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ABOUT THE STONE MATERIAL AND MORTAR COMPOSITION OF THE ROMAN BUILDINGS, *ULCISIA CASTRA*, SZENTENDRE, HUNGARY

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Abstract. The evaluation of the stone material permitted us to identify the origin of the stones (amphibole-biotite andesites and agglomerates from Visegrád Mts) and we differentiated the 2nd century upbuilt wall sectors to the 4th century ones. The composition and the technology of the mortar differ, too. The statistical distribution of the loosse rock fragments shows, that they resulted by violent destruction of the walls and the other stone objects of the Roman site during the Barbar invasions of the end of 4th century A.D.

Key words: Visegrád Mts., Szentendre, Mineralogy, Petrography, Andesite, Tuffs, Lime mortar, Morphological analysis, SEM photos.

The security of the *limes*, i.e. the eastern borders of the Roman Empire was guarded along the Danube by a range of fortified camps and localities. In *Aquincum*, the capital of *Pannonia inferior*, the *legio II Adiutrix* was emplaced. Both northward, in *Ulcisia Castra* (Szentendre, fig. 1.) and southward, in *Intercisia* (Dunaújváros) two *cohors* were cantoned in stone fortresses surrounded by deep trenches, too.

In Szentendre, the archeological excavations begun in 1934, led by Nagy (1937) Based on the initial soundings, the systematic works between 2004-2006 explore the southern side of the military camp (Pl.I., photo 1.), near to the *porta principalis sinistra* (fig. 2.).

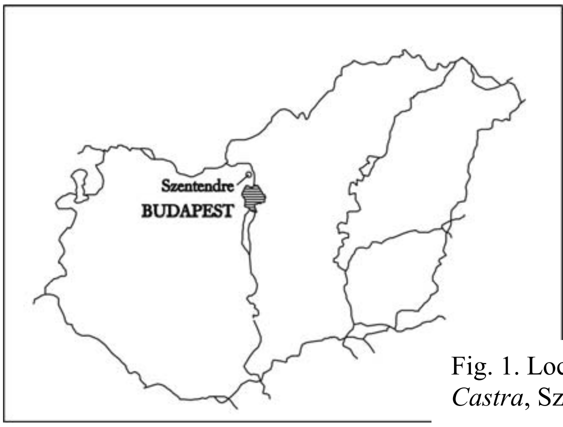

Fig. 1. Location of archeological site *Ulcisia Castra*, Szentendre (Humgary)

The excavations and the observations about the coins and ceramics confirmed the previous hypothesis (Torma, 1986) as concerning the history of the fortress, i.e. their construction and occupation in two phases, in 2nd and respectively in 4th century A.D.

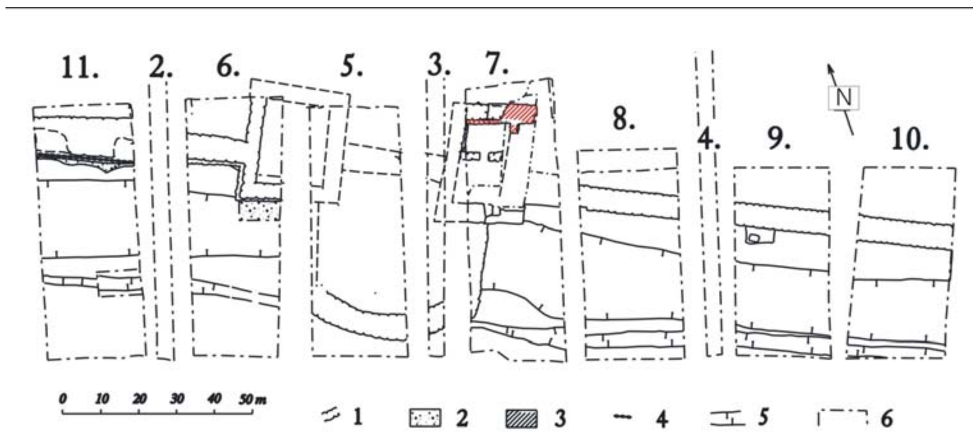

Fig. 2. Plan of the southern side of the *castrum*. 1. Walls; 2. Plastered surface; 3. Visible foundation surface; 4. Pebble pavement; 5. Moat; 6. Archeological sections (1-10)

Thus, the military camp was founded in the second half of the 2nd century, during the reign of Tiberius. In the 4th century it was destroyed and repaired repeatedly, the major reparation consisting in the closing of three of the four gates, by horseshoe-like bastions. Using the geological means of research, beyond of analogies of the plan of constructions, the *terra sigillata* and coin remains, by morphological and mineralogical study of the stone material and by the observations about the mortar of the walls, details of the masonry and the difference of the work style were emphasized.

1. THE STONE MATERIAL

Ten archeological sections explored the southern front of the *castrum*. On three of these sections (No. 6, 7 and 10) the stone building material was examined. Here the dimensions (length and width of the pieces) and the surface, visible in both sides of the wall were measured. The mineralogy and petrography of the rocks were studied too. The mineralogical and petrographical composition was determined by naked eye observation, optical and scanning electron microscopy, X-ray and DTA analyses. Using the published and unpublished geological maps of the Geological Institute of Hungary, (Wein, 1939; Lengyel, 1951; Balla & Korpás, 1980) verified by short field the origin of the stone material was located.

1.1. Petrography of the stone material

The stone material of the walls and additional constructions consists of various igneous and sedimentary rock types (tab. 1.), as follows:

1.1.1. Igneous rocks

Pyroxenic andesites. Black, very hard, massive or bank-like rocks. These are constituted by euhedral, zoned and twinned An_{25-55} plagioclase, euhedral and hemihedral, twinned augite phenocrystals, few brown oxy-hornblende prisms and dark green, fluidal, vitrous matrix with micron sized microlits in hyalopilitic structure. This rock type appears as less extended rests of the youngest lava flows, belonging to the Upper Pyroxenic-Amphibolitic Stratovolcanic Member of Börzsöny and Visegrád Mts, as well as rounded pebbles in alluvia and terraces (e.g. in Bükkös-rivulet, Szentendre).

In the walls of 2nd century, pyroxenic andesite blocs appear only as filling pieces among the large broad-stones. Pebbles of this rock type were used frequently in the foundation level (Pl. 1, photo 4) and in the walls of the constructions of 4th century.

Hornblende andesites, hornblendec-biotite andesites. Grey, greenish, massive, hard but workable rocks, consisting of euhedral, 0,5-3,0 mm sized, zoned and twinned An_{30-45} plagioclase, 0,5-1,5 mm sized green and/or brown, pleochroic hornblende prisms (Pl. II, photo 1.), various amount of hexagonal, intensive pleochroic (brown–light yellow) biotite, and few anhedral quartz grains as phenocrystals and light brown-greenish, vitrous and microlitic matrix. The characteristic structure of these rock types are pylotaxitic and hyalopilitic.

The amphibole andesites appear as lava flows, small dykes and stocks in the eastern Visegrád Mts, in all of sections of the „Lower Amphibolic Stratovolcanic Member". This rock types form pebbles in alluvia and irregular, platy fragments in deluvial deposits.

We found amphibole and amphibole-biotite andesite pieces among the stones of the walls of both building periods: well carved broad-stones, thin void-filling pieces, crushed fragments in the core of the walls and as free bloks in the soil. In the buildings of the 4th century, the platy, irregular (deluvial) bloks and the alluvial pebbles dominate.

Biotite andesite. Grey, hard, massive or bank-like rocks with 0,2-1,5 mm sized, euhedral, pleochroic (red-brown–yellow) biotite sheets as main colored mineral, subordinately green hornblende prisms; euhedral, max 1,5 mm sized An_{20-45} plagioclase, rare anhedral quartz grains and vitrous + microlitic, pylotaxitic matrix, with an incipient sericitic and chloritic hydrothermal alteration and baueritization of the biotite. Biotitic andesite forms small lava flows and stocks in the lower section of the „Lover Amphibole Andesite Stratovolcanic Member" and less frequently, pebbles in alluvia and blocks in deluvial deposits. Among the stone pieces, it appears rarely, mainly as free stone pieces and in walls which were set up in the 4th century.

Basalt. Dark grey, porous-vesicular, but very hard rock fragments, consisting by rare An_{50-75} plagioclase, augite and serpentinized and limonitized olivine and by matrix of An_{65-70} intersertal plagioclase sticks, anhedral augite and dark glass (Pl. II., photo 3.). The 1-3 mm large, sphaerical or irregular vacuoles are empty or are filled by stilbite, quartz, gypsum and goethite. This basalt type outcrops in the western end of Bakony Mts, namely in the northern border of the Tapolca Basin.

Basalt millstone fragments were built in as stones in the walls of 4th century and appear also among the free stone pieces.

1.1.2. Pyroclastics

Amphibolec-biotite and biotite-amphibole andesite tuffs. These rock types give the main building stone material of Ulcisia Castra. They are dirty white or light grey, middle to coarse grained, massive or poorly stratified, medium hard rocks, which can be carved easily and in time, by loss of the pore humidity, become hard and fragile (thus, the chisel traces of the initial and of the later works may be distinguished).

The tuffs are constituted by crystaloclasts: plagioclase, green and brown hornblende fragments, biotite sheets, rarely augite and quartz; lithoclasts: fresh and altered andesite, micaceous quartzite, limy and siliceous sandstone, marl and red shale, pumice. The groundmass is formed by light green, coalescent or colorless, needle-like, interlaced or vesicular volcanic glass. A few, white blocs are pure vitroclastic tuffs, formed near exclusively by glass and pumice fragments. There are argilitised, chloritized, limonitized varieties, too.

Lapillite. Among the stone blocks and fragments, white or grey-yellow, coarse grained, porous pyroclastic rocks were identified. They are formed by subangular or rounded, 2-20 mm in size amphibolic or amphibolic-biotitic andesite gravels, vesicular pumice, rare, fired marl and shale lithoclasts, and vitroclastic groundmass. There are transitional rock types as lapillic tuffs and tuffaceous lapillites, with or without hydrothermal transformations of the groundmass. A few of the 1 m large broad-stones (2nd century), visible in the 6th section were carved of lapillite.

Volcanic breccias. They are coarse grained, rude, porous, massive or banked rocks, constituted by angular or subangular amphibolitic or amphibolitic-biotitic andesite fragments of 20-50 mm in size and tuffaceous or lapillic groundmass. There are also transitional, mixed rock types with various amount of the breccia elements, lapilli and crystalo-vitroclastic tuffs. Approx. half of the broad-stones of the walls of 2nd century, of the stone pieces of the construction of 4th century and of the free stone pieces are constituted by different types of volcanic breccias (Pl. I, photo 2.).

The pyroclastic rock types built in as stone pieces in the *castrum* may form a complete sequence of a single explosive event, which begun with the coarse bombs and fragments, followed by lapilli fall and closed by more and more fine volcanic sand and powder (subaerial) sedimentation. Thus, the Roman quarry has opened one or more complete banks of pyroclastic sequence, which outcrops in neighborhood of the *castrum*, in the modern Szentendre (e.g. Püspökmajor, Izbég, Barackos, Vadőr and Vörös Gyűrű streets). Note, that these quarries were exploited until the 50th years of the XX. century, for carved building stone (Kovács, 1988).

1.1.3. Sedimentary rocks

Tuffites. Grey, greenish, stratified, soft rocks which are constituted by amphibole or biotite tuff levels in sandy marl or sandstone with or without mixed volcanic and siliciclastic sandy material. In the ancient walls, a few, small tuffite broad-stone were identified (10th section), as well some fragments among the free stone pieces.

Sandstones. We identified two sandstone types: grey, light brown and yellow, fine grained, hard, stratified rock fragments with quartz, plagioclase, microcline, muscovite, biotite, andesite fragments and pumice, with calcitic microsparitic cement (Sandstone of Carpathian age interbedded in top of stratovolcanic sequences).and pink or yellow, coarse grained, microconglomeratic quartzose sandstone with silica and limonite cement (millstone fragments, carved of Upper Oligocene Hárshegy sandstone, Buda Mts).

Carbonatic rocks. Triassic dolomite from Budai Mts: light grey, stripped, hard rock fragments with brecciated interbedding and secondary travertine crusts, as free stone pieces. White, pure, massive, hard calcitic marble, with smotted, plane surfaces and fragments of Latin inscriptions; these rock fragments were built in as stone pieces in the bastion of 4th century or appear as free stone fragments.

1.2. Morphology of the stone material

The length (L), width (I) and (for the free fragments) the thickness (S) of the stone pieces, the surface of the stones on the walls and as well, the shape, the quality of the surface and the traces of different tools which appear on the pieces were noted and statistically interpreted.

Distribution of the dimensions. It is known, that the size of the rock fragments, which were crushed under natural conditions shows a normal or lognormal distribution. Thus, comparing the distribution of the length, of the width and of the area of the visible faces of the stone pieces for both periods, significant differences were resulted. In case of the pieces of 4th century, the distribution of this characteristics follow the lognormal rule (verified by χ^2 test), while the pieces of the older construction shows an irregular or hyperbolic distribution. This means, that in case of the constructions of 2nd century, no natural fragmented stone material was built in, because the stone pieces were selected and carved for obtain some preferable dimensions. In this case, a great number of small fragments were resulted; they were used as filling between the broad-stones and in core of the walls. For reparations of the 4th century, all available stone material was included in the walls: deluvial and alluvial pebbles and the fragments of older constructions, too. They show a distribution near to the natural coarse sediments as breccias and pebbles (fig. 3).

The Student test permit to justify if the difference of two collectivities *i* and *j* is significant or no. The test considers the mean value $x_{i,j}$, the dispersion $s_{i,j}$ and the dimension of the population $N_{i,j}$:

$$t = \frac{\left|x_i - x_j\right|}{\sqrt{N_i s_j + N_j s_i}} \sqrt{\frac{N_i N_j \left(N_i + N_j - 2\right)}{N_i + N_j}} > t_{adm} \qquad [1]$$

If the value of test *t* is up to the value t_{adm} listed in statistic tables for significance level *p* and N_i+N_j-2 stone pieces (Sharapov, 1965), the difference between these populations is significant, as it results from the Table 1.

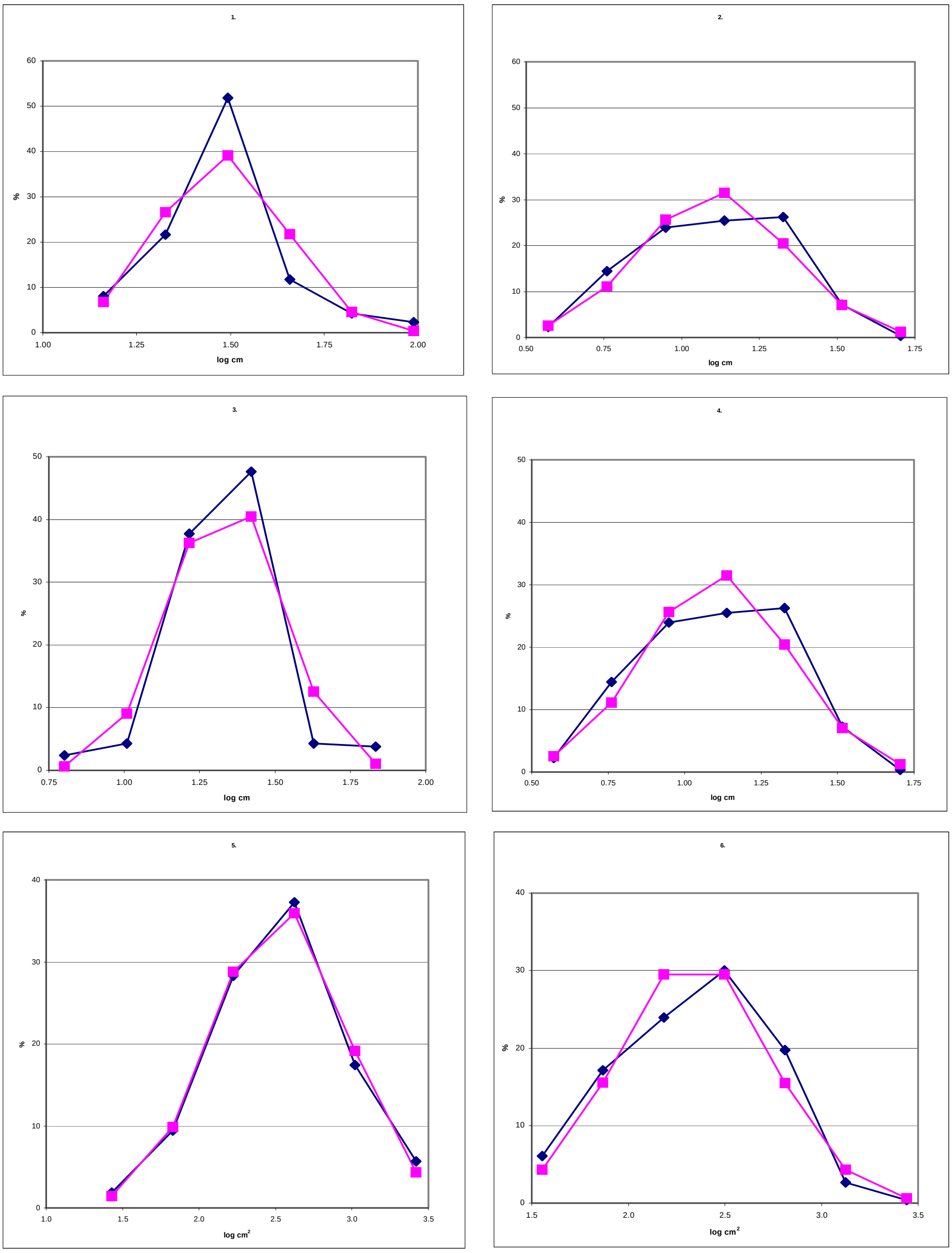

Fig. 3. Distribution of logarithmic values of dimensions (1-4)and surface of the stone pieces (5, 6). Left, the walls IInd built in IInd century right the wall built in the IVth century. Rhombs: the real distribution; squadrats: the theoretic, lognormal distribution.

Table 1

The tested values	t	t_{adm}
Lenght of stone pieces, cm,	21.01	2.78
Widt of stone pieces, cm	21.34	2.78
Surface od stone pieces, cm^2	122.78	2.78

Shape analysis. The shape of the rock fragments — free pieces — was studied considering the empiric shape index (1: column; 2: pyramidal; 3: truncated pyramidal; 4: cube, massive polyhedron; 5: short prism, parallelepiped; 6; flat and 7; platy object) and as well, the I/L–S/I diagram after Zingg (1935, fig. 4.). In both cases, e shape of the old and of the later stone material differ: among the stone material of 2nd century, the brick-like and cubic material dominate, while in the 4th century, the shapes are irregular, with dominance of the platy ones.

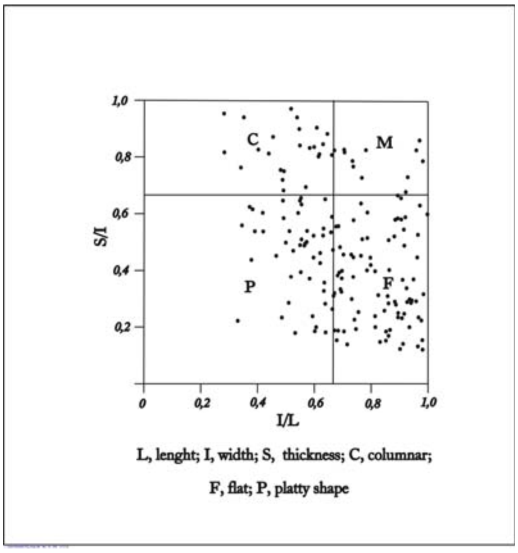

Fig. 4 Study of the rock fragments shape considering the empiric shape index and the I/L–S/I diagram after Zingg (1935)

Surface quality. Apart of some void filling, small pebbles, in the walls of 2nd century the angular pieces with rough surfaces were built in. On the carved surfaces, frequently deep, linear and smooth chisel traces are visible. On the pieces of 4thcentury, shallow, irregular chisel traces and secondary (new) fracture surfaces appear, together with rough natural surfaces of platy deluvial fragments and the polished surface of the alluvial pebbles, often with dissolution voids in place of the plagioclase phenocrystals of andesites.

2. THE MORTAR OF THE WALLS

For the Roman buildings, the mortar among the stone pieces was examined, too.

In thin section, the lime mortar of the walls of the 2nd century is white or colorless. It is constituted by sparry, mosaical, often zoned calcite grains, while for the walls of 4th century grey, greenish, micritic sandy-clayey lime aggregate were used.

The SEM micrographs show an evident difference of these structures (Plate II, photo 4).

The X-ray and thermal analyses shows for mortar of 2nd century, near pure calcite composition, similar to the Triassic limestone exploited now by the Vác Cement Plant. In the mortar sample of 4th century, apart of calcite, dolomite, clay minerals, quartz, feldspars and other minerals appear (Table 2). The trace element contents of mortars differ, too (Table 3).

Table 2

X-ray analysis of mortars

Minerals, %	Mortar of 4th century	Mortar of 2nd century
Montmorillonite	5	3
Illite+muscovite	10	3
Chlorite	3	
Quartz	20	5
Feldspar	2	
Amphibole	1	
Calcite	40	80
Dolomite	13	5
Goethite	1	1
Gypsum	2	1
Amorphous phasis	3	2
Total	100	100

Table 3

Trace elements of mortars

Elements, ppm	Mortar of 4th century	Mortar of 2nd century
Cr	30	udl
Co	10	udl
Ni	25	10
Zn	115	55
Mn	950	1200
Cu	15	udl
V	20	udl
Sr	1620	950
Pb	65	25
Ba	550	755
As	150	udl
Li	5	10

Both analyses executed in laboratories of Geological Institute of Hungary

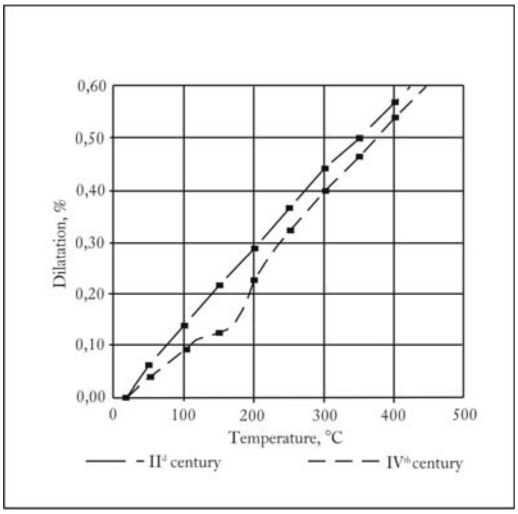

Fig. 5. Dilatometric diagram of the mortars.

The dilatometric diagram (dilatation rate vs. temperature) of the older mortar is linear, while on the younger mortar sample a slight inflexion between 120-150°C was registered (fig. 5.).

Thus, it is probable, that for cementing the broad-stones and other stone pieces, in 2nd century, pure lime powder, staked with cold water was used, while in 4th century, the lime powder was fired of impure material (e.g. of Eocene or of Badenian limestones) and for accelerate the fastening it was staked with hot water.

3. DISCUSSION

The research of archaeological material, i.e. of the stone pieces and mortar by geological means seems to be successful, confirming some presumptions and offering new data about the examined constructions and their evolution in time.

Our study point out the difference of morphology and petrography of the building material used in first period of the constructions (2nd century) and in the last years of the Roman occupation (4th century).

The stone material of the initial walls was obtained of some large quarries, in which a full sequence of a pyroclastic fall was opened. The blocks were sectioned, carved and finished, obtaining regular, parallelepipedon-like broad-stones, a few of its measuring up to 1 m. The cement material of the buildings was obtained fromselected, pure limestone and staked slowly, for obtain a stone-like, resistant mortar. These operations require accurate planning and engineer assistance.

On the contrary, the walls of 4th century were built up by stones with various shapes and origin, mixing deluvial and alluvial rock pieces with crushed, older broad-stones and what is more, fragment of brick, household tools (Pl. I., photo 3.) and of cultic objects. The mortar was prepared from nearest outcropping limestones and staked in the shortest time as possible. Thus, the reparations made in 4th century wear the marks of improvisation. They were executed under threat of Marcoman or other Barbaric invasions, which in finally, have destroyed the fortifications of the *limes* at the end of 4th century.

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Plate I

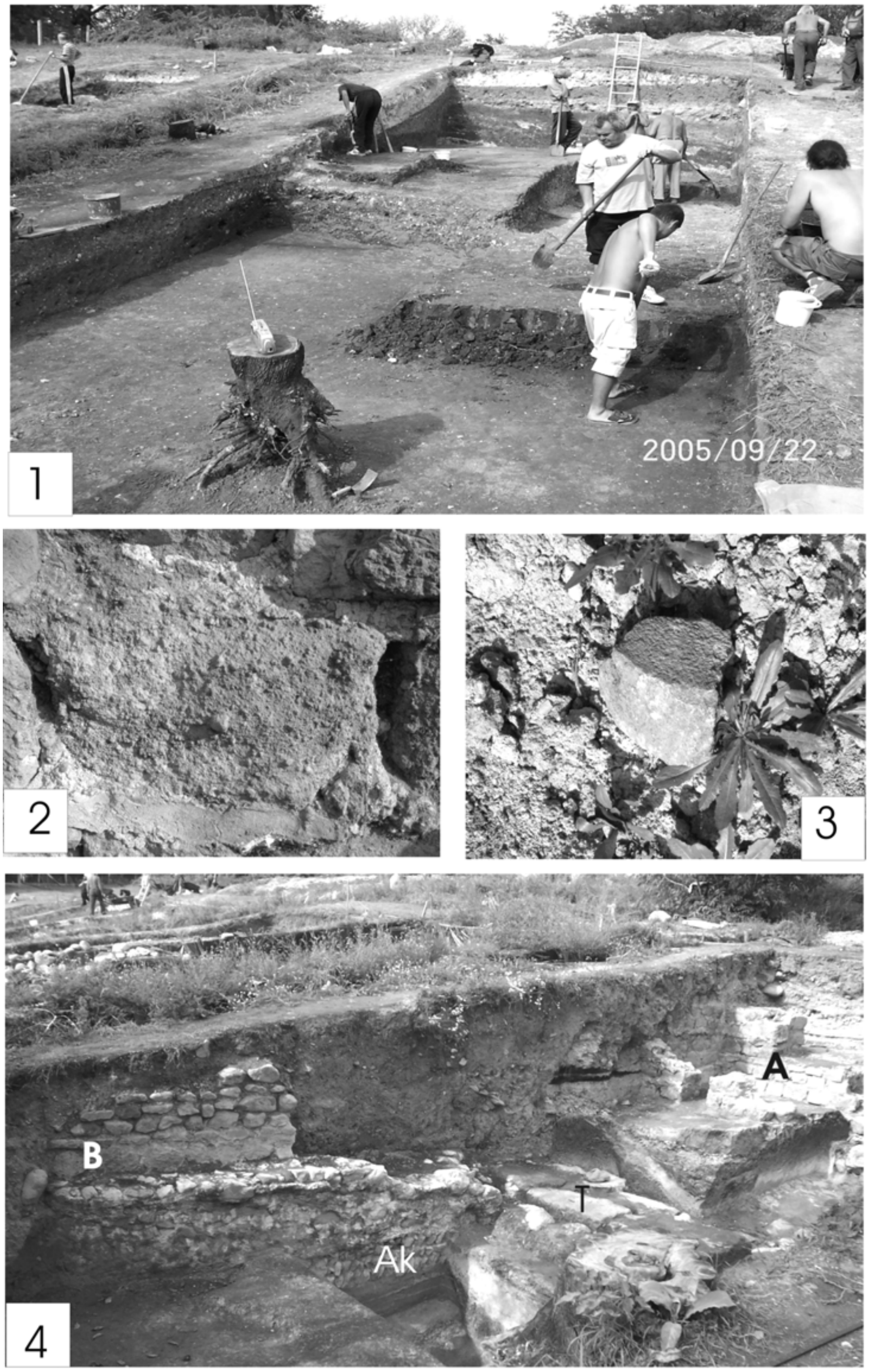

Plate I.

Photo 1. Excavation trench of the 8th section.
Photo 2. Pyroclastic breccias: wind carved broad-stone in the wall opened by 10th section (2nd century)
Photo 3. Basalt millstone fragment, as loose stone piece.
Photo 4. The 7th archeological section. A. Quadrangle town built up in the 2nd century; T, amphibolitic andesite tuff broad-stone pieces, foundation of the wall (2nd century); B, curved wall of the bastion, 4th century; Ak, foundation of the bastion: rounded, smooth andesite pebbles.

Plate II

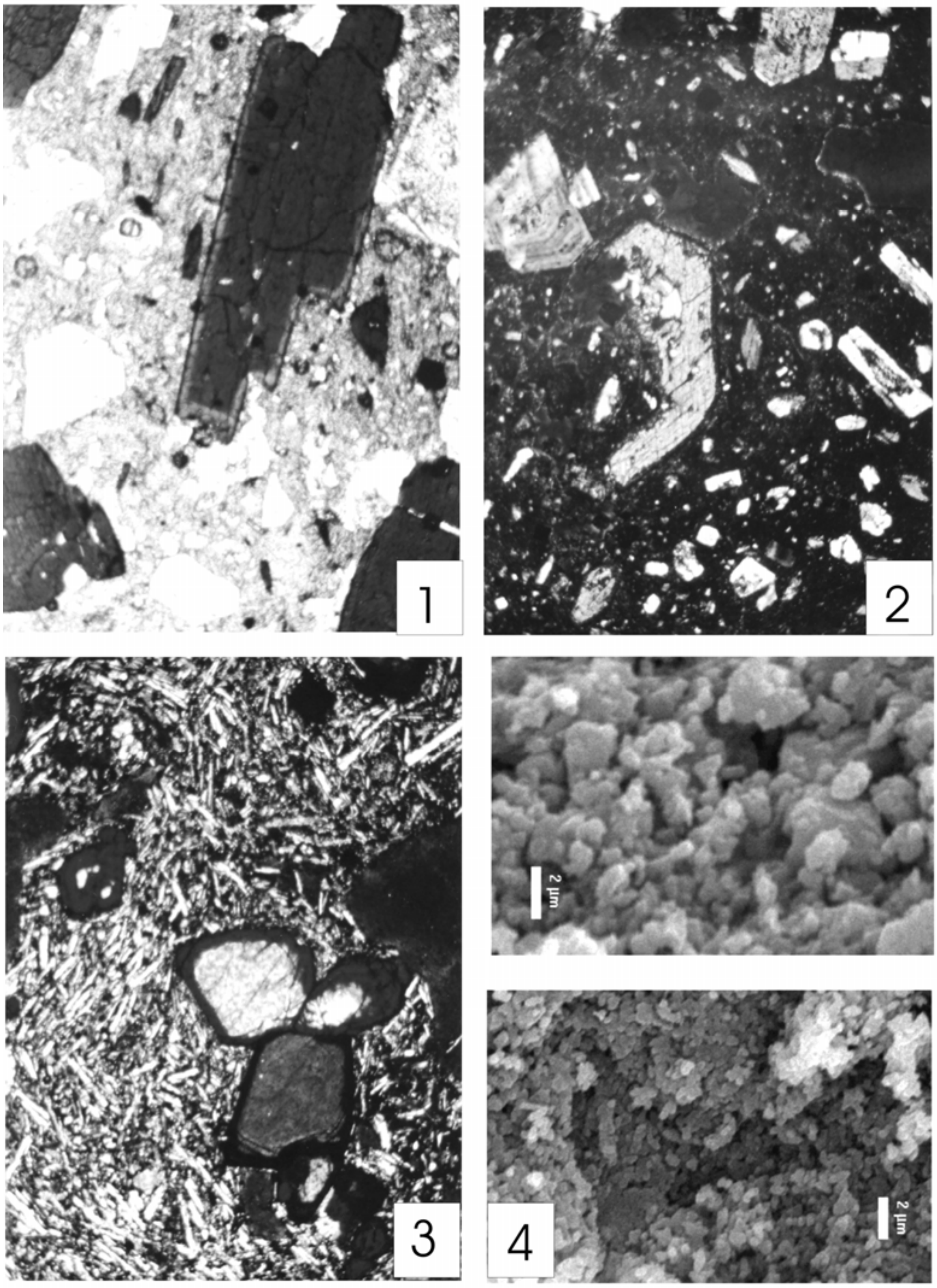

Plate II

Photo 1. Amphibole andesite. Euhedral, red oxy-hornblende and white feldspar phenocrystals in light brown, vitrous matrix. II Nichols, length of the photo, 3,8 mm.
Photo 2. Crystaloclastic tuff. Hornblende (yellow) and plagioclase (grey and white) crystal fragments in dark brown, vitrous groundmass. + Nichols; length of the photo, 3,8 mm.
Photo 3. Basalt millstone fragment: serpentinized and limonitized olivine phenocrystals (blue with brown-red rim) and intersertal, feldspar microlites. + Nichols; length of the photo, 2,6 mm.
Photo 4. Up: SEM micrographs of the mortar of the 2nd and down, of the 4th century.