PĂCUIUL LUI SOARE – BUILDING STONES AND THEIR SOURCES

ALBERT BALTRES, EMIL AVRAM [1]

Introduction

The Byzantine stronghold of Păcuiul lui Soare was erected in the second half of the Xth century AD[2] on an alluvial island confined between the Ostrov Arm and the main channel of the Danube River (Fig. 4). It played the role of nautical base in the Xth and XIth centuries and was an important centre of trade. For these purposes the strong defenses were carefully projected and then erected by qualified stoneworkers. The various arrangements of the stone blocks in the strongholds were analyzed by Vîlceanu[3] who found out definite interrelationships.

The unearthed remains of the stronghold (Figs. 1, 2) show that it was originally built by accurately cut, aligned rows of large blocks of rock, reaching 1.4 meter in length and up to 0.5 m thick. A 1 to 9 centimeter thick layer of coarse concrete occupies the horizontal space between two rows of stones. Concrete of the same thickness fills also the vertical spaces between two adjacent blocks. The space in between the front and rear faces of the walls was stuffed with rough-hewed boulders of various rock types, arranged in somewhat regular order, bound also by concrete.

About eight sedimentary rock types, of various geologic ages, were identified. A short description of these and of the concrete composition follows. The description is based on direct site observation and on microscopic analyses that have been carried on samples in order to assess the geologic age of the rocks and the composition of the bounding material. Then, an overview of the geology of the surroundings of Păcuiul lui Soare, and a description of the sites of Byzantine Epoch quarries found in this area provided additional information regarding the sources of building stones.

The building stones

A first inventory of the building stones at Păcuiul lui Soare was done by Diaconu and Zah[4]. With minor exceptions the fifteen rock types described by these authors were recognized also by us, as follows. Their numbered 1, 2, 4 and 5 lithologies correspond to here described *Cretaceous white calcarenites*, and their number three lithology is equivalent to our *Greenish-gray, very fossiliferous marly calcarenites.* Our *Cretaceous sandstones* were described by the same authors as three sorts of Albian rocks (numbered 6 to 8). Moreover, they signaled the presence in the masonry of Cenomanian sandstones (their number 9 rock type), and of Senonian cherty chalks, not recognized by us. Their number 15 lithology was described by us under *Eocene limestones with Nummulites*, and their 10 to 13 lithologies under *Sarmatian rocks*. In addition, we added to the list the *Upper Pliocene rocks.*

Generally speaking, the carefully shaped, smooth-faced, squared blocks, on the front and rear faces of the walls are almost exclusively Cretaceous limestones (up to 97.75% in the gateway). Few Pliocene limestones and sandstones to microconglomerates, and Sarmatian fossiliferous limestone blocks were also utilized. On the other hand, the stuffed space in between the front and rear faces of the walls contains boulders of various sizes, of prevailing Cretaceous and Sarmatian limestones (68%, and 26%, respectively,

[1] Geological Institute of Romania, 1, Caransebeş Str., 012271, Bucharest, Romania.

[2] According to P. Diaconu, *Quelques problèmes relatifs à la forteresse bzyantine de Păcuiul lui Soare à la lumière des dernières fouilles archéologiques*. Dacia, N.S. 10, 1966, p. 367, it was erected between 972 and 976 A.D.

[3] D. Vîlceanu, *Cu privire la tehnica de construcţie a zidului de incintă al cetăţii bizantine de la Păcuiul lui Soare (Secolul al X-lea e.n.)*. SCIV 16, 1965, 2, p. 291-305.

[4] P. Diaconu et Em. Zah, *Les carrières de pierre de Păcuiul lui Soare,* Dacia, N.S. 15, 1971, pp. 289-306.

DACIA, N.S., tomes XLVI–XLVII, Bucharest, 2002–2003, p. 189–206

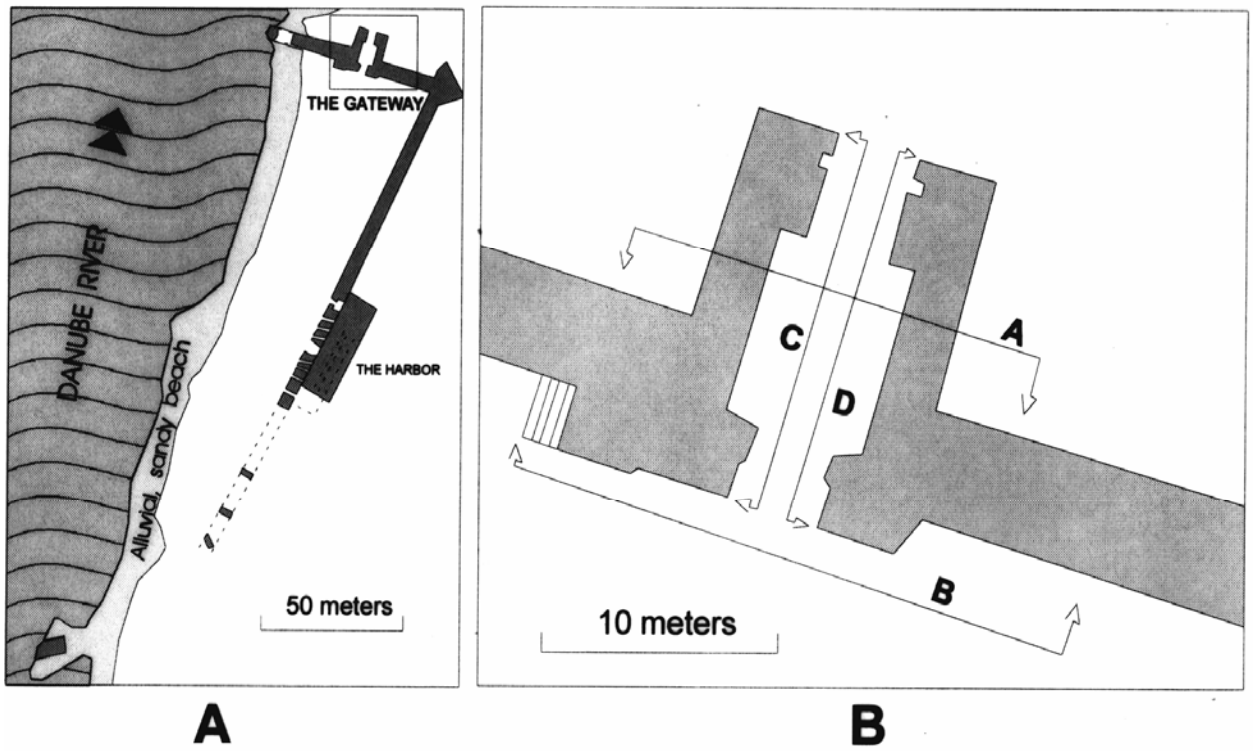

Fig. 1. The stronghold of Păcuiul lui Soare. A. The outlines of the unearthed part of the stronghold showing the emplacement of the gateway (insert). B. The gateway and the position of the four sweeping views (A to D) shown in Fig. 2.

in the gateway), minor quantities of Eocene limestones as well as Sarmatian and Pliocene sandstones and conglomerates.

The Cretaceous rocks (Upper Barremian-Lower Aptian) are of three types: *white calcarenites*, *greenish-gray fossiliferous marly calcarenites*, and *sandstones*. The first two types occur sometimes interlayered, so that some blocks exhibit distinct bands of contrasting appearance.

The white, fine- to coarse-grained calcarenite blocks exhibit commonly smooth surfaces, as a result of their homogeneity due to natural cementation causing a total loss of porosity. On fresh cuttings the rock looks bright white, compact and porcellaneous in appearance. Some blocks show certain compositional variations revealed by alternating coarser and finer grained bands or by increased porosity caused by incomplete cementation or selective solution along some bands. These bands are coincident with the horizontal rock layering which is always parallel to the upper and lower faces of a block, except some cases when a block was cut from an oblique stratified limestone bed. The mentioned inhomogeneities were in some instances accentuated by weathering in the course of centuries, so that the weaker parts of rock stand more recessive due to erosion. These features were encountered mainly at the arched door entrance. Very rare whole fossils were shown in these limestones. The fossils are centimeter-sized pachiodonts (*Toucasia* genera) and large gastropods (*Harpagodes* and *Pseudoglauconia* genera).

Thin-section observation shows that the rock consists of peloids, intraclasts, and various sand-sized skeletal remains: echinoderm plates, recrystallized molluscan shell debris, foraminifera (*Orbitolina*, *Glomospira*, miliolids) and sometimes abundant large bryozoans. The depositional texture is fine to coarse packstone and grainstone.

The white limestones were preferred as building stones for erecting the masonry owing their high quality. The blocks cut from these consistently dominates in all parts of the stronghold and particularly in the completely unearthed gateway. Block counting in the gateway walls shows that about 90% of all are white Cretaceous calcarenites (Fig. 2).

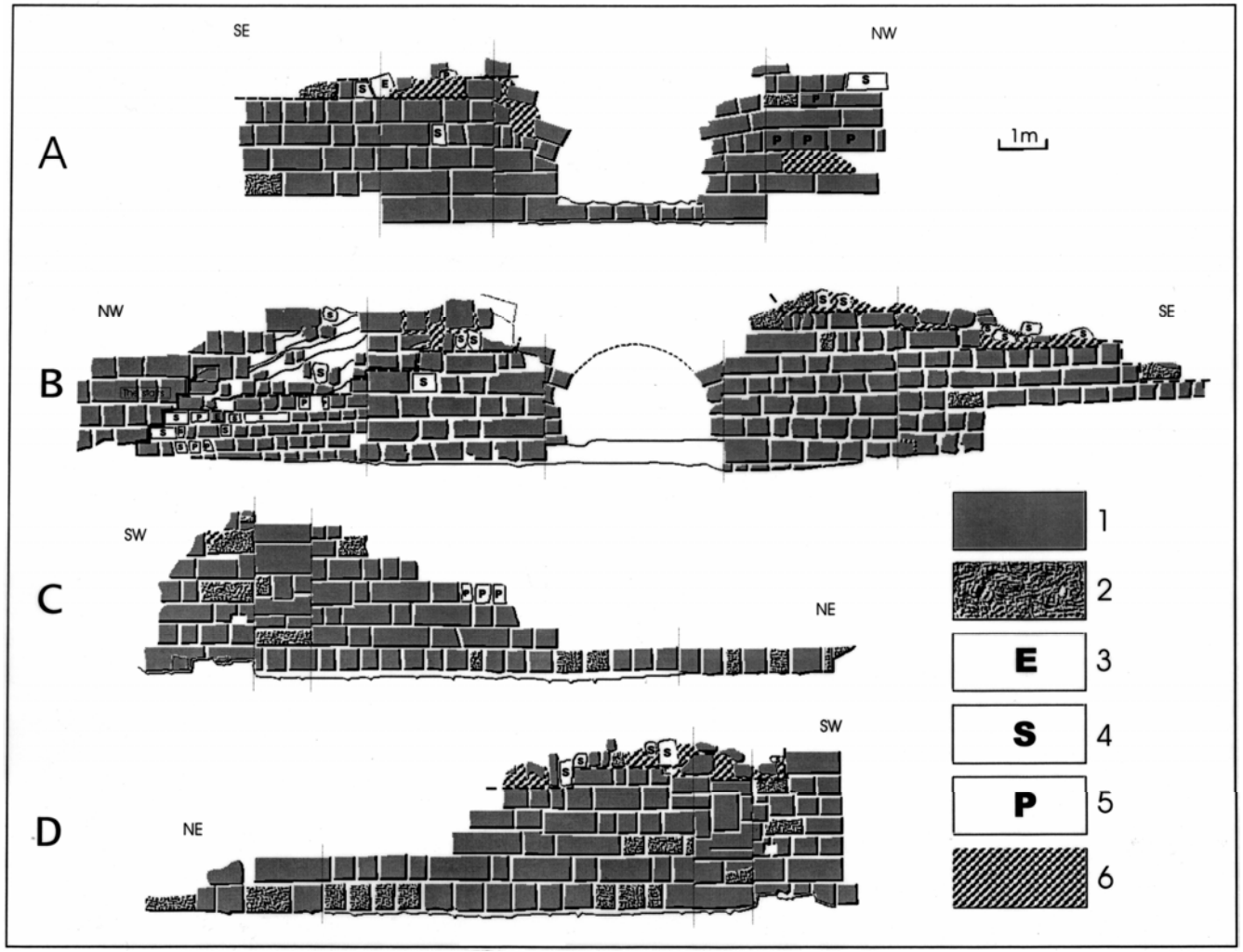

Fig. 2. Sweeping view of the gateway stronghold, depicting the various rock types in the walls. 1. Cretaceous, white calcarenites; 2. Cretaceous, greenish-gray, very fossiliferous marly calcarenites; 3. Eocene limestones with *Nummulites*; 4.Sarmatian rocks; 5. Upper Pliocene rocks. The texture labeled 6 in the Legend illustrates the concrete bounding the blocks in the space between the front and rear faces of the masonry. The dashed line delimit the isodomic masonry (below) from the stuffing material filling the space behind. Geologic data were added on survey of Arch. Dobrescu Fl., Iosipescu Raluca, Iosipescu S., Spoială L., Mehedințeanu C., Brăilescu Sofia, *Consolidare restaurare poarta cetății bizantine «Vicina» insula dunăreană «Păcuiul lui Soare», com. Ostrov, jud. Constanța. Proiect M113*, 1999.

Another sort of Cretaceous rocks, less used for masonry due their poor quality are ***Greenish-gray, very fossiliferous marly calcarenites***. Only 7.75% of the gateway blocks are o this type (Fig. 2), in net contrast with the high participation of the white calcarenites. The abundant, very coarse skeletal remains in these are sometimes concentrated as lumachelles with pachiodonts (*Toucasia*) and large gastropods (*Harpagodes*, *Pseudoglauconia*).

The distinctive appearance of this rock is caused by the overall presence of discontinuous patches of gray to greenish marly sediment. Pellicular, soft marl envelopes surround also the whole fossils, imparting a false breccious aspect of the rock. In some instances the rock grades to a dark, soft, fossiliferous marlstone. The greatly ruined appearance of some blocks in the masonry is proper for the described rocks which were badly damaged by weathering, showing often large fossils projecting from a more recessive, eroded marly calcarenite matrix. The size of the blocks (usually 0.4 to 0.6 m) is less than that of the white calcarenite blocks which can attain up to 1.4 m in length. The southern wall, of which a part can be seen today gently dipping into the river, was made of much larger blocks of the same type of rock, emplaced only in the space between the front and the rear faces of the wall.

Few ***Cretaceous sandstone*** blocks were encountered only as raw, stuffing material. The presence of glauconite grains indicate that these rocks are Albian in age.

Sparse blocks of soft, ***Eocene limestones with Nummulites*** occur in the staircase and as filling material. The largest of these is 0.54 × 0.33 × 0.22 m.

The Sarmatian rocks were largely utilized as stuffing material, and in the staircase (26% and 12.5%, respectively). Only four squared blocks of this type lie interspersed in the gateway wall (Fig. 2). The rocks are essentially fossiliferous calcarenites with sparse *Mactra* and cardiacean shells. The fossils lie amid a mixture of tiny shell harsh, microgastropods, miliolids, *Nubecularia* (*Sinzowella*) and other foraminifera, ooids and vadose diagenetic features, such as pisoids. The intergranular spaces were filled by clear calcite cement. Usually, the blocks of this composition look highly porous, as a result of the selective leaching of some shells; a void left by a leached shell of *Mactra* can reach up to 4 cm in length. Rare, very coarse sandstone blocks with partly leached, fine shells, represent the second type of Sarmatian rocks. These were found assembled only in the staircase.

Upper Pliocene rocks were recognized as few squared blocks in the gateway (Fig. 2), in the staircase and as stuffing material, in proportions varying between 1.5 and 8.0 per cent (the lower content in the gateway, ant the higher in the staircase). Most of these consist of gray microconglomerates and sandstones containing white shell harsh (proper to the Romanian stage of the Pliocene) or rare phosphate grains (Pontian stage). Only one brownish-gray limestone block, in the gateway, seems similar to the lacustrine limestones with *Viviparus,* proper for the Dacian stage.

The bounding material

Two distinct types of bounding materials were recognized. The first of these was utilized for filling the spaces between the rows of blocks (Fig. 3), and in the foundation. It consists of a mixture of gravel and, now completely calcitized, lime. This mixture has a concrete appearance.

The gravel is composed of rounded quartzite granules and/or pebbles (0.5 to 2 cm diameter) which participate with 37.7 to 63.4 wt.% to the mixture (in two distinct samples leached in acid). Another sort of mixture contains exclusively rounded limestone pebbles, 3 to 4 cm in diameter, with intergranular spaces filled with lime.

A 0.5 meter thick masonry in *opus incertum* what lies as foundation of the stronghold consists of raw cobbles, bound also by abundant lime.

The white, calcitized lime is usually brittle. Because of many fine open cracks it degrades to a powder. This is explained by the fact that the secular transformation of lime to calcite was accompanied by volume reduction, because the latter mineral is of higher specific weight and, consequently, occupies less space. Under the microscope the fine, crystalline calcite looks divided by a network of shrinkage cracks into 0.1-0.2 mm angular particles. The calcite contributes 36.6 to 62.3 wt.% (deduced by difference, in the above mentioned samples).

Fig. 3. Horizontal and vertical spaces between adjacent blocks, reaching 4 to 7 cm in width, filled in with concrete containing rounded quartz pebbles of 1 to 3 centimeters in diameter.

The second type of bounding material is a sort of hard mortar containing, invariably, a fine powder of grounded brick. The added brick debris imparts an overall pink color to the mortar. In addition, the mortar is waterproof, being an ideal insulating material for protecting the masonry against weather. It stands to reason that this colored mortar posses also an aesthetic role because, used to plug the visible gaps between the regularly spaced white blocks in the wall, it determined a play of colors, combined with the rhythms of the *isodomic* masonry.

In few places inside the wall the recipe of the described mortar was changed to a concrete by addition of a significant proportion (57wt.%) of rounded quartz pebbles (0.5-1 cm diameter), and about 10% (by visual estimation) of coarse-grounded brick (up to 2 cm in length).

Thin-section observation shows that the mortar consists of a microcrystalline mineral with low birefringence (probably lime, $Ca(OH)_2$), and abundant opaque particles of brick powder. The fine grounded brick triggered the hardening of lime as well as inhibited the alteration of it into calcite, explaining thus the good preservation state of the pink mortar.

The geology of the area around Păcuiul lui Soare

The lithologic types recognized in the walls of the fortress are spread on a large area in South Dobrogea, sometimes far from Păcuiul lui Soare, but the largest part of the material was brought in from a limited area, around it, as was demonstrated by the stoneworks found here.

A short description of the formations, accompanied by a geologic map (Fig. 4), offers an image of the areal distribution of the most utilized rocks in the strongholds as well as the location of the quarries found to date. The description of the geologic formations was accomplished, as usually, from the oldest to the youngest.

Berriasian-Valanginian In the region here under discussion the Berriasian-Valanginian rock-sequence crops out along the Canaraua Fetei Valley, from the Romanian-Bulgarian border northward up to the Oltina Lake, and also in the middle courses of the Ceair and Caraghioz valleys (east of the Bugeac

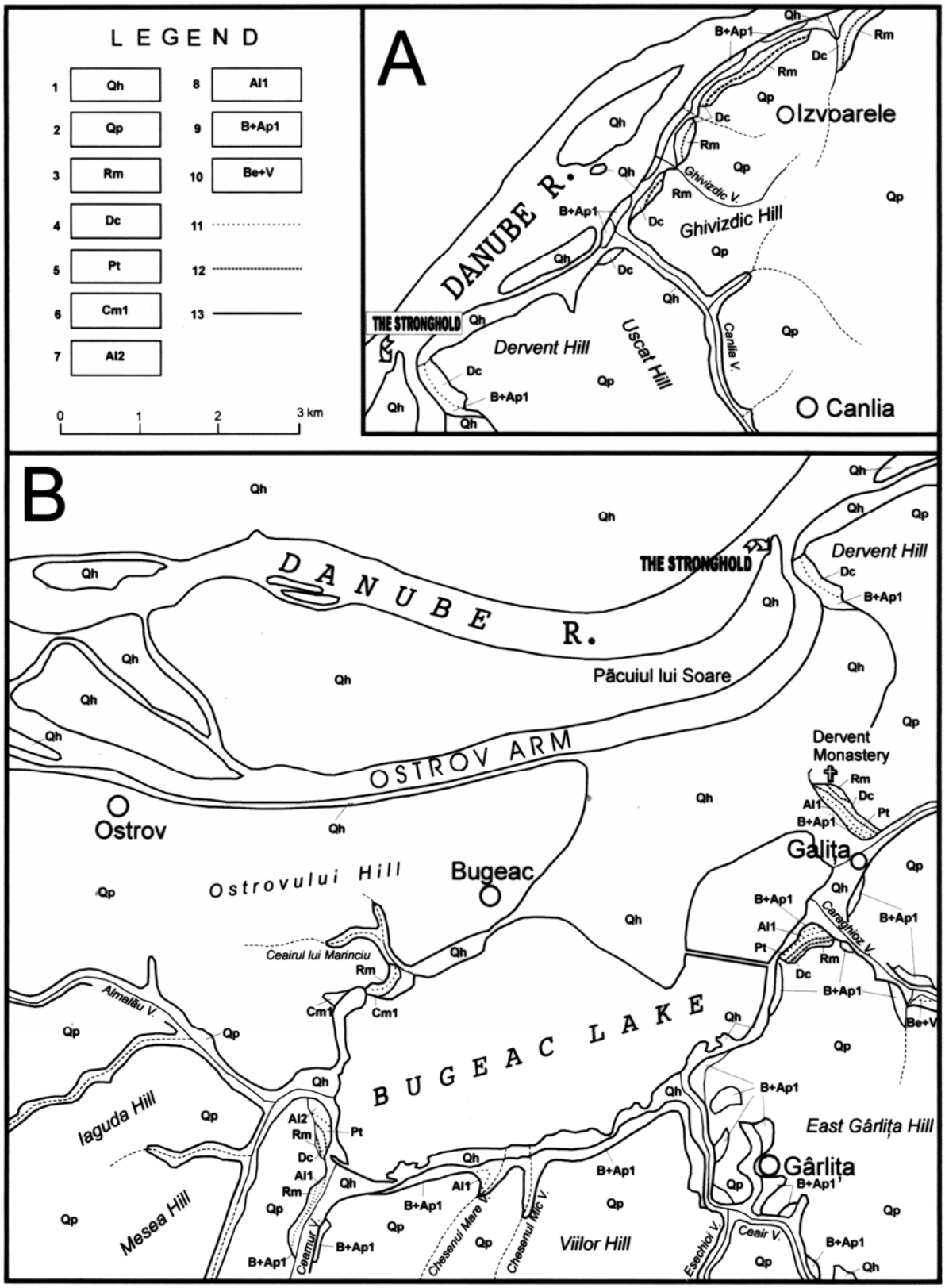

Fig. 4. Geologic maps of the surroundings of Păcuiul lui Soare.

Legend: 1. Holocene (Qh); 2. Pleistocene (Qp); 3. Romanian (Rm); 4. Dacian (Dc); 5. Pontian (Pt); 6. Lower Cenomanian (Pe]tera Formation, Cm_1); 7. Middle Albian (Băcăleşti Formation, Al_2); 8. Lower Albian (Cochirleni Formation, Al_1); 9. Upper Barremian-Lower Aptian (Ramadan Formation, $B+Ap_1$); 10. Berriasian-Valanginian (Cernavodă Formation, Be+V); 11.Unconformity; 12. Stratigraphic boundary; 13. Boundary of the Quaternary deposits.

Lake). It is constituted of strongly cemented biocalcarenites, biocalcirudites, pseudostromata-algal limestones, oosparites, stromatolites etc. belonging to the Lipnița, Adamclisi and Băneasa members of the Cernavodă and Dumbrăveni formations. Its age was proved by microfacial studies[12,13]. Although the rocks mentioned above are remarkably hard, they break into small fragments under hammer, and were not used for building due to difficulties in carving them.

Upper Barremian-Lower Aptian Largely exposed in the study area, the Upper Barremian-Lower Aptian sequence occurs along the right bank of the Danube River from the site called La Piatră (4 km west of Ostrov Village), eastwards, through the Dervent promontory and then, nearly uninterrupted, from the Canlia Valley mouth to Izvoarele Village; in the south-western promontory of the Oltina Lake; on both western and eastern sides of the Ceamurlia Lake, then eastwards to the western end of the Iortmac Quarry; around the Bugeac Lake from 500 m south of the Dervent Monastery up to the Ceamur Valley mouth, and also in the lower course of the Caraghioz, Ceair, Chesenul Mic, Chesenul Mare and Ceamur valleys. This sequence includes white, corpuscular calcarenites, in places rich in foraminifera, corals or gastropods (*Harpagodes*, *Pseudoglauconia*), with interbeds of marly calcarenites and even of greenish marly limestones with abundant bivalves (especially Toucasia). There are numerous transitions between these lithological types, but somewhere (e.g. along the southern side of the Bugeac Lake, west of the Chesenul Mare Creek) the white calcarenites are developed almost exclusively in strongly cemented beds, 1 to 4 m thick.. Between the Canlia Valley mouth and the Izvoarele village the right bank of the Danube expose similar calcarenites, capped by a rusty hardground. The hardground underlies a thin bed of quartzose-phosphatic conglomerate, Upper Neogene in age. In the south-western side of the Oltina Lake the rusty hardground surface includes numerous shells of *Toucasia*, looking identical to one of the paving-stones at the entryway of the fortress. The above described lithologies are typical of the Ramadan Formation[5]. Their age[6] has been established[7] on their foraminifera[8] and bivalve content (*Palorbitolina*, *Orbitolinopsis*, *Toucasia carinata)*[9] [10] [11]. The frequent specimens of the large gastropod *Pseudoglauconia* (preserved as molds in calcarenites) are, in the study area, exclussively related to the Upper Barremian-Lower Aptian deposits.

Lower Albian This sequence, composed of glauconitic, clayey sands with discontinuous interbeds of glauconitic sandstones, belongs to the Cochirleni Formation. It overlaps transgressively the Aptian calcarenites in the eastern part of the Bugeac Lake (west of Gârlița village), on the left bank of the Caraghioz Valley, near its mouth, at the mouths of Chesenul Mare and Ceamur valleys, and also on the eastern bank of the Canaraua Fetei Valley, eastern side of the Ceamurlia Lake and, both eastern and western shores of the of the Oltina Lake. Their age, based on ammonites, is Lower Albian (older in the Ceamurlia and Oltina lakes area, and younger around Bugeac Lake). In the latter area the glauconitic sands are fine grained and contain a higher amount of clay. As the quality of these rocks, as building material, is very poor, they were not used in the fortress.

Middle Albian Locally, on the western side of the Bugeac Lake, near Almalău Valley mouth, a ca. 10 m thick sequence of siltstones and clayey siltstones is developed, overlying the Lower Albian sands exposed in the left side of the Ceamur Valley, near its mouth. Its Middle Albian age was proved by the ammonite species *Anahoplites*. Here is the unique occurence of the Băcăleşti Formation in South

[5] E. Avram, T. Neagu, I. Andreescu, M. Crihan, Ioana Pan, Simona Pestrea, G. Popescu, *Stratigraphy of the Cretaceous, Paleogene and Neogene deposits from South Dobrogea,* Annuaire de l'Institut de Géologie et de Géophysique, 69, Supplément 6, Excursion Guide D5, IGR-90, 1996a, 72 p.

[6] T. Neagu; M. Melinte, in: E Avram, L. Szasz, E. Antonescu, A. Baltres, M. Iva, M. Melinte, T. Neagu, S. Rădan, C. Tomescu, *Cretaceous terrestrial and shallow marine deposits in northern South Dobrogea (SE Romania)*, Cretaceous Research, 14, 1993, pp. 265-305.

[7] O. Dragastan, in E. Avram, L. Costea, O. Dragastan, R. Muțiu, T. Neagu, V. Sindilar, C. Vinogradov, *Distribution of the Middle-Upper Jurassic and Cretaceous facies in the Romanian eastern part of the Moesian Platform*, Revue roumaine de géologie, géophysique et de géographie, Sér. Géologie 39-40, 1996b, pp. 3-33.

[8] Avram E. and others, *op. cit*., 1996b.

[9] T. Neagu, Ioana Pană, O. Dragastan, *Biostratigraphie de la série des calcaires eocrétacés de l'aire Cernavodă-Alimanu-Ostrov*, Revue roumaine de géologie, géophysique et de géographie, Sér. Géologie 21 pp.137-144.

[10] T. Neagu, O. Dragastan, *Stratigrafia depozitelor neo-jurasice şi eocretacice din Dobrogea de Sud*, Studii şi cercetări de geologie, geofizică, şi geografie, Seria Geologie 29, 1984, pp. 80-87.

[11] E. Avram, A. Drăgănescu, L. Szasz, T. Neagu, *Stratigraphy of the outcropping Cretaceous deposits in Southern Dobrogea (SE Romania)*, Mem. Institut de Géologie et Géophysique. Mémoires 33, 1988, pp. 5-43.

Dobrogea[12]. It is however largely developed in the subsurface of the Romanian Plain. Although not very proper, few blocks of these rocks were used, as stuffing material in the strongholds of Păcuiul lui Soare.

Lower Cenomanian The Cenomanian sequence is exposed only in the northern side of the Bugeac Lake, west of the Ceairul lui Moş Marinciu Valley. It is represented by the members 'b' and 'c' of the succession of the Peştera Formation[13], namely: thick, cross-bedded, uneven cemented quartzose sandstones (member 'b'), and fossiliferous chalky-glauconitic sandstones (member 'c').

Sarmatian In the neighborhood of Păcuiul lui Soare the Sarmatian deposits do not occur. Outside the areas in Fig. 4 these occur in the Ceair, Caraghioz-Carvăn, Goruni and Canaraua Fetei valleys as thin-bedded (or up to 0.6 m thick beds as in the Carvăn quarry) white limestones, a rock type which was not found at Păcuiul lui Soare. Nevertheless, in the strongholds were encountered other kinds of Sarmatian limestones which crop out in other parts of South Dobrogea, as follows: (a) *Nubecularia* limestones exposed in the area north of Deleni village and also in the zones Vâlcele-Coroana and Albeşti-Vârtop[14]. (b) Fossiliferous calcarenites with abundant moulds of leached shells. These are locally rich in intraclasts, gastropods and/or oolites and occur in a large area, from Şipotele-Ion Corvin-Peştera-Tibrinu vilages eastward up to the Black Sea shore and southward to the Romanian-Bulgarian border. The same rocks occur also in the valleys joining the Danube River: on the left bank of the Pestera Valley, near their mouth, and in the Aliman-Adâncata Valley, south-east of Alimanu Village. Here can be the source of some blocks in the strongholds.

Apart from the mentioned rock types, the stuffing material in the walls includes coarse grained quartzose sandstones with shell debris, probably also of Sarmatian age. Such sandstones are associated with the 'upper limestones'[15] in the Negreşti-Curcani-Independența and in the Ion Corvin-Băneasa-Negreni areas. The latter of these can be the source area of the similar material in the strongholds.

Pontian Built up mainly of marls, clays and silty-clays, the Pontian rock sequence is exposed along the eastern shore of the Bugeac Lake (south of Dervent Monastery, and on the left bank of the Caraghioz Valley), along their western shore (between Almalău and Ceamur valleys), and also on both sides of the Oltina Lake. In the last area the base of the Pontian succession consists of a well cemented qurtz-phosphatic conglomerate. A thin veneer of such conglomerate overlies also the Aptian white calcarenite occuring along the Danube, downstream of Păcuiul lui Soare. Few blocks of this rock type were recognized as stuffing material in the strongholds.

Dacian The Dacian sequence is built mainly of sands with clay interbeds, locally quartzose gravels and, in the upper part, lacustrine siltic limestones (Siensian)[16]. It is developed in the same areas as the Pontian. In addition it occurs along the right bank of the Danube between the Dervent promontory and Cochirleni village (Peştera Valley mouth). Only the lacustrine limestones were recognized as a small block in the stuffing material.

Romanian The last member of the Pliocene succession consists of fluviatile sediments: siltstones, sands, sandstones, gravels, sometimes strongly cemented in the lower part of the sequence. The deposits crop out, discontinuously, overall in South Dobrogea, overlying older formations and underlying the Pleistocene red clays. The composition of the pebbles in the gravels is obviously related to the lithology of the substratum, proving a short distance of transport. Among these rocks were used as stuffing material only the thoroughly cemented gravels of the type exposed along the Danube bank between the Canlia Valley mouth and the Mârleanu Lake and some soft sandstones of the type occurring in a restricted area, north-east of the Canlia Valley mouth. The quartzose and calcareous pebbles occurring along the western and northern shore of the Bugeac Lake, between the Ceamur Valley and Ceairul lui Moş Marinciu Valley mouths are of the type utilized for concrete in the strongholds

Quaternary Covering more than 90% of the region, the Quaternary deposits consist of a basal red clay, followed by loess with several levels of paleosoil (Pleistocene) and alluvial deposits (Holocene)[17]. A discontinuous gravel beach occurs in the western part of the Bugeac Lake.

[12] R. Muțiu, in: E. Avram and others, *op. cit*., 1996b.
[13] *Ibidem*.
[14] I. Andreescu, in: E. Avram and others, *op. cit.,* 1996a.
[15] *Ibidem*.
[16] I. Andreescu, Ioana Pană, in: E. Avram and others, *op. cit.*, 1996a.
[17] E. Munteanu, in: E. Avram, I. Andreescu, A. Baltres, N. Mihăilescu, E. Munteanu, R. Platon, *Harta geologică a României, sc. 1:50.000, Foaia Ostrov*, 1988. Unpublished report.

Beside the above geological formations, developed in the surroundings of Păcuiul lui Soare, the strongholds includes some blocks of ***Eocene limestones with Nummulites***, belonging to the Cetate Formation. The rocks are exposed along the Enişenli Valley, showing traces of ancient cutouts[18] [19]. They occur also in the Dobromiru and Lespezi valleys, in the Ceşmelei Valley (east of Cernavodă), and also on the northern slope of the Poarta Albă-Năvodari canal, north of Nazarcea village. The age of these limestones is Upper Eocene (Ypresian)[20].

The sources of the building stones

Because the overwhelming number of blocks in the strongholds are Cretaceous limestones, it is to be expected that their sources were the outcrops in the neighbourhood of Păcuiul lui Soare. This was demonstrated by Diaconu and Zah[21] which described eight field-identified quarries, namely Dervent Hill, Canlia Valley mouth, 'Grota Călugărului', Caraghioz Valley mouth, right bank of Caraghioz Valley; the cliff bordering the Bugeac Lake, north-east of Gârlița village; the left and right banks of Chesenul Mic Brook. They signaled other three presumed places where occur rocks of the sorts encountered at Păcuiul lui Soare and described the different techniques adopted by stonecutters in each case. Some of the illustrated field features were subsequently buried under slope debris, being now lost for observation.

Based on own observations, we concluded that the approach of stoneworkers followed different techniques, according to various local conditions with respect to the rock appearance and mode of exposure (massive rocks exposed on steep cliffs; bedded rocks on hill slopes; top surface of rocky terraces). The blocks were extracted by steps (sometimes as multi-level cutouts on cliff faces) cut into the massive or bedded limestone. Large-scale quarries show high, successively retiring fronts to allow simultaneous access of many quarriers. Scant remains of another type of cutouts are still standing along the right bank of the Danube River, as sinks (rectangular hollow recesses) on top of a limestone terrace.

A cutout was done for each block by scooping-out narrow and deep trenches by chisel, in the technique named *à la trace*. These trenches run all around the piece of rock shaped for masonry. The outlines of most of the cutouts can still be seen in various places, keeping up evidences that the upper and lower surfaces of each block was cut parallel to the bedding plane of the limestone. The cutout dimensions range between 0.9 and 2 meters in length, 0.3 to 0.75 m in width, 0.18 to 0.5 m in depth.

The description what follows is an attempt to provide a brief guide to the string of quarries occurring around Păcuiul lui Soare. The quarries are in close connection with the Cretaceous limestone outcrops along the rocky terrace of the Danube River right bank, downstream of Păcuiul lui Soare, as well as along the cliff bordering the eastern and southern shore of the Bugeac Lake (Fig. 5). The distance from Păcuiul lui Soare to the most distant quarry is, along a straight line, of about 9 kilometers, and to the nearest of only 3 km. All the sites described by Diaconu and Zah[22] were recognized. There were added few new places where building stones were excavated by cutting (Ghivizdic Valley mouth, 'La Vapor', Chesenul Mare Brook mouth). Moreover, two possible sources of limestone gravel were identified, of the same type to that in the concrete bounding the stones in the masonry.

The right bank of the Danube River, downstream of Păcuiul lui Soare is a rocky terrace which stretches for more than 3 km, between the mouth of Canlia Valley and Izvoarele village, rising 1.5 to 2 meters above the water mark only in the dry season. A dirt road runs parallel with their landward margin. The terrace surface corresponds to the topmost bed of the Cretacoeus limestone pile, and is capped by a few millimeter thick rusty crust of iron hydroxide. Some blocks in the masonry of Păcuiul lui Soare, carrying a thin rusty crust, provide proof that these were cut from this limestone bed. The rock

[18] R. Pascu, *Carierele şi apele minerale din România. Carierele şi apele minerale din Dobrogea*, Institutul Geologic. Studii tehnice şi economice, 6/1 1913, 160 p.

[19] A. Baltres, E. Avram, A. Seghedi, J. Ion, L. Szasz, *Cercetări privind rocile utilizate la construirea monumentelor şi ansamblurilor din siturile istorice Histria, Adamclisi, Dinogetia, Păcuiul lui Soare*, 1993. Unpublished report.

[20] G. Bombiță, in: E. Avram, I. Andreescu, G. Bombiță, C. Ghenea, R. Platon, G. Pop, L. Szasz, L. Stoian, *Harta geologică a României, sc. 1:50.000, Foaia Băneas*a, 1992. Unpublished report.

[21] P. Diaconu et Em. Zah, *op. cit.*, pp. 294-298.

[22] Idem.

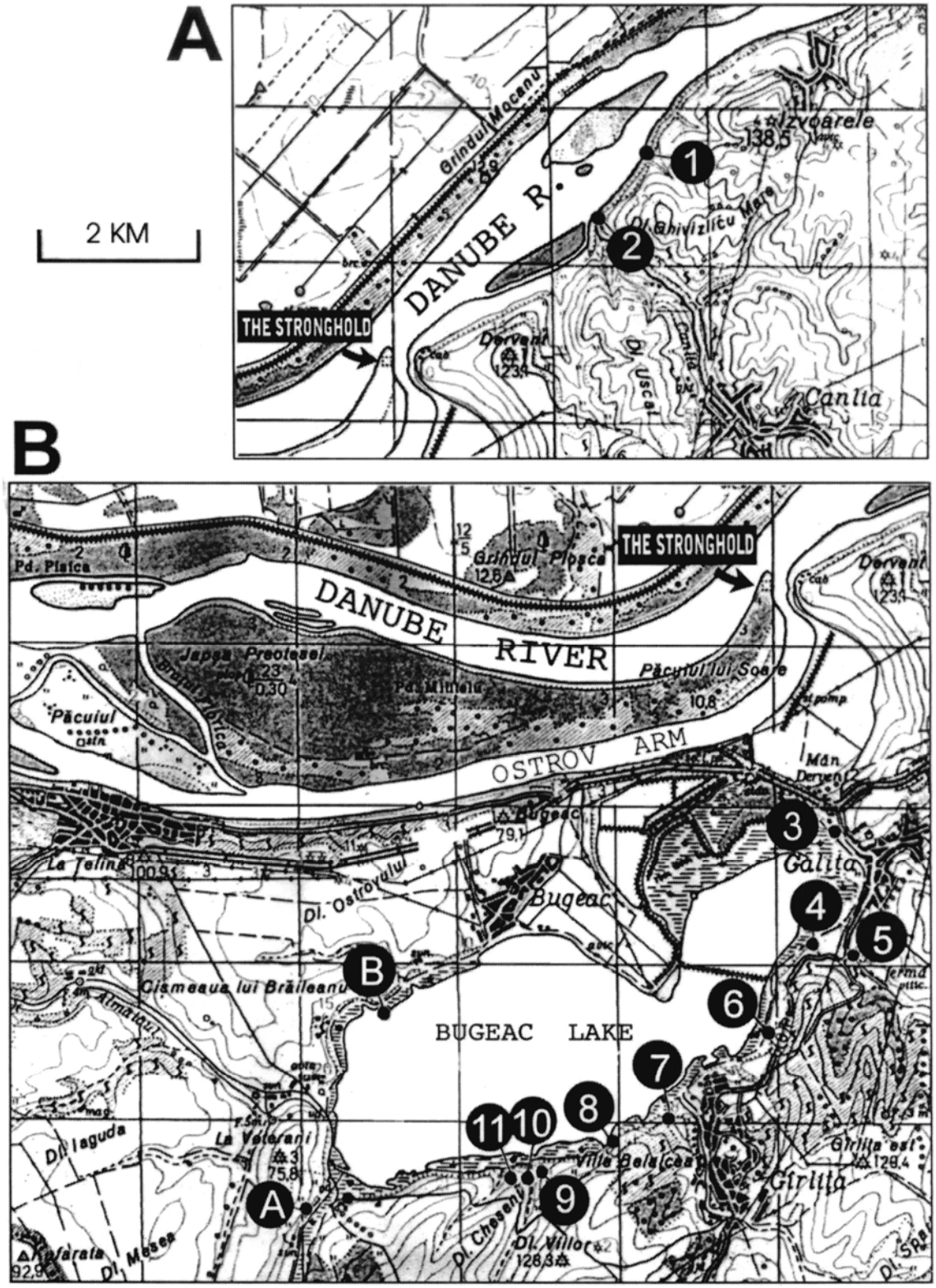

Fig. 5. The location of the quarries around Păcuiul lui Soare stronghold (encircled numbers): 1. Ghivizdic Valley mouth; 2. Canlia Valley mouth; 3. "Grota Călugărului"; 4. Caraghioz Valley mouth; 5. Caraghioz Valley, five hundreds meters upstream from their mouth; 6. The cliff bordering the Bugeac Lake, two kilometers south of Caraghioz Valley mouth; 7. Ceair Valley mouth; 8. "La Vapor"; 9. Right bank of Chesenul Mic Brook; 10. Left bank of Chesenul Mic Brook; 11. East of Chesenul Mare Brook.

The location of gravel sources (encircled letters): A. Ceamur Valley; B. Gravel beach near Ceairul lui Moş Marinciu Valley.

below the crust is a *white calcarenite* showing gastropods and small corals. Exploitation traces leaving their marks upon the face of the terrace may be seen in two places at present time: at the mouths of Ghivizdic Valley and Canlia Valley (Fig. 5A).

At the mouth of Ghivizdic Valley, on a large area, 200 meters in length and 50 m wide, one can see a series of steps cut into a 0.5 meter thick limestone bed (Fig. 6). This area, situated at about 4 km downstream of Păcuiul lui Soare, provided considerable quantities of blocks for the strongholds. Outlines of most cutouts can still be seen as well as partly detached, rectangular blocks of 0.3 m thick. From a lower level of the terrace, composed of *greenish-gray, very fossiliferous marly calcarenites* that fell into serious decay, were also extracted a number of blocks but, because their inhomogeneous character, these rocks were less suitable for cutting. This was probably the source of the scattered blocks in the gateway, which weathers back to form recesses.

Fig. 6. The top of the limestone terrace along the right bank of the Danube River, downstream of Ghivizdic Valley mouth, showing the signs of an old stonework preserved as numerous rectangular cutouts spread on a large area.

The limestone terrace shows clear evidences of quarrying also in the vicinity of the mouth of Canlia Valley, at only 3 km downstream of Păcuiul lui Soare (Fig. 7). Here the cutouts were oriented at random, contrasting with the oriented disposal of those at the mouth of Ghivizdic Valley. The rectangular hollow, on the terrace surface, left after one of the extracted blocks is 1.6 m long, 0.4 m wide and 0.18 m deep. The cutout was performed by carving a 7 centimeter wide, deep trench around the block. The rugged vertical surface of the trench margins still shows the oblique scratches left by chisel.

As concerns the site of Dervent Hill, fronting the Păcuiul lui Soare Island, we found not clear evidences for a quarry. Rather, a series of meter-scale, shallow, rectangular cavities and deep, vertical hollows, a few centimeters in diameter, carved at top of the cliff as well as two short and deep channel-like, inclined skipways, incised at the steep cliff edge (Fig. 8), suggest a machinery dating back into the Byzantine Epoch. It equipped probably a landing-stage or a wharf and served for loading ships lying alongside the cliff.

A girdle of stoneworks were recognized southwards of Păcuiul lui Soare, beginning not far from Dervent Monastery. Here, at the place named 'Grota Clugărului' Diaconu and Zah[23] described the vestiges of an old, small quarry on *white calcarenites* outcropping close to the Bugeac Lake shore. They found here a block of 1.2 × 0.4 m, and figured a partially detached block, in the technique *à la trace*. All

[23] Ibidem, p. 294.

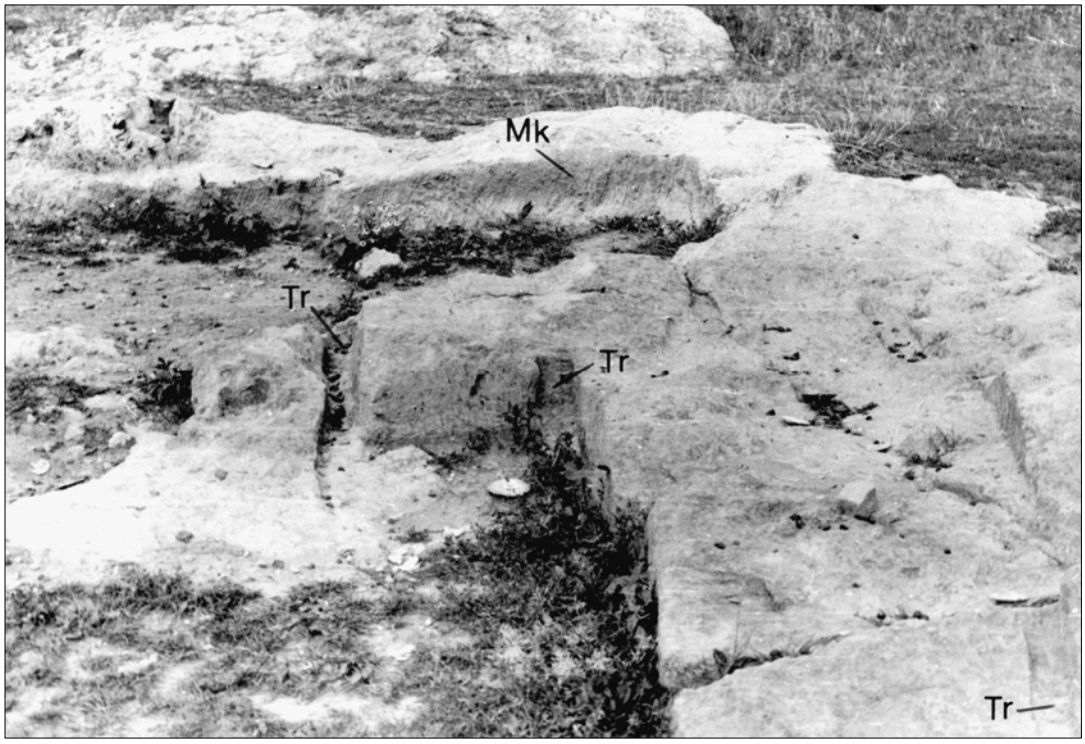

Fig. 7. Cutouts on top of the limestone terrace at the mouth of Canlia Valley, showing the signs of a narrow and deep trench (Tr) chiseled around each block that was extracted in the technique *à la trace*. The width of the trench is 7 cm. Note the oblique markings (Mk) produced by chisel on the uppermost cutout side.

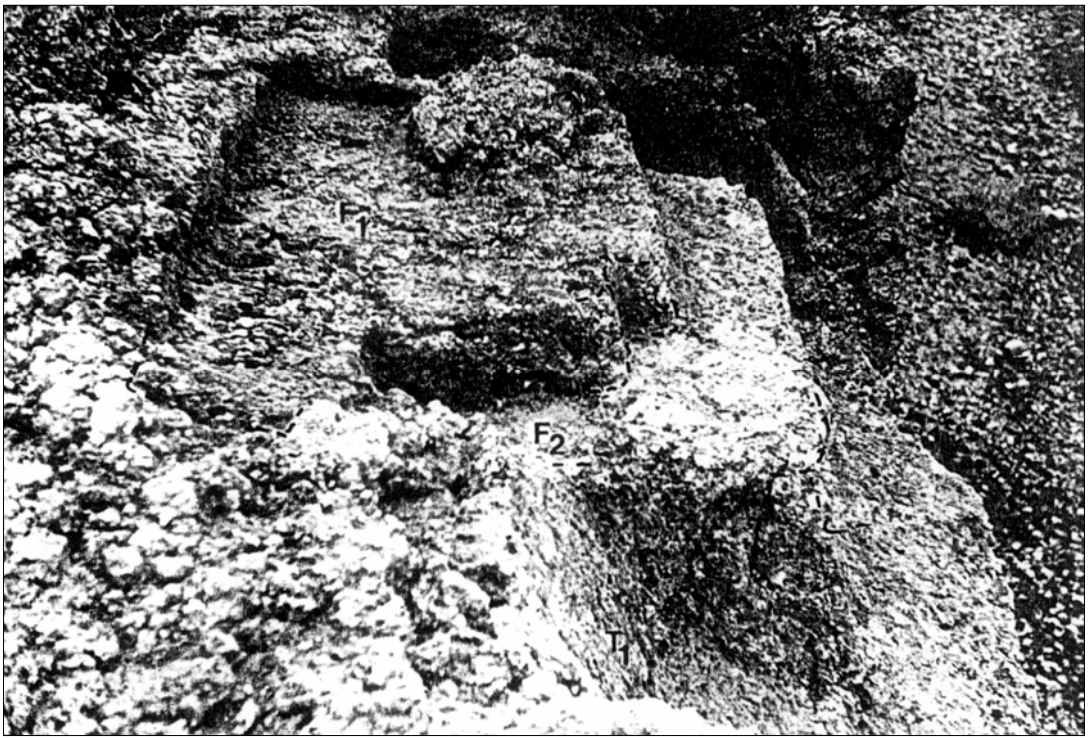

Fig. 8. View of part of a supposed foundation of anchorage facilities atop of the cliff fronting the Păcuiul lui Soare Island. At about three meters above the water mark, the leveled rock surface shows various meter-size, shallow, rectangular cavities (F1), some open ended (F2), and small, deep vertical hollows, carved probably to support and anchor a wooden superstructure destined for ship loading along the cliff. In addition, broad, inclined skipways (T1), accurately incised at the sheer cliff edge, served probably for carying wares down to ship decks.

that we can see today are scant remains of extracted blocks as cutouts with sides of 0.4 to 0.6 m long and 0.25 m deep, and a niche? of 0.35 x 0.45 m, about completely buried under slope debris. In the same place the mentioned authors found few blocks cut from a bed of Cretaceous glauconitic sandstone overlying the white calcarenites.

Starting from the Caraghioz Valley mouth the next group of quarries are relatively closely spaced, along the southern shore of the Bugeac Lake. Just at the mouth of Caraghioz Valley, on the left hand, on top of a gently tilted *white calcarenite* bed standing as a 1.5 meter high step, we still can see signs of a small but orderly quarry, covering a small area, enough to illustrate the working manner. Approached from their part facing the lake, the uppermost part of the calcarenite bed was thoroughly removed on an area of 7 x 2 meters. The cutouts, as seen in surface, show a zig-zag pattern. Individual cutouts range between 0.9 and 1.55 m in length and 0.45 to 0.6 m in width. The removed blocks were 0.25 to 0.5 m thick. The corners connecting two vertical faces of each cutout at a right angle, are not sharp but rounded. Near this quarry, on top of the same calcarenite bed, a series of shallow, grass-covered grooves show few outlines of blocks that were never extracted.

Five hundred meters upstream from the mouth of the same valley, after crossing the winding route, we can see a small occurrence of very coarse to fine, porcellaneous calcarenites with a cutout having sides of 0.5 m in length and 0.45 m high.

Returning to the Caraghioz Valley mouth and following southward the cliffed margin of the Bugeac Lake, at their foot for about 2 km, we can see on the exposed face of *a white calcarenite* bed the zig-zag pattern of a few cutouts.

Following then the dirt road along the lake shore further south-west for less than one kilometer, then crossing the large muddy plain at the mouth of Ceair Valley, we reach the foot of a hill. The gentle, lower slope of the hill exhibit five prominent steps of *white calcarenite* beds, alternating with grass-covered intervals (Fig. 9). The beds are 0.3 to 0.5 m thick. Two of these beds show the characteristic zig-zag pattern of cutouts (Fig. 10). The rectangular cutouts are 0.6 to 0.9 m long, 0.3 to 0.4 m wide, and more than 0.2 m deep. An incipient groove cut in the technique *à la trace* shows a V-shaped cross section.

Westward from the Ceair Valley mouth, along the white limestone cliff which dips down into the southern shore of the lake, was found another group of cutouts at the place called 'La Vapor'. Here, the cliff sent few huge blocks of limestone into the lake. The cliff proper and one of these tilted blocks measuring 20 × 8 × 4 m exhibit cutouts (Fig. 11). Among these one is 1.2 m long, 0.3 m wide and 0.2 m deep.

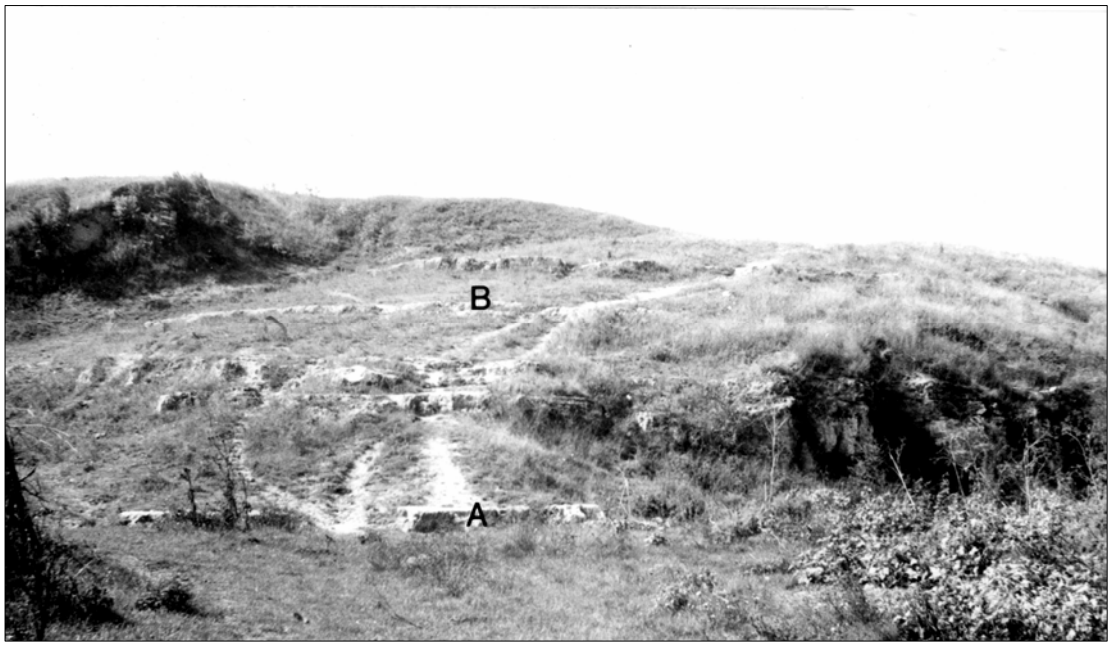

Fig. 9. The lower slope of the hill descending to Ceair Valley mouth, showing prominent steps of white calcarenite beds. The A and B beds exhibit cutouts of the type shown in Fig. 10.

Fig. 10. Zig-zag pattern of cutouts shown on bed B depicted in Fig. 9. The arrow mark an incipient groove intended to delimit a new block.

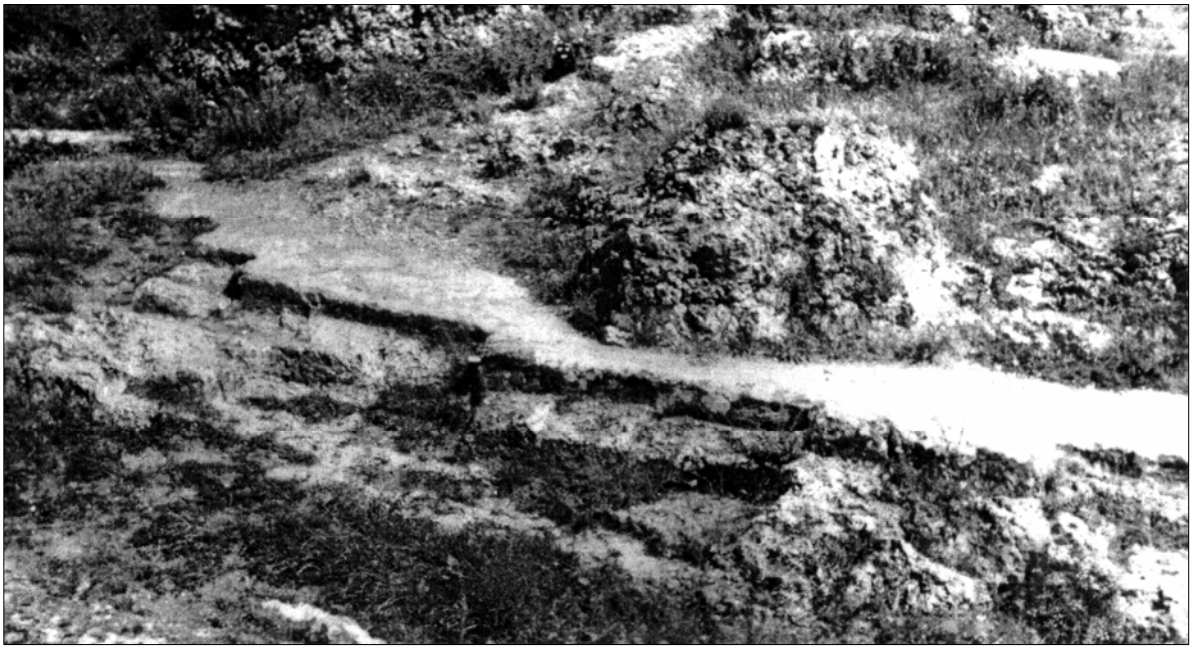

Fig. 11. Zig-zag pattern of cutouts and poorly preserved steps cut into the rock, showing vague outlines of extracted blocks, at the place called "La Vapor".

To the sunset from this place, at about one kilometer, is the mouth of a precipitous dry brook named Chesenul Mic. Traces of stoneworks and also of isolated cutouts occur along both the right and left steep banks of the brook, along about 100-150 meters upstream from the mouth. Here is the second site which provided considerable quantities of blocks, if not the most part of the building stones in the strongholds of Păcuiul lui Soare.

The up to seven meter thick, crudely layered *white calcarenite* wall which forms the precipitous right side of the brook, near its mouth, is remarkably homogeneous and are disclosing clear signs of a large-scale quarry. This was provided with a series of successively retiring fronts of 1.4 to 2.0 m in width with offsets of 1.5 m (Fig. 12). Each front begins at the base of the steep rock wall and is 2.8 m high. The cutouts were probably performed in a descending order, in each individual front. In plane view the outline of this quarry appears as a zig-zag pattern of segments lying at right angle each other. Diaconu and Zah[24] explained that this pattern was adopted to avoid the entangling of the quarriers working simultaneously along the front. Upstream, two other large fronts, of 20-25 m long were poorly preserved.

Fig. 12. Successively retiring fronts (A to D) of an 2.8 meter high stonework located near the mouth of Chesenul Mic Brook. Lying at high angle each other, the 1.4 to 2 m wide fronts show offsets of 1.5 m.

In contrast with these thoroughly exploited fronts, little upstream the same wall shows scant, multi-level cutouts as high steps cut into the rock. The outlines of these large cutouts can still be seen on the face of the 7 m high white calcarenite wall (Fig. 13). Here, as in other places, the corners connecting two vertical faces of a rectangular cutout are not sharp but rounded. It is not clear if the cutouts were made in an orderly manner (descending) or at random, by a less rigorously organized work or, possibly, in a later time, revealing a lower activity.

Near the mentioned multi-level cutouts occurs a deep, rectangular niche, stepwise narrower toward their rear. The niche, endowed with a threshold and a sort of shelf was carved in the white calcarenite wall, probably with a ritual scope.

Two overlapping calcarenite beds, one of 3.5-4 m thick and another of 1.3 m occurring along the left bank of the same brook, show the imprints of many cutouts, as 0.3 to 0.9 m high steps. The rectangular, hollow recesses left by the extracted blocks are 1 to 2 m long. We can also see scant remains of unfinished work as partially extracted blocks surrounded by wide trenches scooped out by chisel (Fig. 14).

[24] P. Diaconu et Em. Zah, *op. cit.*, p. 298.

Fig. 13. Partial view of multi-level cutouts rising as high steps on the right bank of Chesenul Mic Brook. The white calcarenite bed carying cutouts is seven meters thick.

On the top face of the upper calcarenite bed occur, vaguely delimited by shallow grooves, the outlines of few blocks (Fig. 15). Among these, one outlining a block of 1.7 × 0.58 × 0.3 m, is ten centimeters wide. The above described features occur along a large stonework showing a pattern of alternating 20 m long fronts with offsets of 2-3 m.

The last place where we found indices of stoneworks is located about 100 meters east of the mouth of Chesenul Mare, a dry brook which flows north to join the cliffed lake shore, not far from the previous site. At the top of the five meter high cliff margin a leveled area, almost covered by grass, was a 12 × 12 m quarry, cut 1.2 m deep in the fine, *white calcarenites* of high quality. The front advanced southward as 0.3 to 0.4 m high steps. A nearly finished cutout of a block of 1.6 × 0.6 × 0.3 m lies, half hidden by grass and bushes, at the base of the stonework front. Four of their six sides stand detached, at sight.

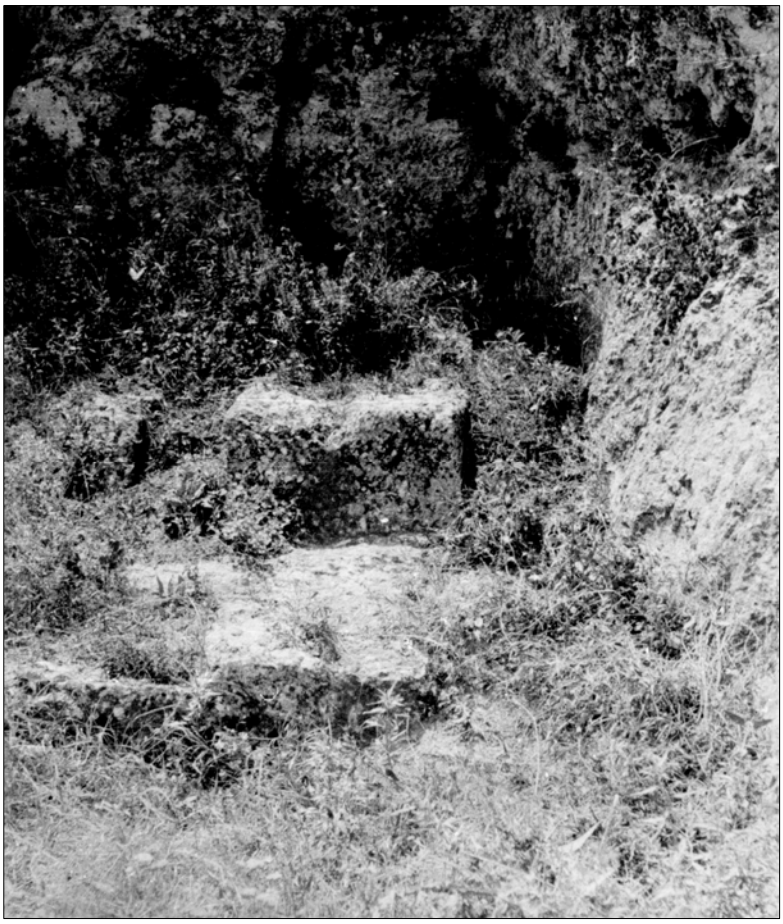

Fig. 14. Partially extracted block of white calcarenite, on the left bank of Chesenul Mic Brook. Note the wide trenches (Tr) scooped by chisel in the technique *à la trace*, delimiting both left and right sides of the block.

Fig. 15. Shallow, grass-covered groove (Gr) outlining two sides of a never extracted block (of 0.45 × 0.45 m) on the top face of a calcarenite bed outcropping on the left bank of Chesenul Mic Brook. The groove is 6 cm wide and is V-shaped in cross section.

Outside the quarry area, scant remains of rejected blocks are still seeing. The blocks were abandoned because the rock was broken along unwanted paths. One of these is 1.8 × 0.75 m; another shows an incomplete, V-shaped, groove of 3-5 cm wide and 5 cm deep. Moreover, the level surface stretching eastward along the top of the cliff for some 50 m, shows also sporadic cutouts.

As concerns the gravel of rounded limestone pebbles in the composition of the concrete in the masonry of Păcuiul lui Soare, two possible sources were identified (Fig. 5B). The first, represented by a Pliocene gravel deposit, about 6 m thick, occurs on the left bank of Ceamur Valley, at about 600 m upstream of their mouth. The second is represented by a Quaternary gravelly beach located near the Ceairul lui Moş Marinciu Valley.