.

4 COLLECTION, TRANSPORT AND STORAGE OF WATER

The rainwater collecting pipes inside the cities were covered (Fig.10) making up a vast water collecting network. The stone blocks of the sewerage system are still amazing due to impeccable interior and exterior shaping, carried out in andesite or limestone. The perfect functioning was also assured by the fact that in the direction change points (Fig.11) there are interior thresholds removing clogging and making water flow down without the danger of overflowing, even in large quantities.

In high altitude regions the water pipes are built at the base of the walls of the cities used for draining or flowing are called in the present technique inverse filter weepers, which are special arrangements consisting in placing some successive layers of gravel and sand of a certain size distribution, enabling flowing of the water without entraining material that might clog the draining way. These weepers were so properly built as to be still functional. In the places they were damaged and were not restored, the land was affected, as it slid together with the falling wall. Therefore, their aim was evidently to protect the constructions by preventing landslides. Because this type of draining





Figures 10, 11. System of covered canals for water catching or draining within the premises of the Sanctuaries of Sarmizegetusa Regia, Sureanu Mountains

was not known and because the assistance of a specialist in construction works was not requested, the walls were badly restored by the archaeologists.

The troughs on the city walls, which only some traces remained, had the role of collecting the water from the vertical surfaces of the construction and from the roofs and to direct it into tanks.

Thus, the water cistern from the Blidaru city is made of large stone slabs of micaschists, the same type as the rock the city is built. These "bricks" from micaschists obtained by breaking along the foliation lines of the rocks by a method used until present times by traditional builders, are fixed together with mortar. The composition of the mortar is similar to that of the concretes made according to current standards. The composition of the mortar also includes large coal grain with about 15% offering the mortar septic properties, required for maintaining high quality of the water under stationary storing conditions. Cisterns of a similar type, but without mortar, are found at other walled cities, too, placed differently against the main entrance of the city.

5 WORSHIP CONSTRUCTIONS

The worship buildings have a maxim concentration at Sarmizegetusa Regia, the capital of Dacian kingdom. At 600 m altitude, in the middle part of a micaschists mountain, 15 terraces has built, for different aims. In the present, on the IX-XIth terraces, the traces of one of the most fascinate sanctuaries with astronomic and sacred character have been found [5] (Fig. 12, 13, 14). These are built by andesites and limestones and destroyed by the roman conquerors in 106 A.D.

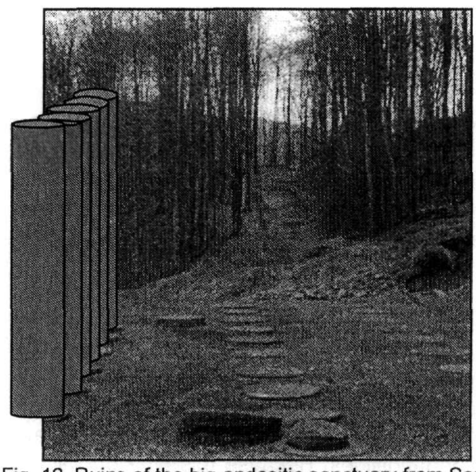


Fig. 12 Ruins of the big andesitic sanctuary from Sarmizegetusa Regia

Now it remained only fragments of columns (until 2.10 m diameter) or pillars which make up 11 sanctuaries, with circular or rectangular shapes. The depth and the foundation layers (until 6 m), archeological inventory, the size and number of elements (included an "andesitic sun" = compass = "astrolabe") give us indications about the old elements (like the high of andesitic column – 11-15 m) or about the probable aims of these sanctuaries. Beside of information of the most exact astronomic calendar B.C., the length and configuration of the year, N-S, geomagnetic, solsticial or equinoxial alignments [3, 6].

Figure 13. Ruins of limestone sanctuary at Sarmizegetusa Regia

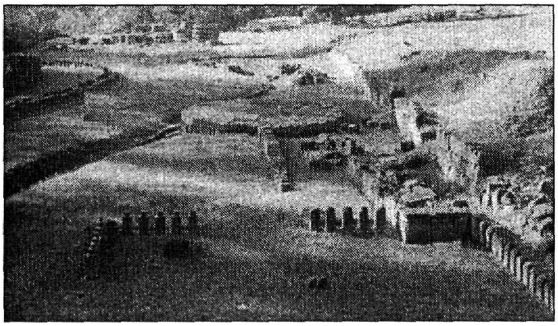


Figure 14. The small sanctuary and astronomic compass from Sarmizegetusa Regia, built of andesite

6 CONCLUSIONS

Built of large and average size limestone blocks, the fortified and civil cities from Sureanu Mountains, in the Meridionali Carpathians, impress not only by their chosen location, but also by the extraordinary building techniques, in accordance with the most up-to date principles of strength, equilibrium, waterproofing, alignment to the axis of the magnetic poles of the globe in the period they were built. These cities had both a military role and an economic-administrative one, as they were able to assure not only the water supply system but also an ingenious water transport, purification or storage system in areas without an aquiferous network, an efficient draining area, iron processing workshops and time measuring devices.

A practical lesson of science, a proof of more then three millenniums of history. Traces in stone which speak to us about the astronomic knowledge and elaborate building construction techniques of the old inhabitants of Dacia, the intra and extra-Carpathian territory in the first millennium B.C.

REFERENCES

[1] Cetean V. , 2000. The study of territorial distribution of building materials, Procema Geological Archive

[2] Brezeanu L. & Cetean V. 2003. Construction techniques of geto-dacs in the 1st millennium B.C., Romanian Journal of Building Materials (in Romanian and English)

[3] Glodariu I., Iaroslavschi E., Rusu-Pescariu A. & Stănescu F., 1996. Sarmizegetusa Regia, the capital of pre-Romanic Dacia, Acta Musei Devensis, Deva, (in Romanian)

[4] Daicoviciu H. 1972. Dacs. Romanian Encyclopedic Editor, Bucharest (in Romanian).

[5] Densusianu N. 2002. Prehystorical Dacia. Ed. Arhetip, Bucharest (in Romanian).

[6] Busuioceanu A. 1985. Zamolxis or dacic myth in the Spanish history and legends. Ed. Meridiane, Bucharest (in Romanian and Spanish)

[7] Cetean V. , Brezeanu I., Giurgiu I. & Matei A, 2000-2003. Photos