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TITOLO TESI

STUDY OF THE BUILDING AND DECORATIVE MATERIALS AND TECHNIQUES USED IN HUNGARIAN ROMAN SITES

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Solve et coagula

A Chiara, che ben conosce il significato della *Resistenza*

To Chiara, who well knows the meaning of *Resistance*

Index

1. The research project

This three years research project (2006-2009) in the EPISCON/Marie Curie Action was developed in Hungary in the frame of a micro-regional research plan of the Hungarian National Museum in Budapest and aimed to analyse several historical places (regions) in Hungary and to achieve a possible preservation in situ. The first two years were hosted by the Hungarian National Museum, in collaboration with Etvos Lorand University, where sampling and subsequent petrographical and mineralogical analyses were carried out. The last year of research was spent at the Aristotle University in Thessaloniki, Greece, where all the investigations on physical, mechanical and chemical properties were performed. Further analyses were also carried out in Italy.

The research topic proposed by the Museum aimed at understanding the phenomenon of decay and weathering of building and decorative stones caused by different factors, acting in different conditions, and at trying to evaluate and draw possible conservative interventions in order to make the site available to the public.

The first step of this research project was to analyze the unstudied material collected during the 60's and 80's excavation campaigns from a Roman Archaeological site located in the southern countryside of Hungary, about 200 km far from Budapest: Nagyharsány Roman villa.

Most of the building and decorative stones from Nagyharsány lay still under the ground, while a large number of mosaics and mural painting fragments were collected during the excavations and are now stored at the Hungarian National Museum's basement.

This leads to some considerations.

First of all, the number of samples comprises a quite large variety of different material, including building stones, mortars and decorative elements, which can be affected and react in different ways, under weathering conditions.

Secondly, the environmental conditions and risks are actually not the same, being part of the decorative elements stored in the Museum's basement, while the whole archaeological open air site is almost completely buried.

Although a new excavation campaign was planned by the Museum during the period of this research, it finally turned out that it was not possible. This affected the possibility to carry out direct observations on structures and elements in situ, to evaluate the effective state of conservation of the monument and to have access to the few visible traces of the walls.

Nevertheless, it is worth to note that, at present, keeping the site hidden and buried is the only solution to avoid further damage by heavy weathering actions or vandalism: this could guarantee the protection of its historical and archaeological value for the future.

Firstly, a characterization and identification of the material through petrographical, mineralogical, geochemical analyses and investigations about its physical and mechanical properties were carried out.

To better understand the results from Nagyharsány Roman villa and to put them in the proper frame, these observations were compared with the study of other Hungarian Roman sites (see map below). Particularly interesting were the Military and Civil towns of Aquincum (Budapest) and in the Nemesvámos-Balácapuszta Roman villa in Baláca, the largest villa-estate of the Transdanubian region (Transdanubia), where it was possible to collect samples and carry out observations of the plan structures, the wall structures and of the dimensions and distribution of the different elements. Furthermore, because of the poor conditions of Nagyharsány site, the study of these two archaeological sites could represent the only way to observe the restoring and preserving interventions carried out in Hungary during the past decades, the criteria of selecting and applying the new material and the effects due to the weathering. Only on this base, it has been possible to give a contribution in the drawing conservation strategies suitable for Nagyharsány Roman villa.

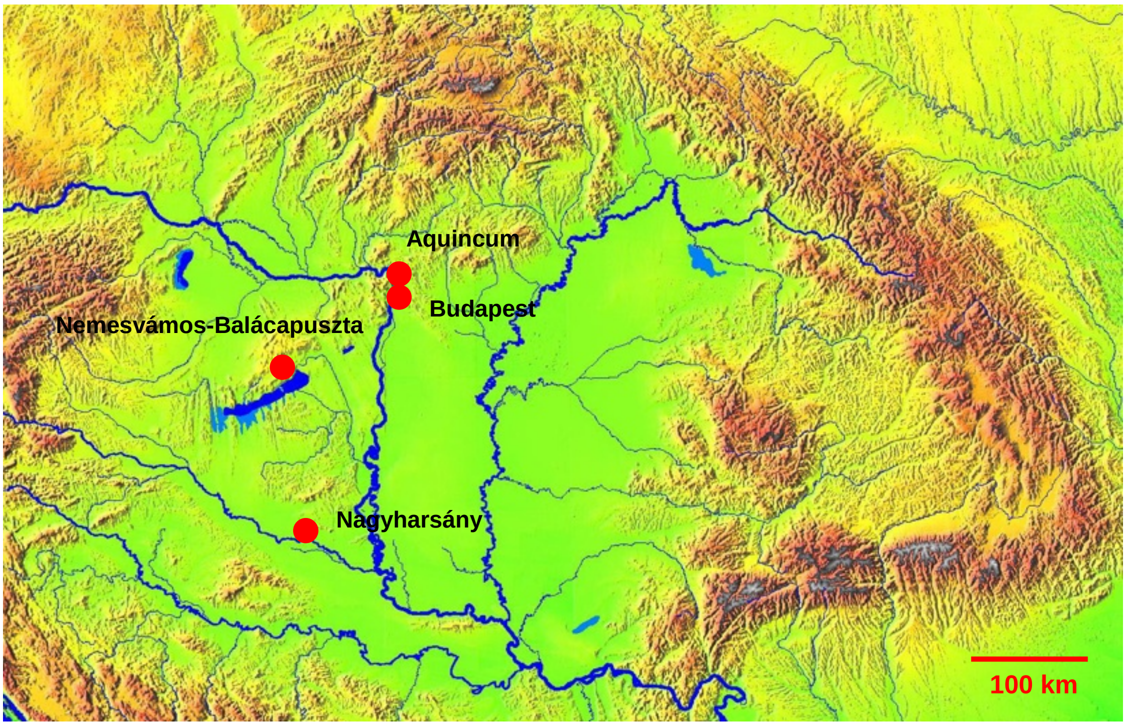
Furthermore, the comparison among different Hungarian Roman sites made it possible to observe the many similarities of the Roman building and decorating techniques, also allowing to understand how and in what measure a common knowledge was spread in the whole eastern region of the Empire through lines that are possible to be traced.

The second step of the research was to compare what observed in the Hungarian Roman sites, in terms of building and decorative techniques and material, with the classical Roman literature by Vitruvius, and the practise applied by the Romans in other regions of the Empire.

For this reason, two different sites were taken into account in Greece: the Galerius Palace Complex in Thessaloniki and the archaeological site of Dion, located in the foothills of Mount Olympus. Furthermore, comparisons with thin sections belonging to two Italian Roman churches were also drawn which became helpful in an attempt to interpret some aspects of the study.

All these comparison revealed that there are some differences in the way the Romans applied building and decorating techniques in their colonies. Although they were definitely able to bring their great knowledge and most precious material to the farthest borders, their techniques and methodologies, based on the same central knowledge and experience, were performed taking into account the local needs and conditions and the material availability.

As a concluding part of the research, most of the results, data and conclusions were set, organized and included in a database which would represent a multifaceted information archive, hopefully useful for Archaeologists, Historians and Conservation Scientists in charge for Roman sites in Hungary.



Physical map and location of the Hungarian archaeological sites (with the permission of the MAFI Institute).

2. Introduction

Historical frame: Romans in Pannonia

By the first century AD, the Roman troops entered the Carpathian Basin (Transdanubia), enlarging the borders till they reached the river Ister (Danube), where they found a favourable geographic setting to control the frontiers of the Empire and to place their fortresses. The armies marched in the area in four different phases and in less then twenty years, by the 49 AD, the region was conquered. (Kiss, 2003)

Although the earlier traditions and cults belonging to the local tribes survived for a long time, the Romans arrival represented a sharp change in the growth of Transdanubia. The cultural environment was radically changed, rural settlements turned into well planned villages or towns, networks of roads were built, simple huts were replaced by clay and sand structures (adobe) and later by stone houses, while new techniques and knowledge on mortars, cement and plaster allowed the construction of larger stable structures, provided with heating systems, new public buildings were erected such as theatres, temples, baths, markets, villas, military forts, bridges and aqueducts. Thus, with the new immigrant population, the daily life of the inhabitants was completely transformed, technologies unknown in the past took place, and the trades increased the economy of the area. (Kiss, 2003).

As part of an administrative unit, Transdanubia, which had never formed a geographical and political unit before the Roman occupation, became a province called *Pannonia*.

Pannonia remained unified until 106 AD, when it was divided into two provinces for political and military reasons, *Inferior* and *Superior Pannonia* (Lower and Upper), and then, at the turn of the III and IV century AD, a fourfold subdivision was made, *Prima*, *Valeria*, *Savia* and *Secunda Pannonia,* with four different capitals.

With the V century the decline of the Empire started. By the half of the same century, local tribes defeated Roman armies and Pannonia was progressively ceded.

During five centuries, Romans had been able to change the culture, the life style, the uses and knowledge of an entire huge area. When they left, even in the far eastern regions a very elaborate network of main and secondary roads remained, connecting the most part of Middle Danubian provinces and settlements to the centre and other parts of the Empire.

Testifying example is an important manuscript showing a map of the main roads from *Britannia* to *Pannonia* passing through Italy, the Tabula Peutingeriana. It is supposed a XIII century copy of an ancient Roman map and it takes the name from Konrad Peuntinger which he reported to have inherited it from a friend. At present, the Tabula is retained by the Hofbibliothek in Vienna and it has been renaimed as Codex Vindobonensis. Its dating and its provenance are still an open issue. The 12 sheet map, 34 cm wide and 6 m long, shows, besides more then 4000 localities and cities, also geographical references, making evident that the different parts of the Empire were well connected.

The map clearly support that the Romans were able to expand their trades and exchanges all over their Empire, and effectively transferred their construction techniques, knowledge, raw materials and handicraft products to the most distant regions, including the eastern borders.

A copy of the Tabula can be seen in the main museum of the Roman period in Hungary, which is situated in Aquincum, the ancient capital of the Pannonia province, which is nowadays an open-air Archaeological site, not far from the city centre of Budapest.

<u>Nagyharsány: from the Roman time to the present</u>

In Roman terms, *villa* means a rural settlement, which can be separated from the town and completely isolated since it is the centre of agricultural productions; so it can be considered as an independent economic unit (Biró, 1974; Kiss2003). An agricultural unit needs a number of different buildings (outbuilding*s*) beside the living-house; thus the whole group of buildings constitute a closed unit, which cannot be divided in smaller sections. Owners of these villas in Pannonia were either Romans from Italy or members of the Romanized Celtic aristocracy, most frequently retired veterans from the army, who received territory's grants settled in towns, or colonies founded along and close to the Amber Route, the ancient trade route for the transport of amber from the Baltic sea to the Southern Italy (Basilicata) (Kisfaludi, 2008; Kiss., 2003).

Nagyharsány archaeological site is located in the middle of the countryside, among open fields, close to the southern border of Hungary, about 200 kilometres southward from

Budapest. The whole archaeological area covers a large region along E-W direction, lying between the towns of Siklós and Villány at Southern side of the Szársomlyó hill, between the highway Kopáraljad and Lapáncsa road which runs along N-S direction. This road separates the site in two parts, North and South side, which present different characteristics in terms of geographical features also reflected in the distribution of the archaeological finds. During the past decades, the western border of the site was well defined by the archaeologists, while the eastern one has been only supposed on the base of the decreasing presence of surface finds. The total extension of the area is assumed to be between 500 and 600 m along the E-W line, and circa 300 m along the N-S one, with a total surface of circa 15 hectares.

The first archaeological surveys and excavations have been started in 1959 by László Papp and continued then by Ferenc Fülep in the 1960's and 1980's. Fülep's map of the site (Fig. 1), drawn in 1963 during his first excavation campaigns, represents the only way to have an idea of the wideness and organization of the site, since it is nowadays completely buried. More recent aerial pictures confirm Fülep's estimation of its dimensions.

According to the archaeological studies, the first evidences of a Roman presence in Nagyharsány date back to the second half of the I century AD, during the Flavian period. The settlement had a rural character, based on agriculture.

It was partially destroyed during the Marcomannic wars (around II and III century AD) (Hajnóczi, 1987), but somehow continuously used. At the turn of the III century the settlement became more organized, with permanent inhabitants and most probably with a sort of economical self-sufficiency.

In that period were firstly built the *Thermae* (baths) and the villa (one of the finest Roman villas came to light in the territory of Hungary), the walls were decorated by mural paintings and mosaics with geometrical patterns. Some mosaics with figural patterns and personifications are from the second half of the IV century AD; their fine quality and the use of more precious material (glassy tesserae) may testify that the estate was rather rich. The lack of earlier finds suggests that during the first decades of the 5th century it was abandoned (Mráv, et al., 2008)

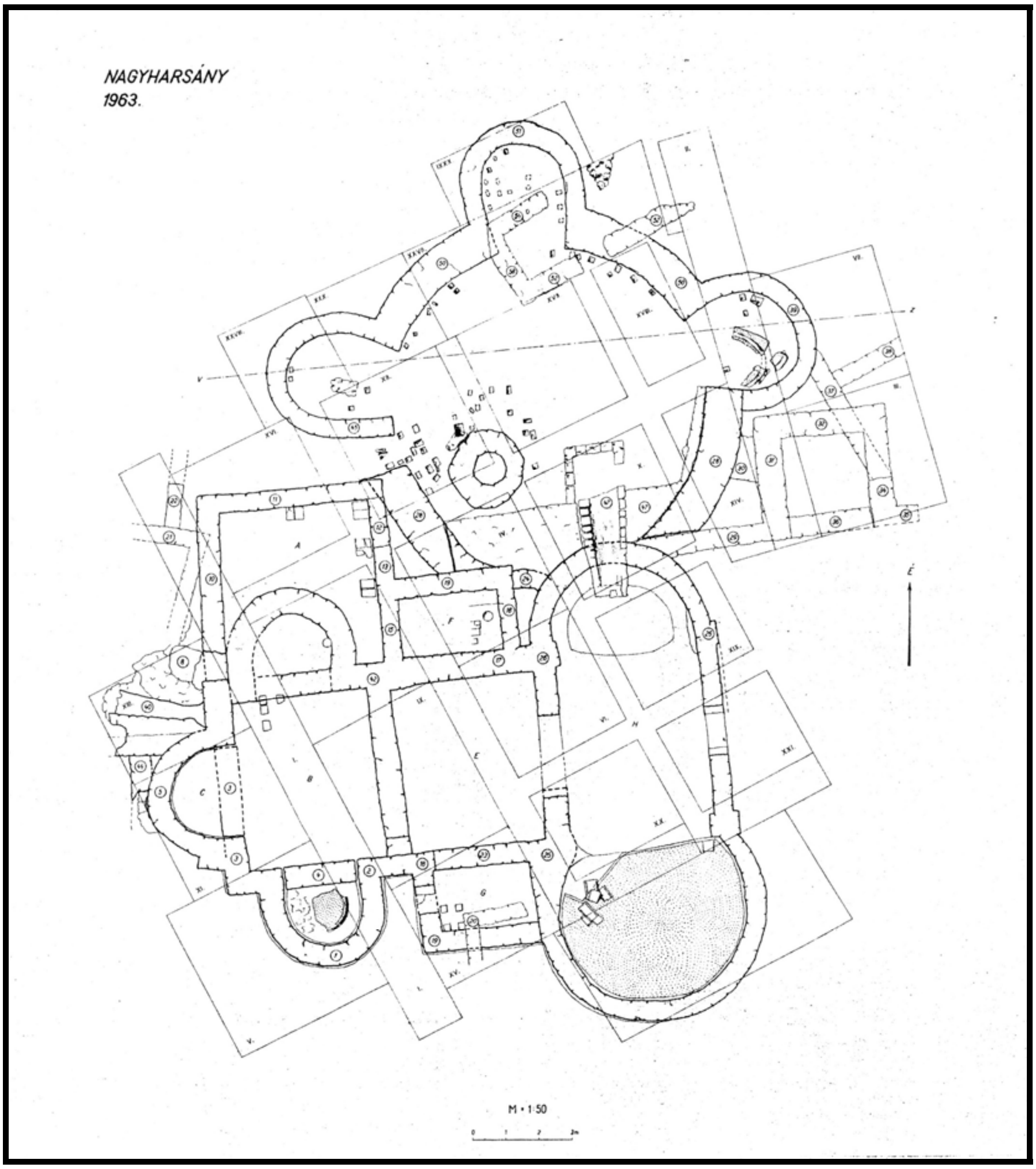


Fig.1 Map of the site drawn by Ferenc Fülep, 1963, with the permission of Zsolt Mráv.

After the last excavation, the site was completely buried, only a few traces of the main walls, higher then the ground level, have been left visible. The only restoring interventions on wall's remains were executed during the 1980's, using modern cement and local building stones for replacements. The restorers set up a red brick line as a marker of their intervention. This line divides the wall into two parts: down the line is the unchanged original part of the Roman wall, while up the line there is the restored part, characterized by the presence of modern cement and replaced building stones.

What is known about the site is due to archaeological diaries written by Papp and Fülep during their excavations, and never published: those manuscripts represent the only source of information of the archaeological area and the events referred to it. The following quotations have been translated from Hungarian.

"*I perambulated the ground several times in my free time* […]" and "*This area is situated in the south of the middle of the southern side of Nagyharsány hill, 50-60m far from the hill-foot where the ground is flat* […] *and I found the following: if we go 200 metres from the cellars at the eastern end of the village towards Villány, on the right hand side, i.e. 50-60m far from the south of the main road, we can find smaller pieces of stones, bricks and Roman bricks on the surface* […]. *We can see piles of pieces of Roman bricks, roof tiles mixed with smaller or bigger pieces of lime-stone on the small parcels which were gathered by farmers during work.* […] *pieces of Roman edged bricks, we found in this layer: small fragments of Roman pots, and terra sigillata* […] *piece of plate-glass smoothing at the unbroken side in very iridescent condition. In its intact form it could have been triangular-shaped, supposedly served as a glaze. Nearby we found some thin, flat pieces of glass* […]" (II Excavation Report written by L. Papp in Nagyharsány on September 1959).

Reading the first reports, it seems that the site was an unexpected discovery. Mentioning objects, bricks, pot fragments, and *terra sigillata* (a kind of ceramic), Papp gives information about the Roman settlement itself, its richness, the ability of its trades to be connected with the surrounding areas and with the centre of the Empire, sharing materials, techniques, knowledge. Although the inhabitants used to import handicraft products from other regions like Italy or France, there are "[…] *Remains of primitively burnt, hand-made earthenware of rough material were found in 80cm depth, 50cm far from the northern side of wall b: these are parts of the same sort of pot that were found half a kilometre far from here, in the Avar cemetery*. […]"(ibidem)

Despite the fact that the two archaeologists had not enough time to complete the excavation, "[…] *I have to mention here that the complete sectioning that would fulfil* *the aims of the excavations more professionally and the necessary earthwork cannot be carried out because of the relative shortness of time and the character of the excavation; it would take much more time than planned and it would be much more expensive. Further excavations – there is no doubt about it- are promising*" (ibidem), Papp, already in 1959, realized that the entire complex structure of the site could have been built during different construction phases. He concluded his campaign leaving this statement for following research: "*The further researches will have to define the following: whether the walls of the oblong-shaped section of 10.8x4.5m measures have a partition wall, what the link is between the walls of the eastern side, and what the purpose of building was. It is evident that the semicircular execution of the southern side was closed and walled up later (on the eastern side of the wall b, presumably, there is a doorway)*." (ibidem).

Two years later, in 1961, Fülep was nominated the head of the excavation. In his diary he wrote: "*We started excavations on the territory of Roman settlement on 15th July, 1963, with authorization of the Hungarian Academy of Sciences, No. 15327/II/Dm 1963, costs to be borne by Janus Pannonius Museum, Pécs."*(II Excavation Report written by Fülep in Nagyharsány on July 1963) . Then Fülep went on describing the excavation, what they were seeing and finding. His words give an idea of the complexity and richness of the site: "[…] *large building with circular ground-plan to the north of the 1961 excavation site. Its terracotta flooring was found on the same level. Small columns of brick stood on this flooring. They could have been the columns of the under-heat system that supported the 20cm-wide terrazzo flooring, whose large pieces were found everywhere. A thick terracotta layer covered the inner surfaces of the walls. Those red-painted fragments were found all around.* […] *We opened up B, C, D, E ditches in the east of this ditch; we found hypocaust, numerous little columns, a nicely carried out heating flue and terrazzo flooring. To the south of this room we found black and white mosaic flooring 'in situ'.* […] *In the area with hypocaust we found numerous remains of the mosaic flooring that had been supported by the small columns. This mosaic flooring shows figural representations and two woman portraits of early Byzantine style* […]. *There were inscriptions around the portraits, so we hope, they will be solved. The mosaic flooring is originated in the second part of the 3rd century and one of the most ornamented mosaic floorings that have ever been found in Hungary."*(ibidem)

In 1982 Fülep announced his intention to ask the permission for a new excavation at the site in order to take care of a situation that seemed even more badly damaged: "*The reason for the excavation was that Imre Layber, a teacher visited me in 1981 and informed me that on the territory, where the well-known mosaics had been destroyed, large, continuous pieces of mosaics lay hidden in the depth which he had experienced with an iron stick. I have asked an authorization on the basis of the above reason, with the aim of executing a rescue excavation*." (II Excavation Report by Fülep written in Nagyharsány ,1982)

At the end of the campaign, Fülep and his team collected all data and consigned their observations and suggestions to the architect in charge. Then they filled up the trenches again, covered the walls and left the site.

"*I drew a profile of the western side of ditch A/1, to the south of wall 'b' and on the western side of surface D.* […] *We filled up all the ditches with earth to prevent further damaging. We covered the walls with foils. We completed the ground-plan, took photos, made a film, levelled and started filling up the smaller ditches and preparing them for the conservation. We talked to the site architect about the methods of the conserving. We finished excavation after the necessary filling up*." (ibidem)

Nowadays, after thirty years, many factors make the situation in Nagyharsány archaeological site (Fig. 2-3) even more complex. Above all, the fact that it is located in the middle of the countryside, between two small villages, 50 km far from the main city of the area (Pécs) and about 200 km from Budapest, results in difficulties in planning any conservative intervention, in managing and protecting precious finds from vandalism, and finally in being a quite isolated area where there is a high risk of a low rate of visitors: a multifaceted issue demanding a great attention, time and funds.

There is no documentation on the criteria of selection and the typology of the material used during the partial restoring intervention on walls, carried out during last excavation's campaigns. According to the common belief, the building stone used for replacing some parts of the ancient walls is compact limestone from local quarries.

Fig.2 -3 Nagyharsány archaeological site from distance and a detail of a wall section.

Aquincum archaeological site

Aquincum, whose ruins can be found today in the territory of Budapest (Óbuda), became a part of the Roman Empire during the I century AD. Originally a Celtic settlement, Aquincum served at first as a military base (*castrum*), being part of the Roman border protection system called "limes". It was situated on the North-Eastern borders of the Pannonia province. Around the 41-54 AD, a strong cavalry unit arrived, while a Roman legion of thousands men had stationed here by 89 AD. Thus the first settlement was a legionary fortress, which was built up as a base to control the eastern border of the Roman Empire and that remained the core of the community during the whole time of its long life. The structure of the Military town, running along the limes road, grew up around the fortress, and the plans of aqueducts paths, roads and buildings were realized according to the typical Roman rules. The earliest phase of the construction can be dated to the second half of the first century AD, roads were bordered on both sides by small channels and, during the centuries, different districts were set for different activities, including buildings of administrative, sacral, industrial and residential functions. The Civil town was born North of the legionary fortress and gradually expanded all around it, and could receive not only the families of the soldiers, but also merchants, artisans and craftsmen, serving the Military town. (Zsidi, 1995).

After Pannonia was reorganised by Romans in AD 106, Aquincum became the capital city of the Pannonia Inferior. The city had already 30000-40000 inhabitants by the end of the 2nd century.

On the base of the innumerable finds from the many excavations carried out in the last decades, archaeologists have been able to draw a pretty clear picture of the interaction between the pre-existent Celtic culture and the Roman one. Roman and Greek inscriptions have been found, together with the Celtic ones, showing that those languages were all used. Deity statues and magical inscriptions belonging to Roman, Greek and Celtic cults had been also found, thus it can be deduced that Roman Gods were venerated as well as the Greek and the Celtic ones. (Zsidi, 2008).

It is also reported (Zsidi, 2008) that some Celtic settlements were preserved from demolition, and locally the original population was able to keep their own traditions.

However culture, habits, skills and technologies quickly turned into the Roman ones.

People living in the settlement could enjoy the achievements of the Empire, like central heating in the houses, public baths, palaces, or amphitheatres for social events.

During the first and second century AD, most of the material used for daily life was imported: glasses from Germany, pottery and bronze vessels from Italy and France, amphforae from Greece.

Between the second and the third century local workshop activities gradually began to develop, starting from the western territories of the settlement, proceeding to the eastern and southern areas during the course of the third century.

Local productions supplied the needs of the population and became useful also for exportation, mostly to France (Gallia) and South Germany (Germania). (Zsidi, 2000).

The criteria for selecting the material and the methodologies and technologies for the production of tegulae, pottery and glass used in Aquincum followed the habits **and skill** applied in the central parts of the Roman empire (Dr. Zsidi, Aquincum Museum, personal communication).

Nemesvámos-Balácapuszta (Baláca)

Situated between the Balaton and the Bakony hills, north of Lake Pelso, Nemesvámos-Balácapuszta Roman villa (Baláca) represents the largest villa-estate of the Transdanubian region. According to Archaeologists and historians, it was first owned by an Italian family in the second half of the second century, but it reached its largest extension, about four hectares, during the third century. Probably, the presence of natural resources in the surrounding area, like open fields, water and forest, trade routes and a particularly fine and warm clime, made the settlement appreciable. Further traces of construction phases belonging to the fourth century can be detected, but by that time the settlement started to be abandoned. (Kiss, 1973).

The excavations at the beginning of the 90's, and the previous one carried out in the 70's, found 17 different stone buildings, where finely decorated walls and pavements are frequent. The buildings were decorated with very high quality frescoes and mosaics according to the earliest post Pompeian style (Mócsy, 1974). Also the monumental tomb of the first owner family was built in the Italian style and the decoration techniques suggest that the craftsmen was most probably Italian. Quite famous are the large mosaic floors, dated to late Severan time (Mócsy, 1974; Járó, et al., 1987).

Buildings and inner walls were also equipped with heating systems by circulating water.

The Baláca villa's remaining parts are certainly among the most significant Roman relics found in the Hungarian territory, since they include very rich and fine decorative elements (Kiss, 1973)

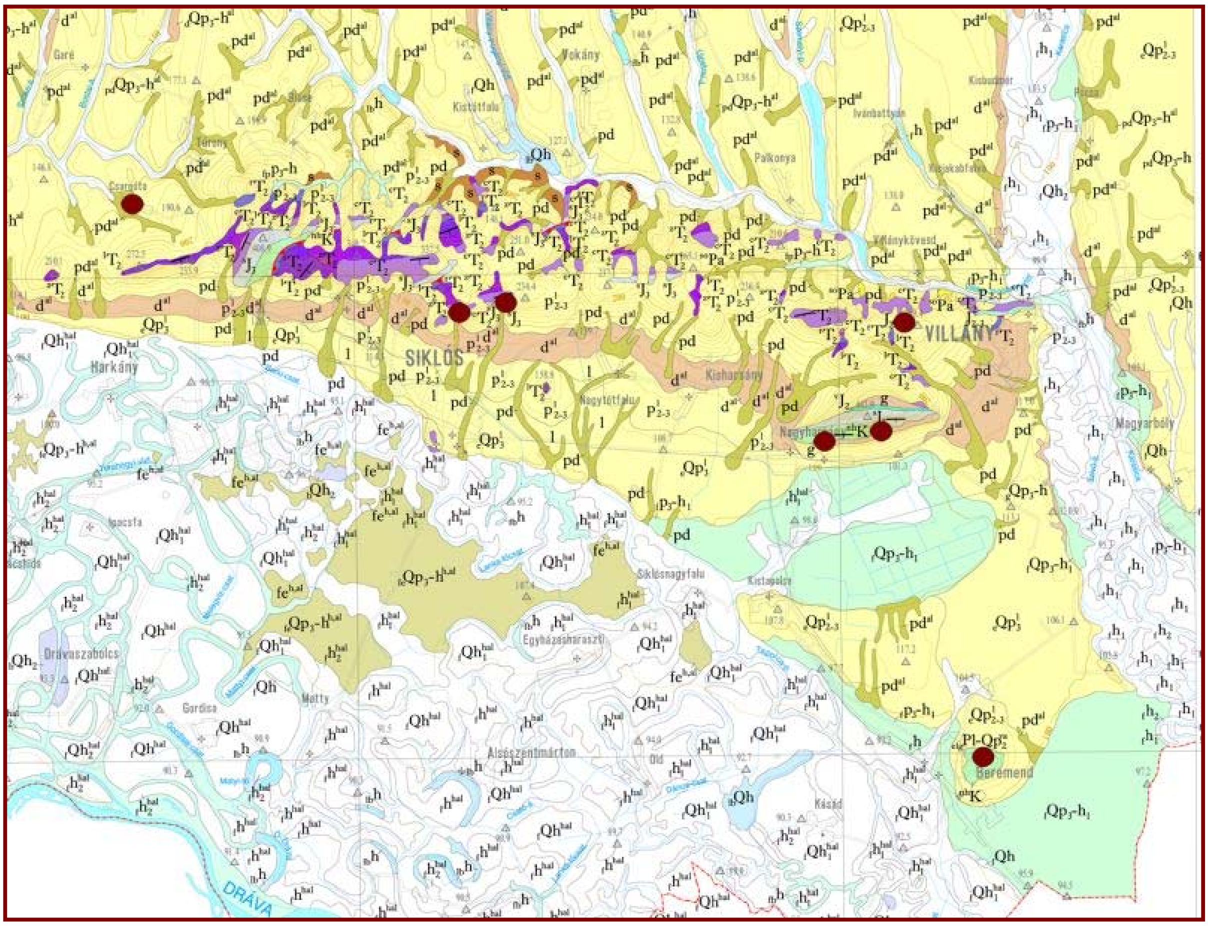
Geological aspects of the archaeological area

Romans had been probably the first in recognizing and starting the utilization of dimensional stones in the territory of Hungary. Local limestone, but also travertine and marls were among their favourites.

The area surrounding Nagyharsány archaeological site, embrassed by the Villany Mountains, is characterized by a widespread presence of Mesozoic compact limestones and dolomites. (Géza, 2002)

Reflecting the tectonic evolution of the Carpathian Basin, (Kazmér et al. 1985; Csontos et al. 1992), during the Paleozoic and Tertiary all the area was characterized by rifting and plate collision movements. These mountain building processes were followed by the formation of a young basin (Pannonia Basin), due to a crustal thinning and subsidence, and then filled up by Tertiary sediments (Török, 2007). Coastal-terrestrial sedimentation, shallow marine deposits and carbonate ramp systems resulted in what we can see today in the Villany Mountain area.

From the Late-Triassic alternation of dolomite, dolomitic marls, sandy siltstones and quartzarenite, it can be also found discontinuous shallow marine, sandy, crinoidal limestones with conglomerate interlayers belonging to the Jurassic, while, during the Middle Cretaceous, low marine carbonate accumulation began, leading to the formation of different thick-bedded limestones. Evidences of metre-scale variations in colour, composition and fossil content are the result of short-term sea level oscillations (Haas, 1987; Lóczy, 2003)



Geological map of the area surrounding Nagyharsány; the sites of the sampled quarries are shown.

3. Material and methods

Sampling

From the very beginning, efforts were done in considering Nagyharsány Roman villa as a whole system composed by different structures, techniques and functions. For this reason, a large amount of samples of different nature and meaning and from different structures were collected.

During the first sampling campaign, in March 2007, we have collected several specimens of building stone and samples of mortar from the ruins of the original villa's walls. During two further campaigns (2008), we collected samples from the surrounding quarries (Fig.4-5), in order to be able to make a comparison with the original ones.

Fig.4-5 Sampling in Nagyarsany –Szoborpark and Beremend quarry

Furthermore, building stones, mosaic tesserae, mural paintings fragments and specimens of decorative mortar were collected from Nemesvámos-Balácapuszta Roman villa (Baláca, Fig.6-7)) and building mortar samples were collected from Aquincum Archaeological site (Fig.8-9).

Fig.6-7 Nemesvámos-Balácapuszta Roman villa, reconstructed walls.

Fig.8-9 Aquincum archaeological site

More precious and useful material was also sampled directly from the finds collected during the old excavations in Nagyharsány and stored in the basement of the Hungarian National Museum: mosaic tesserae, mural paintings fragments and specimens of decorative mortar (Fig.10-11).

Fig.10-11 Mosaic fragment in their boxes from the Museum’s basement

In 2009 further samples of mortar (decorative and building) and building stones were collected in a new and last visit to Nagyharsány site.

During the sampling at Nagyharsány, particular attention has been paid in collecting samples from the original building stones, avoiding the parts replaced during the previous partial restoring intervention. The red brick line, used by the restorers as a marker of their intervention, was fundamental. Specimens of building stones have been collected from different walls, in the few different sections of the site that are accessible. Since there is no documentation concerning the source of the material used for the 80’s replacement, the samples of original Roman building stone have been studied and compared with the ones collected from quarries, in order to find out the best match among the different lithologies for future replacements.

Samples of building stones

In total 28 samples of building stones from the original walls of Nagyharsány villa;

15 samples from the original walls of Nemesvámos-Balácapuszta Roman villa.

Samples from quarries

22 samples from different quarries: Nagyarsany –Szoborpark; Beremend quarry; Csukma quarry; Koves màj, Siklòs, Csarnòta quarry.

The quite large variety of lithotypes collected allowed us to observe several different kinds of limestone and dolomite and to compare them in order to find out the possible source of the material used by Romans and to be able to provide suggestions for future restoring interventions.

Samples of mortars

8 samples from Nagyharsány villa's walls;

3 samples from the mosaic fragment in the Museum's basement were collected too.

According to the Archaeologists knowledge, the Roman settlement was constructed in different phases, thus efforts were done in gathering mortar specimens representative of the chronological development of the site.

3 samples from the original walls in Aquincum.

The sampling has followed two main goals: to distinguish between the original and the replaced mortars and to identify differences and similarities among the original ones, in terms of their composition, characteristics and use. Particular attention has been paid in collecting mortar from both the inner part of walls and the more superficial one, in order to distinguish between the one used for building and supporting structural elements and the one used as substratum for mosaics and mural paintings.

Samples of mural paintings and mosaics

4 samples of mural painting;

6 tessera of mosaic's fragments in the Museum's basement.

In the case of mural paintings it was possible to collect specimens of different colours (red, dark red, violet red and olive green) and from different patterns (more or less complex); in the case of mosaic we tried to have one sample for each present typology of tessera (black, white, red, yellow and pink). Unfortunately, it was not possible to collect glassy tesserae present in the fine and high quality mosaics.

4 mosaic tessera (pale yellow and black)

7 sample of mural painting. from Balácapuszta Roman villa

Macroscopical observations

Each sample was observed by stereomicroscope (Leica Wild M10), (Fig.12).

Fig.12 The stereomicroscope

Thin sections (at the Petrographical laboratory of Eötvös Loránd University of Budapest, Hungary)

Afterwards, all specimens were cut and prepared for the thin section making process, The samples were cut by two different circular saw water-supplied systems, then fixed to the slides by the common bi-component epoxy adhesive Araldite (epoxyn resin with polyamine hardener Renshape Solutions REN HY 956). After the hardening, the excess of material was cut again and subjected to the thinning procedure, through abrasive powder of different granulometry on granitic slabs (fig.13-14).

Thin sections were observed by polarizing microscope (Leitz Laborlux 12 Pol S) for petrographical and mineralogical characterization.

Fig.13-14 Heating table for the hardening of the resin and the equipment for the thinning procedure through abrasive powder of different granulometry (ELTE University laboratory in Budapest).

Particular attention was paid to samples of mural paintings and mosaic tessera. Because of the value and the importance of those specimens, representative but very small specimens were collected. Dealing especially with mural paintings, the orientation for the cutting of the sample was set in order to obtain a thin section crossing the whole stratigraphy of the different layers, from the mortar substratum to the superficial painting layer. All samples were completely embedded in UV-hardenable reaction resin compounds (Custom Acrylic Resins, CAR-F150-F5). Afterwards they were irradiated in an UV-light applicator for the hardening. An initial, not activated reaction resin compound is irradiated after entering an input opening in a reactor having an irradiation space, a UV-radiation source.. Immediately after, the activated compound is supplied to the specimen to be surrounded, in an open casting mold. The final results (Fig.15-16) were many little glue cubes, which were cut and prepared for the thinning process.

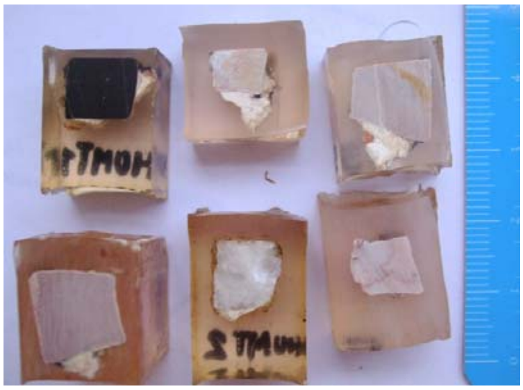
 

Fig.15-16 Cubes embedding mosaic tessera and mural painting samples.

All samples were photographed during each step of the process.

Special treatements

In order to better define the presence of silicatic compounds, some mortar’s thin sections from Nagyharsány have been also treated with a solution of the natural red dye Alizarin in hydrochloric acid (2 %): the acid interacts with the carbonatic component, with the resulting precipitation of a red varnish (“garanza” lacquer), thus confirmed the presence of silicic compounds. A second treatment was done with a fluoridric acid vapours. The silicatic compounds, under the effects of the vapours, turn into a gelatinous state, becoming blue (methylene blue), and can be easily recognized.

Analyses of physical and mechanical properties (at the laboratory of Building Materials, Department of Civil Engineering, Aristotle University of Thessaloniki, Greece)

a) ultrasound resistance and compressive strength tests on building stone samples (Fig.17-18)

Samples have been cut in cubes (4x 4x 4 cm) and dried in the oven at 70 ± 5 ºC for 24 hours before starting with the ultrasound velocity tests.

Afterwards, they have been immerged into water for 24 hours, for performing open porosity tests by vacuum assisted water absorption, according to the EN 1936: 2006 standard procedure for natural stones.

Fig.17-18 The equipments for ultrasound resistance and compressive strength tests

b) Open porosity tests, determined by vacuum assisted water absorption, were calculated, according to the EN 1936: 2006 standards, for limestone sampled from Nagyarsany, Balaca and quarries (Fig.19).

Pores distribution and porosity were measured also by gas absorption (Nitrogen) and calculated by BET (Brunauer-Emmet-Teller) methodology. The gas intrude into the specimen under increasing pressure. The increasing in the pressure corresponds to the increasing of the number of Nitrogen molecules that reach the surface of the specimen and condense on it. This corresponds to the number of molecules necessary to create a one layer covering the whole surface. The data nitrogen isotherm can provide information on the pores size of the material. The results are shown as the relative volume of the pore versus the pore's size.

Fig.19 The tank for open porosity tests determined by vacuum assisted water absorption

Drilling tests (in collaboration with the CNR-ICVBC Institute in Florence (Italy) by the Molab equipments in the frame of the MOLAB-EU ARTECH Project)

The Drilling Resistance Measurements System (DRMS, Fig.20) is a portable apparatus able to evaluate in situ the superficial "hardness" of a material. The resulting graphs shows on the X axes the depth of the drilling (mm) and on the Y axes the necessary Force (N). Picks and differences in the values of Force represent lack of homogeneity due to the possible presence of grains, gravel or voids. The system is usually used for the characterization of the cohesion profile of materials, and, as a consequence, gives information concerning the superficial state of decay and, in case of consolidating intervention, the efficiency and the depth of penetration of the treatments.

Nevertheless, it was applied also in the frame of this research in order to obtain further information concerning the characteristics and properties of the analysed material and to be able to make a comparison between different materilas.

Tests were carried out successfully on mortars from mosaic fragments in the basement of the Museum.

Other in situ drilling tests were performed on the limestones of Nagyharsány villa's walls. Although several attempts, it was not possible to carry out the tests properly: the drill bits were abraded from this kind of materials, that resulted too hard for both diamond and fischer drill bits.

Fig.20 Molab drilling tests on mortar. The driller.

X Ray Diffractions analyses (at the University of Siena)

X Ray diffraction analyses were carried out on pigments from mural paintings in

Chemical analyses (at the laboratory of Building Materials, Department of Civil Engineering, Aristotle University of Thessaloniki, Greece)

Chemical analyses were carried out on the content in oxides and granulometry test have been carried out on different kinds of mortars, belonging to different archaeological sites.

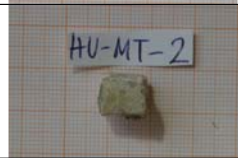
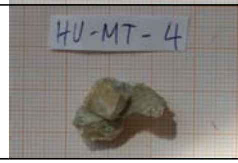
Monument	Code nr.	Sampling area	Sampling	Macro pictures	Stereoscope observations
Nagyharsány Villa	**HU1-NV**	eastern corner, E600792-N056011	two fragments of roman building mortar		Pale yellow, high percentage of aggregate: fine sand
Nagyharsány Villa	**HU2-NV**	E600806-N055987 on replaced limestone	one fragment modern building mortar		Grey, high hardness, fragnebts of stone as aggregates
Nagyharsány Villa	**HU3-NV**	E600808-N056009 wall section n.11	one fragment modern building mortar; upper part of the brick line		Grey, high hardness, fragnebts of stone as aggregates
Nagyharsány Villa	**HU4-NV**	E600808-N056009 wall section n.11	one fragment modern building mortar; upper part of the brick line		Dark grey, high hardness, fragments of stone as aggregates
Nagyharsány Villa	**HU5-NV**	E600808-N056009 wall section n.11	One fragment of building roman mortar, 50 cm below the brick line		Pale yellow, high percentage of aggregate: fine sand. Brittle.
Nagyharsány Villa	**HU6-NV**	wall section n.11	one piece of limestone with traces of roman mortar		Grey, very hard and compact

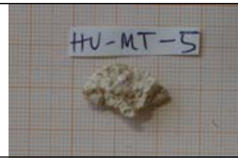
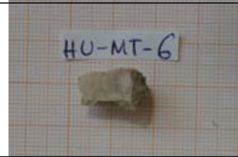
Nagyharsány Villa	**HU7-NV**	Open field, close to the villa remains	brick with roman mortar		Grey, very high porosity, traces of straw in the mortar
Nagyharsány Villa	**HU8-NV**	E600810-N056003 wall section n.19	two fragments of roman mortar, 50 cm below the brick line		Pale yellow, high percentage of aggregate: fine sand
Nagyharsány Villa	**HU9-NO**	E600883-N056054 open field	one fragment of roman brick		Red, high porosity, traces of straw
Nagyharsány Villa	**HU10a-NO HU10b-NO HU10c-NO**	E600883-N056054 open field	three fragments of limestone		Grey, very compact, fine texture
Outcrops	**HU11-NO**	top of the hill, Nagyarsany	one fragment of limestone		Pale brown, very compact, presence of fossil, Ammonite
Outcrops	**HU12-NO**	open field	Limestone from roman building stone		massive coarse texture

Nagyarsany – Szoborpark	**HU13-NQ**	main wall, left side	two fragments limestone		Dark grey, very fine texture, fractured
Nagyarsany - Szoborpark	**HU14-NQ**	main wall, central part	one fragment, limestone		Dark grey, coarse texture, fractured
Nagyarsany - Szoborpark	**HU15-NQ**	main wall, right side	one fragment, limestone		Dark grey, coarse texture
Nagyarsany - Szoborpark	**HU16-NQ**	main wall, right side, 50 cm above HU15-NQ	one fragment, limestone		Dark grey, fine texture
Beremend quarry	**HU17-NQ**,.	central part of the wall of the quarry, detonation star-structures	two fragments of Limestone		Grey, fine texture
Beremend quarry	**HU19-NQ**	right side of the quarry	four fragments of Limestone,		Dark grey, very compact and hard, presence of bivalves fossils

Csukma quarry	**HU20a-NQ**		four fragments conglomerate		Pale pink, yellowish components
Csukma quarry	**HU20b-NQ**		limestone		pale brown with pinkish-joints
Csukma quarry	**HU20c-NQ**		limestone (“Red Marble”)		Reddish, compact, hard
Csukma quarry	**HU20d-NQ**		limestone		red-violet, fractured, presence of joints
Csukma quarry	**HU21-NO**		two fragments of limestone		Pale brown, massive, fine texture
Koves màj, Siklòs	**HU22-NQ**	Right side of the wall, upper part.	one fragment of Limestone		Pale yellow, massive, hard, compact, fine texture

Koves màj, Siklòs	**HU23-NQ**	Right side, lower part	three fragments of Limestone		Pale yellow, massive, hard, compact, fine texture
Koves màj, Siklòs	**HU24-NQ**	Left side	two fragments of massive Limestone.		Pale brown, massive, hard, compact, fine texture
Csarnòta Quarry	**HU25-NQ**,		fragment of limestone		Grey, compact, fine texture
Quarry	**HU26-NO**		spatic calcite.		Coarse crystals, 0,5-1 cm
Nagyharsány Villa	**HUMP-1**	HNM Basement	Mural painting fragment		Two lime based mortar layers, presence of calcite and brick fragments, red pigment layer
Nagyharsány Villa	**HUMP-2**	HNM Basement	Mural painting fragment		Two lime based mortar layers, presence of calcite and brick fragments, dark red pigment layer

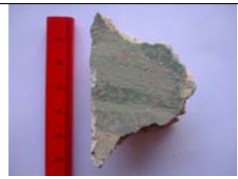
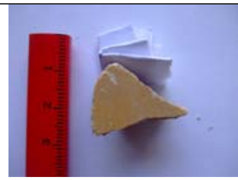
Nagyharsány Villa	**HUMP-3**	HNM Basement	Mural painting fragment		Visible one lime based mortar layer, presence of calcite and brick fragments, dark red pigment layer
Nagyharsány Villa	**HUMP-4**	HNM Basement	Mural painting fragment		Two lime based mortar layers, presence of calcite and brick fragments, olive green pigment layer
Nagyharsány Villa	**HUMT-1**	HNM Basement	Mosaic tessera		Black tessera, lime based mortar
Nagyharsány Villa	**HUMT-2**	HNM Basement	Mosaic tessera		White tessera, lime based mortar
Nagyharsány Villa	**HUMT-3**	HNM Basement	Mosaic tessera		Red tessera, lime based mortar
Nagyharsány Villa	**HUMT-4**	HNM Basement	Mosaic tessera		Yellow tessera, lime based mortar

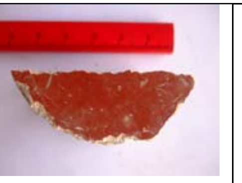
Nagyharsány Villa	**HUMT-5**	HNM Basement	Mortar fragment from mosaic (HUMT-4)		Lime based mortar, presence of calcite and brick fragments
Nagyharsány Villa	**HUMT-6**	HNM Basement	Mosaic tessera		Pale pink tessera, lime based mortar, presence of calcite and brick fragments
Nagyharsány Villa	**HUNVmec1-1 HUNVmec1-2 HUNVmec1-3**	wall section n.11	Limestone cubes: 4x4x4 cm		Compact limestone, veins.
Nagyharsány Villa	**HUNVmec2-1 HUNVmec2-2 HUNVmec2-3**	wall section n.11	Limestone cubes: 4x4x4 cm		Compact limestone, veins.
Nagyharsány Villa	**HUNVmec3-1 HUNVmec3-2 HUNVmec3-3**	wall section n.11	Limestone cubes: 4x4x4 cm		Compact limestone, veins.
Nagyharsány Villa	**HUNVmec4-1 HUNVmec4-2 HUNVmec4-3**	wall section n.19	Limestone cubes: 4x4x4 cm		Compact limestone, veins.

Nagyharsány Villa	**HUNVmec5-1 HUNVmec5-2 HUNVmec5-3**	Wall section n.19	Limestone cubes: 4x4x4 cm		Compact limestone, veins.
Aquincum	**HUAQ-1**	Thermal baths	Roman mortar		Lime based mortar, fragmented, aggregates of different sizes (0,2-3cm) of natural origin
Aquincum	**HUAQ-2**	Thermal baths	Roman mortar		Lime based mortar, aggregates of different sizes (0,2-3cm) of natural origin
Aquincum	**HUAQ-3**	Thermal baths	Roman mortar		Lime based mortar, compact, aggregates of different sizes (0,2-2,5cm) of natural origin
Nagyharsány Villa	**HUNA-1**	eastern corner	Roman mortar		Lime based mortar, compact, aggregates of different sizes (0,2-1,5cm)of natural origin

Nagyharsány Villa	**HUNA-2**	eastern corner	Roman mortar		Lime based mortar, compact, aggregates of different sizes (0,2-1,5cm) of natural origin
Nagyharsány Villa	**HUNA-3**	eastern corner	Roman mortar		Lime based mortar, compact, aggregates of different sizes (0,2-1 cm)of natural origin
Nagyharsány Villa	**HUNA-4**	eastern corner	Roman mortar		Lime based mortar, compact, aggregates of different sizes (0,2-1 cm) of natural origin
Nagyharsány Villa	**HUNA-5a**	Wall section n.11, close to the surface of the wall, inner side.	Roman mortar		Lime based mortar for mural painting support, very compact, aggregates of different sizes (0,2-0,8 cm), brick fragments
Nagyharsány Villa	**HUNA-5b**	Wall section n.11, from the core of the wall	Roman mortar		Lime based mortar, very compact, aggregates of different sizes (0,2-1 cm) of natural origin

Nagyharsány Villa	**HUNA-6**	Wall section n.19	Roman mortar		Lime based mortar, very compact, aggregates of different sizes (0,2-1,5 cm) of natural origin
Nagyharsány Villa	**HUNA-7**	Wall section n.19	Roman mortar		Lime based mortar, very compact, aggregates of different sizes (0,2-1,5 cm) of natural origin
Nagyharsány Villa	**HUNA-8**	Wall section n.19	Roman mortar with painting layer		Lime based mortar, very compact, aggregates of different sizes (0,2-0,8 cm), brick fragments
Nemesvámos-Balácapuszta Roman villa	**HUBA 1-1** **HUBA 1-2** **HUBA 1-3** **HUBA 1-4** **HUBA 1-5**	Building nr. X, northern wall	Limestone cubes, 4x4x4		Massive compact limestone
Nemesvámos-Balácapuszta Roman villa	**HUBA 2-1** **HUBA 2-2** **HUBA 2-3** **HUBA 2-4** **HUBA 2-5**	Building nr. X, northern wall	Limestone cubes, 4x4x4		Massive compact limestone

Nemesvámos-Balácapuszta Roman villa	**HUBA 3-1** **HUBA 3-2** **HUBA 3-3** **HUBA 3-4** **HUBA 3-5**	Building nr. X, northern wall	Limestone cubes, 4x4x4		Massive compact limestone
Veszprém Bakonyi Múzeum	**HUBAP-1**	Store room, Museum's basement	Mural painting fragment, two different greens and yellow pigments		Hard mortar, fine pebbles, no bricks fragments, not very smooth surface
Veszprém Bakonyi Múzeum	**HUBAP-2**	Store room, Museum's basement	Mural painting fragment, yellow pigment		Hard mortar, fine pebbles, no bricks fragments, very smooth surface, double pigment layers
Veszprém Bakonyi Múzeum	**HUBAP-3**	Store room, Museum's basement	Mural painting fragment, white pigment		Hard mortar, coarser pebbles, no bricks fragments, very rowgh surface
Veszprém Bakonyi Múzeum	**HUBAP-4**	Store room, Museum's basement	Mural painting fragment, black pigment		Hard mortar, fine pebbles, low percentage of bricks fragments, traces of straw, very smooth surface

Veszprém Bakonyi Múzeum	**HUBAP-5**	Store room, Museum's basement	Mural painting fragment, red pigment		Hard mortar, fine pebbles, low percentage of bricks fragments, traces of straw, very smooth surface
Veszprém Bakonyi Múzeum	**HUBAP-6**	Store room, Museum's basement	Mural painting fragment, pale blue pigment		Hard mortar, fine pebbles, no bricks fragments, traces of straw, not very smooth surface
Veszprém Bakonyi Múzeum	**HUBAP-7**	Store room, Museum's basement	Mural painting fragment, two different greens and white pigments		Hard mortar, fine pebbles, no bricks fragments, not very smooth surface
Veszprém Bakonyi Múzeum	**HUBAT-8**	Store room, Museum's basement	Mosaic tessera, Pale yellow		Pale yellow tessera, limestone, 1x1,5 cm
Veszprém Bakonyi Múzeum	**HUBAT-9**	Store room, Museum's basement	Mosaic tessera, Black		Black tessera, 0,8x0,8 cm

Veszprém Bakonyi Múzeum	**HUBAT-10**	Store room, Museum's basement	Mosaic tessera, Black		Black tessera, 0,8x1 cm
Veszprém Bakonyi Múzeum	**HUBAT-11**	Store room, Museum's basement	Mosaic tessera, Pale yellow		Pale yellow tessera, limestone, 1x1 cm

Legenda

HU1-NV—HU8-NV	**HU**ngarian project - **N**agyharsàny **V**illa, samples 1-8
HU9-NO—HU26-NQ	**HU**ngarian project - **N**agyharsàny **O**utcrop and **Q**uarries, samples 9-26, total 22
HUMP-1-- HUMP-4	**HU**ngarian project –**M**ural **P**aintings, samples 1-4
HUMT-1-- HUMT-6	**HU**ngarian project –**M**osaic **T**essera, samples 1-6
HUNVmec1-1—HUNVmec5-3	**HU**ngarian project - **N**agyharsàny **V**illa, samples 1-1—5-3 for investigations on physical and mechanical properties, total 15
HUAQ-1-- HUAQ-3	**HU**ngarian project – Aquincum, samples 1-3
HUNA-1-- HUNA-8	**HU**ngarian project - **N**agyharsàny **V**illa, samples 1-8, total 9
HUBA 1-1-- HUBA 3-5	**HU**ngarian project - Nemesvámos-**Ba**lácapuszta Roman villa, samples 1-1—3-5, total 15
HUBAP-1-- HUBAP-7	**HU**ngarian project - Veszprém Bakonyi Múzeum, samples 1-7
HUBAT-8-- HUBAT-11	**HU**ngarian project - Veszprém Bakonyi Múzeum, samples 8-11
Total	**93**

4. Results

Macroscopical observations on building stone

Macroscopically the limestones used as building stone by Romans appear very compact and resistant. Infact, an effort of drilling resistance test in situ failed because of the extreme hardness. In some cases they are fractured and show calcitic veins.

Microscopical observations

Petrographical and mineralogical analyses showed that limestones are different varieties of Biosparite and Oosparite. Biosparites have generally a high content of Foraminifera, belonging to two main families: the Miliolidae and Textulariidae (Fig.22-23). The structure is almost always lumpy, including micritic regions, micritic interstices, sparite and presence of Calcite with high content of Magnesium and evidences of dolomitization processes (Fig.25). Foraminifera in agglutinating forms and Miliolidi have different sizes, according to the variability of the depositional environment. Intraclastic elements have been found as well.

Oosparites show micritic lumps and sparitic regions in the interstices (Fig, 24). Dolomitization processes are not infrequent. Stilolitic texture and calcitic veins are present and can be dominant in some cases, especially in limestones with macro-fractures. Oolites can vary a lot in terms of dimensions. In some case they have a homogeneous distribution (75-100 μm), while, in some other, their size shows a large variation into the same specimen (35-150 μm).

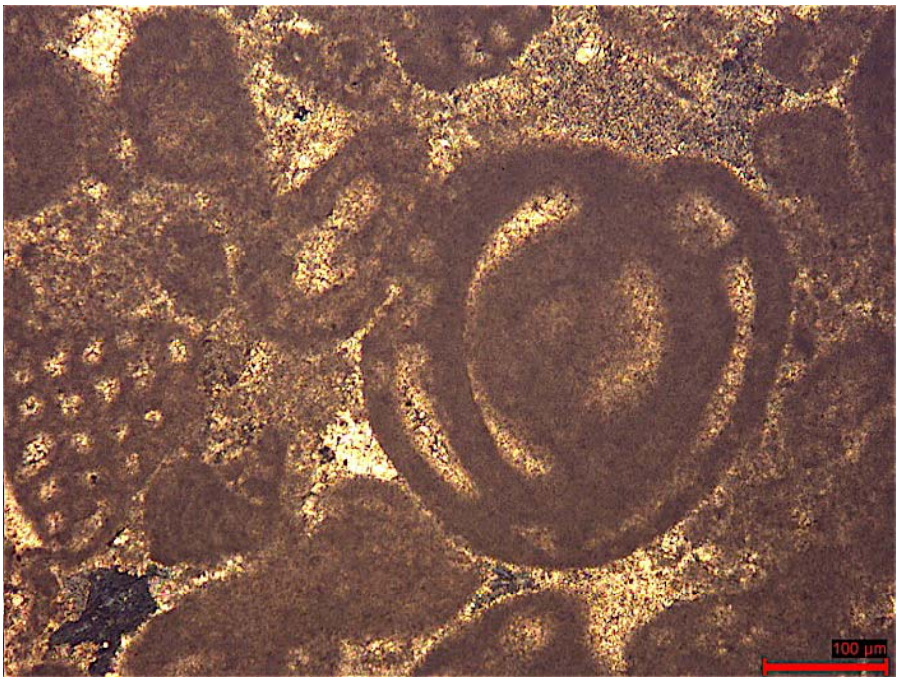


Fig.22 Detail of sample HUNVMEC4-3: Nagyharsány villa's walls. Biosparite with a big Miliolidae.

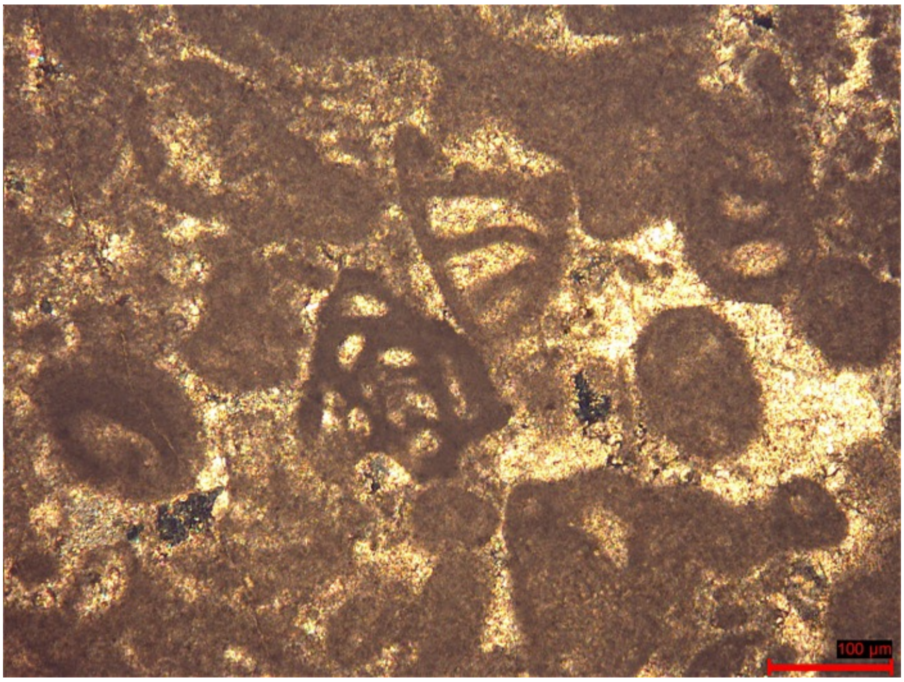


Fig.23 Detail of sample HUNVMEC4-1: Nagyharsány villa's walls. Biosparite with micritic lumps and sparite in the interstices.

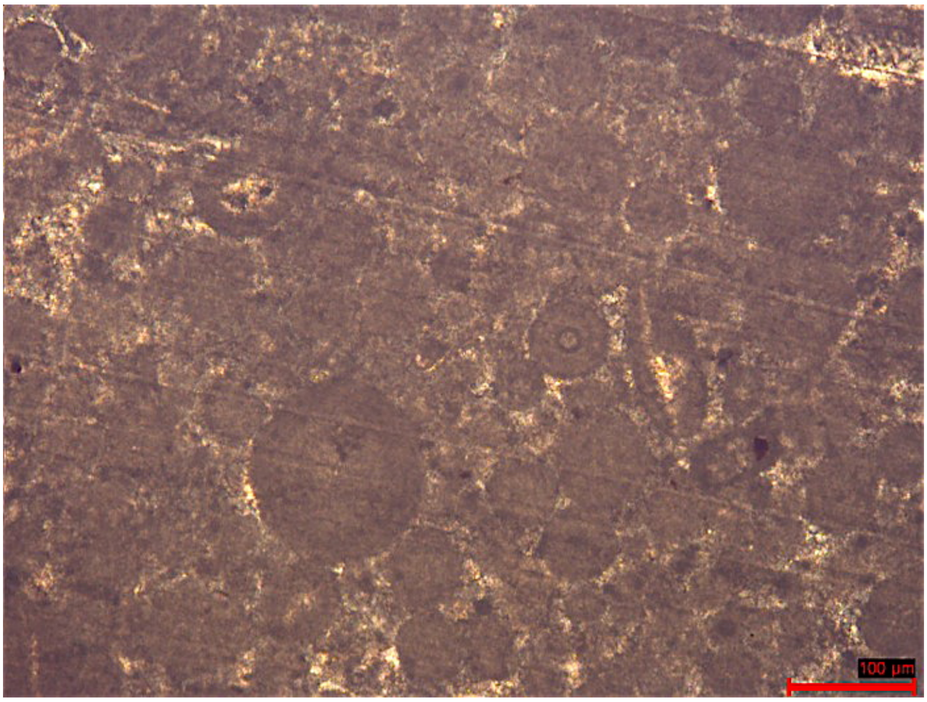


Fig.24 Detail of sample HU10cNO: Nagyharsány villa's walls. Oosparite. Sparitic regions are well visible in the interstices, oolits have different sizes.

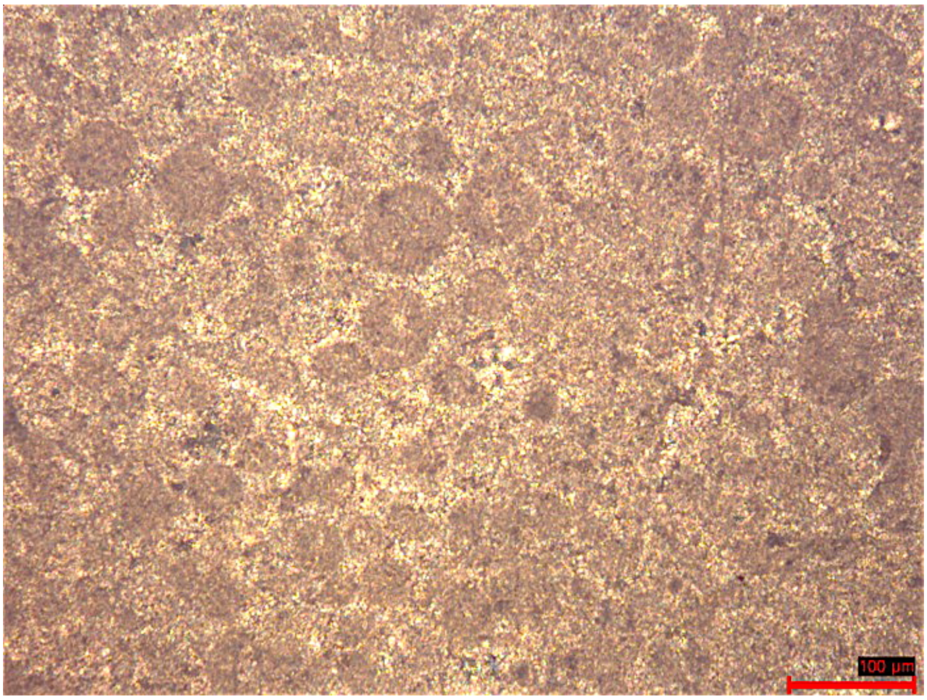


Fig.25 Detail of sample HU10aNO: Nagyharsány villa's walls. Oosparite. Effects of dolomitization processes are visible in the darker spots.

Among all samples collected from the quarries in the area surrounding Nagyharsány, special attention was paid to four main lithotypes: Csukma Dolomite, Villány Limestone, Szársomlyó Limestone and Nagyharsány Limestone. These are Formations started to be deposited from the Middle Triassic, as a coastal-terrestrial sedimentation, further evolving in a carbonate platform during the Middle and Upper Cretaceous.

Csukma Formation consists of a thick-bedded dolomite and limestones, alternate with marly dolomite (Fig.26-27). The different members testify a transition from deep marine deposits to lagoonal facies (Haas, J. 2001). Some members are ooidic, crinoidal or gastropodal oncoidal limestones, developing towards the top of the Formation into dolomite.

Villány Limestone Formation (Fig.28) was formed in a deep marine environment to a shallow one; it consists of a grey, yellow or dark red bioclastic limestone, characterized in the lower part by the presence of iron ooids and pisoids and in the upper level by stromatolite masses and by big oncoids. Rare presence of mega-fossils was also observed (Haas, J. 2001).

Pelagic fauna is predominant in the lowest level, while shallow marine fauna takes place in the upper one.

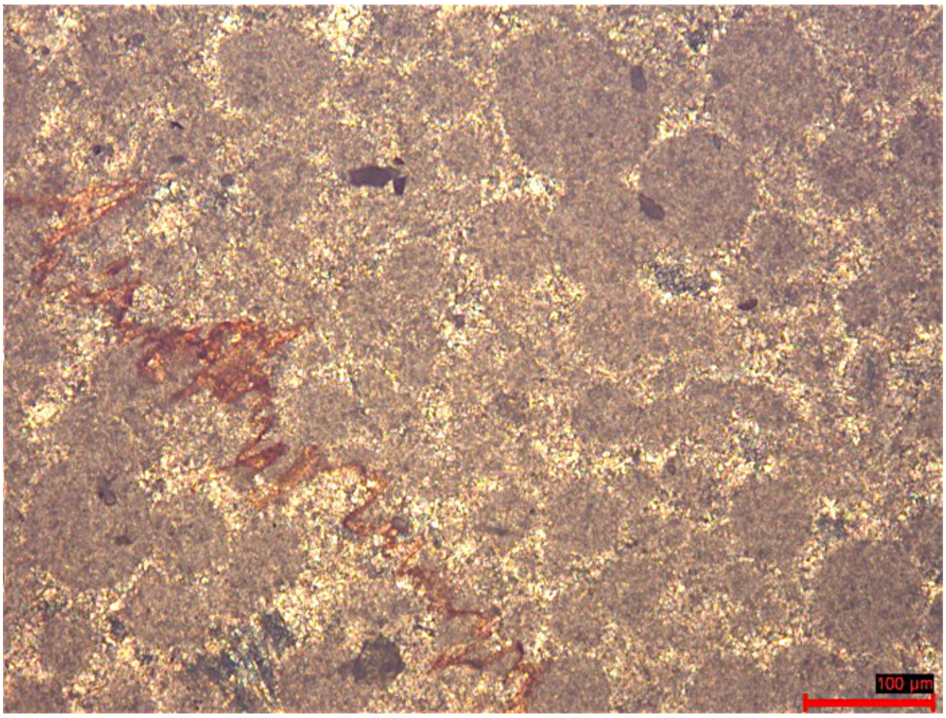


Fig.26 Csukma Formation. Detail of sample HU20aNQ: Csukma Quarry. Oosparite characterized by the presence of a strong presence of stilolitic structures.

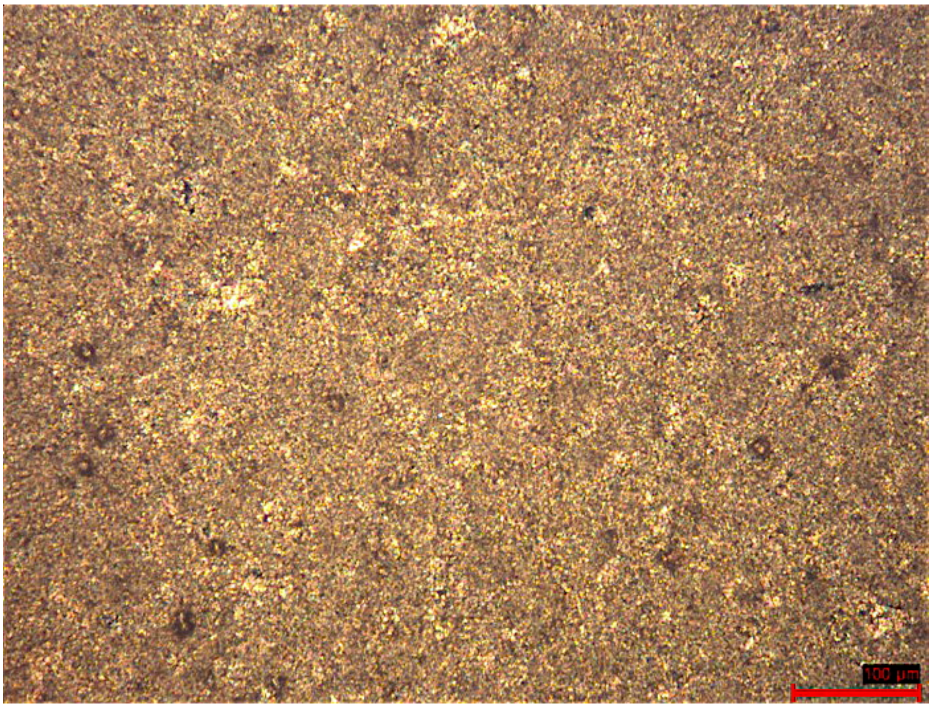


Fig.27 Csukma Formation. Detail of sample HU20bNQ: Csukma Quarry. Dolomitic Oosparite.

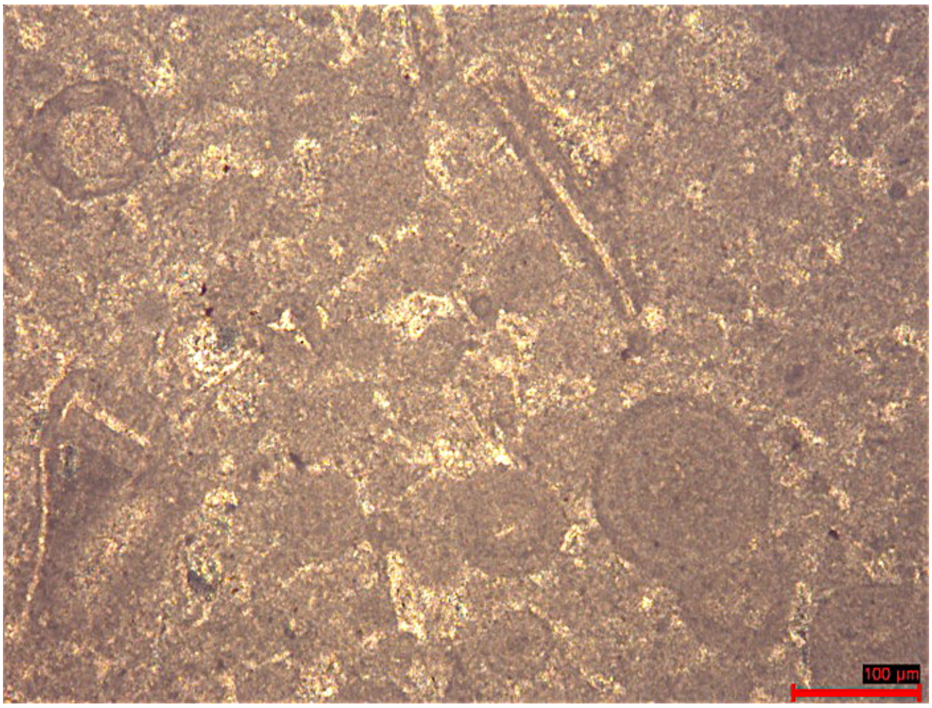


Fig.28 Villány Limestone Formation. Detail of sample HU12NO: Oosparite with bivalves fragements.

Szársomlyó Limestone Formation (Fig.29-30) is formed in a shallow marine environment a whitish or light grey thick-bedded limestone, characterized by peloidal, oolitic-oncoidal micritic texture, but it can include also bioclastic reddish limestone levels. It belongs to the Upper Jurassic. (Haas, 2001).

Nagyharsány Limestone Formation (Fig. 31-32-33) consists of massive, thick-bedded light grey limestone, resulted of a carbonate platform development in the Early-Middle Cretaceous. Its facies vary from supratidal to lagoon environment (Cászár, et al. 1993; Cászár, et al.1995), containing also black limestone breccia. Among fossils, Rudists and Foraminiferi are present.

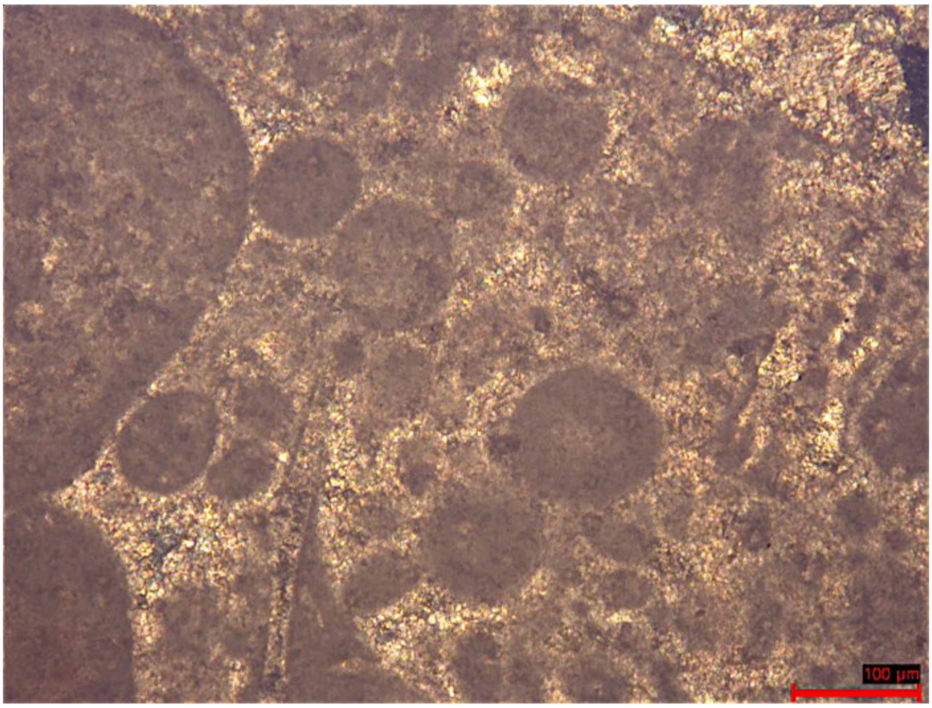


Fig.29 Szársomlyó Limestone Formation. Siklós. Detail of sample HU11NQ: micritic structures with ooids and interstitial sparite.

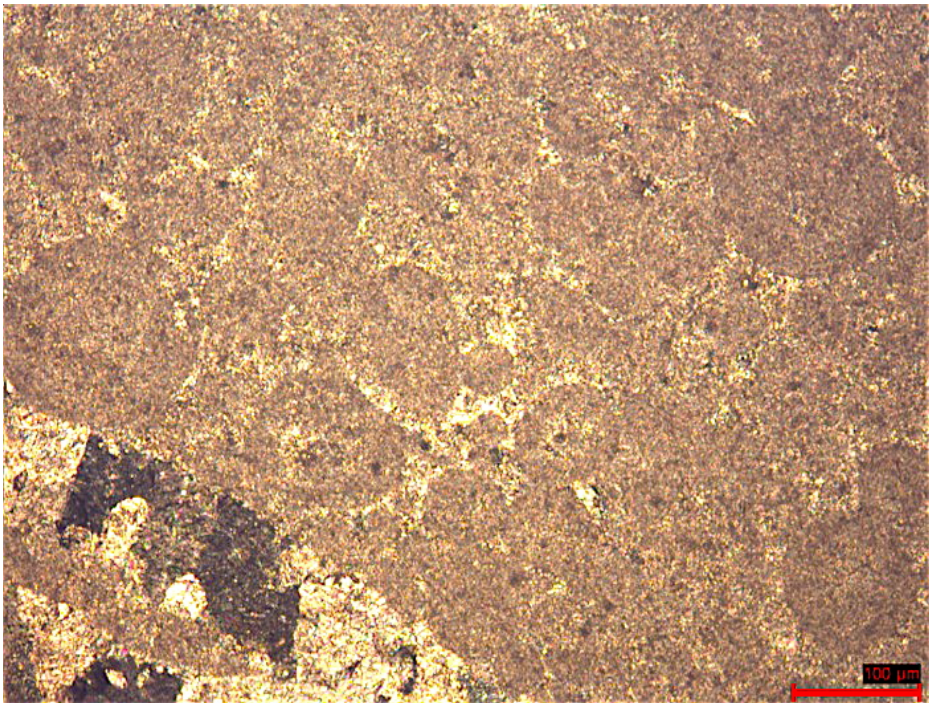


Fig.30 Szársomlyó Limestone Formation. Siklós. Detail of sample HU23NQ: ooids and interstitial sparite.

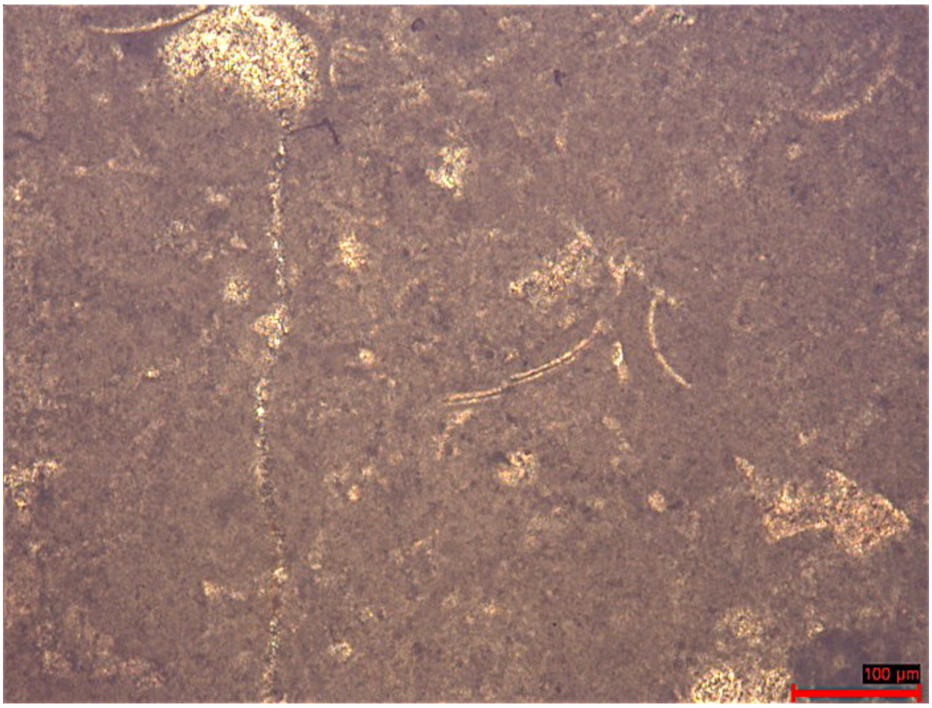


Fig.31 Nagyharsány Limestone Formation. Detail of sample HU14NQ: bivalves fragment in a biomicritic region

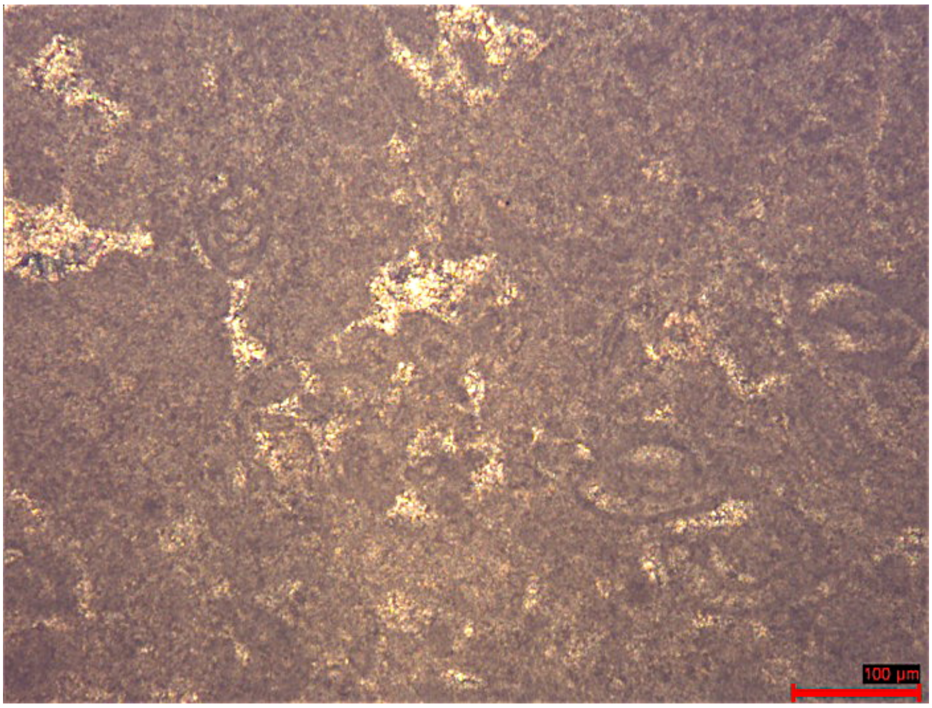


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Fig.32 Nagyharsány Limestone Formation. Detail of sample HU17NQ: Beremend Quarry. Biomicrite with interstitial sparite

Fig.33 Nagyharsány Limestone Formation. Detail of sample HU19NQ: Beremend Quarry. Biosparite with detail of big bivalve.

Physical and mechanical analyses

Chart 1 shows the summary of the analyses performed. For the sake of clarity, results on limestone from Nemesvámos-Balácapuszta Roman villa (HUBA 1-1/HUBA 3-3) are also included in this chart.

Chart 1. Summary of the performed analyses.

Code nr	Sample shape	Porosity	Hg Absorption	Compressive strengh	Ultrasound
HUNV mec 1-1	Cubic	X		X	X
HUNV mec 1-2	Cubic	X		X	X
HUNV mec 1-3	Cubic				X

HUNV mec 2-1	Cubic	X			X
HUNV mec 2-2	Cubic	X			X
HUNV mec 3-1	Cubic	X		X	X
HUNV mec 3-2	Cubic	X		X	X
HUNV mec 3-3	Cubic				X
HUNV mec 4-1	Cubic	X		X	X
HUNV mec 4-2	Cubic	X		X	X
HUNV mec 4-3	Cubic				X
HUNV mec 5-1	Cubic	X			X
HUNV mec 5-2	Cubic	X			X
HUBA 1-1	Cubic	X			X
HUBA 1-2	Cubic	X		X	X
HUBA 1-3	Cubic	X		X	X
HUBA 2-1	Cubic	X			X
HUBA 2-2	Cubic	X		X	X

HUBA 2-3	Cubic	X		X	X
HUBA 3-1	Cubic	X			X
HUBA 3-2	Cubic	X		X	X
HUBA 3-3	Cubic	X		X	X
HU13NQ	Cubic		X		
HU14NQ	Cubic		X		
HU23NQ	Cubic		X		
HU20bNQ	Cubic		X		

sample	a(cm)	b(cm)	c(cm)	A(cm2)	V(cm3)	m(g)	ρ(kg/m3)	US t (μs-1)	USV(km/s)	Av.USV (km/s)	Ed (GPa)	Av.Ed (GPa)	F (kN)	R (MPa)	Av.R (MPa)
HUNV mec 1-1	4,015	4,037	4,070	16,209	65,969	178,020	2698,548	68	5,99		89		117,8	73	
HUNV mec 1-2	4,123	4,068	4,117	16,772	69,052	187,510	2715,497	71	5,80		84		252,4	150	
HUNV mec 1-3	4,08	4,112	4,037	16,777	67,729	183,02	2702,212	68	5,94	5,91	88	87	171,3	102	108
HUNV mec 2-1	4,196	4,267	4,107	17,904	73,533	169,17	2300,597	75	5,48		64				
HUNV mec 2-2	4,201	4,253	4,084	17,867	72,968	183,52	2515,067	69	5,92	5,70	81	73			
HUNV mec 3-1	4,103	4,203	4,031	17,245	69,514	180,98	2603,496	67	6,02		87		158,9	92	
HUNV mec 3-2	4,067	4,134	4,247	16,813	71,405	187,52	2626,157	75	5,66		78		140,2	83	
HUNV mec 3-3	4,017	4,081	4,233	16,393	69,393	185,91	2679,082	68	6,23	5,97	96	87	147,3	90	88
HUNV mec 4-1	4,088	4,055	4,017	16,577	66,589	177,06	2658,991	71	5,66		79		78,6	47	
HUNV mec 4-2	4,09	4,01	4,066	16,401	66,686	171,15	2566,503	67	6,07		87		61	37	
HUNV mec 4-3	4,022	4,123	4,098	16,583	67,956	176,17	2592,415	70	5,85	5,86	82	83	67,3	41	42
HUNV mec 5-1	3,929	4,129	4,033	16,223	65,427	171,46	2620,642	76	5,31	5,70	68	80			

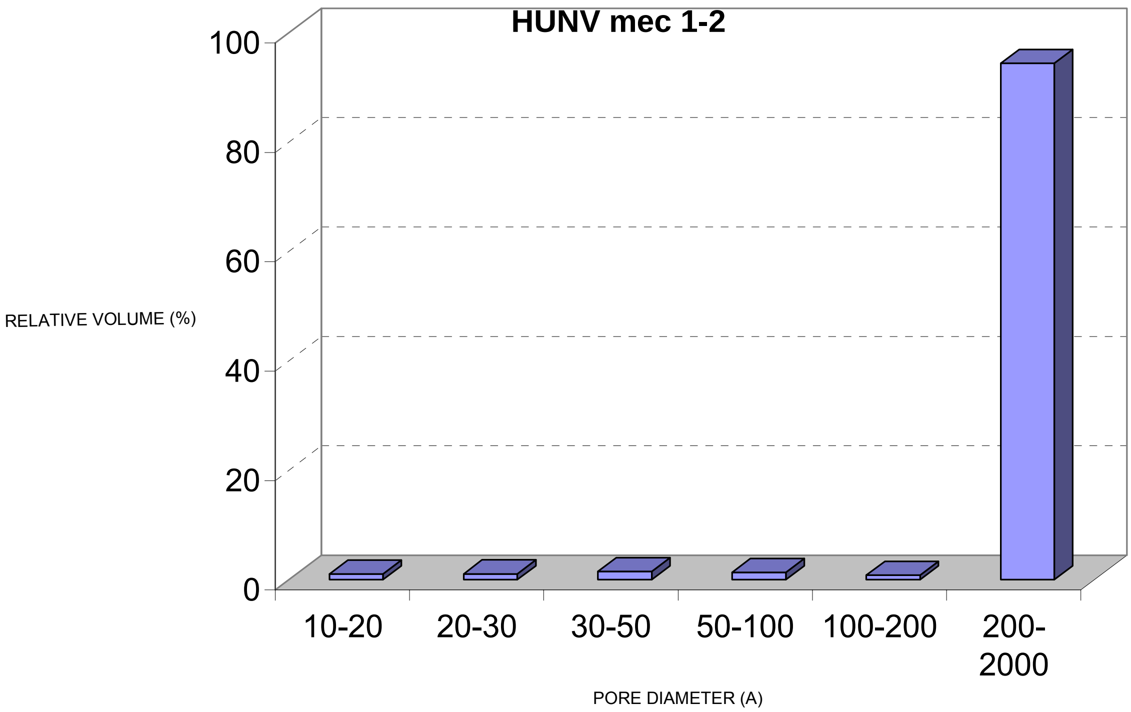
HUNV mec 5-2	3,991	3,984	4,016	15,900	63,855	169,96	2661,656	66	6,08		91				
HUBA 1-1	4,152	3,976	3,974	16,508	65,604	165,83	2527,735	73	5,44		69		171,3	104	
HUBA 1-2	4,008	4,075	3,899	16,333	63,681	173,53	2724,997	67	5,82		85		232,6	142	
HUBA 1-3	3,991	3,89	4,113	15,525	63,854	173,33	2714,462	73	5,63	5,63	80	78	136,5	88	111
HUBA 2-1	4,01	4,298	4,03	17,235	69,457	184,94	2662,656	83	4,86		58		163,5	95	
HUBA 2-2	4,201	4,203	4,18	17,657	73,805	195,07	2643,030	86	4,86		58		163,3	92	
HUBA 2-3	4,146	4,158	4,121	17,239	71,042	183,3	2580,157	83	4,97	4,89	59	58	164,1	95	94
HUBA 3-1	4,087	4,195	3,889	17,145	66,677	174,88	2622,803	76	5,12		63		71,3	42	
HUBA 3-2	4,154	4,233	4,067	17,584	71,514	181,64	2539,935	66	6,16		89		42,8	24	
HUBA 3-3	4,024	3,942	4,111	15,863	65,211	166,12	2547,416	60	6,85	6,04	111	88	90,3	57	41

Chart 2. Summary of the results from physical and mechanical analyses.

All average values were calculated on the base of the values of three cubes of the same sample. In the case of limestone collected from the villa's walls in Nagyharsány, average values of Dynamic Modulus of Elasticity (Ed) stay between 73 and 91 GPa, which are higher then the one belonging to the limestone sampled from the Roman villa in Nemesvámos-Balácapuszta (between 58 and 88 GPa). Density values are generally higher then 2500 kg/m3 in both cases. Ultrasound velocity average values vary between 5,31 and 6,08 km/s in Nagyharsány while in Nemesvámos-Balácapuszta the variation is larger (4,86-6,85 km/s). Compressive strength tests show values between 150 and 37 MPa, which are higher then the one in Nemesvámos-Balácapuszta (142 - 24MPa). (EN 1936).

Chart 3 shows that the size distribution of the material is unimodal and corresponds to a pore diameter value of 200-2000 A.

Chart 3. Porosimetry tests on building stone samples (HUNVmec1-1)



Cahrt 4. shows that pores of different sizes are present in the material, with a prevalence of the ones with diameter’s value of 200-2000 A.

Chart 4. Porosimetry tests on building stone samples (HUNVmec3-1)

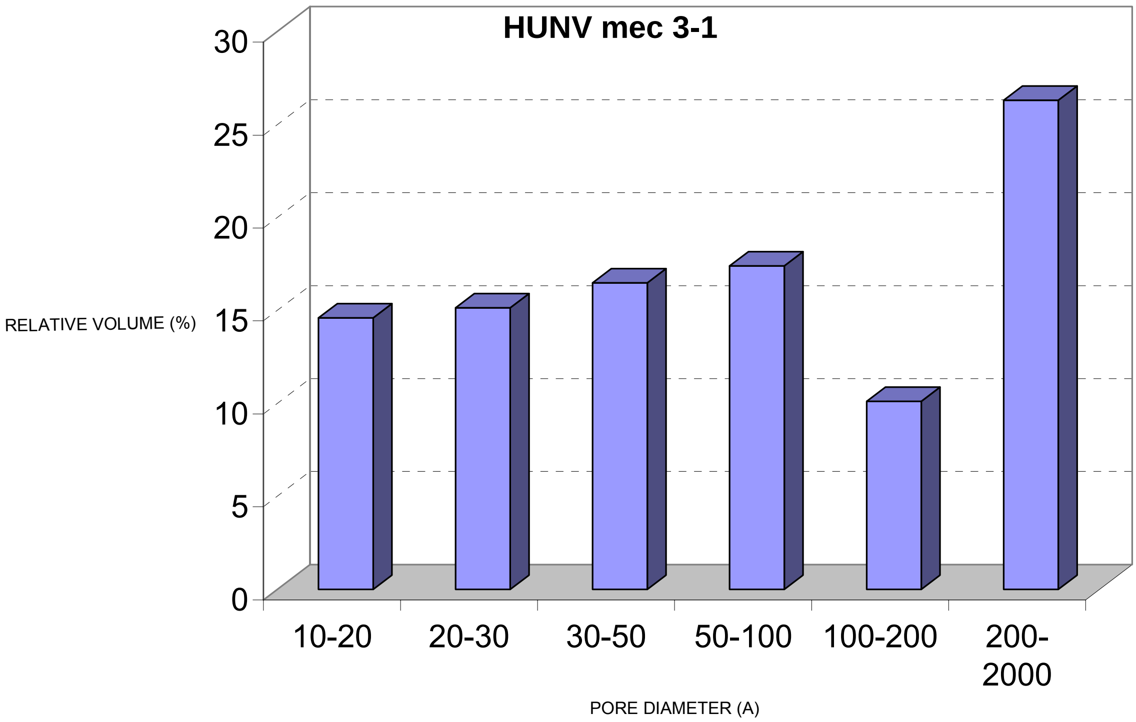


Chart 5 shows that pores of different sizes are present in the material, with no particular prevalence of certain diameter.

Chart 5. Porosimetry tests on building stone samples HUNVmec3-2

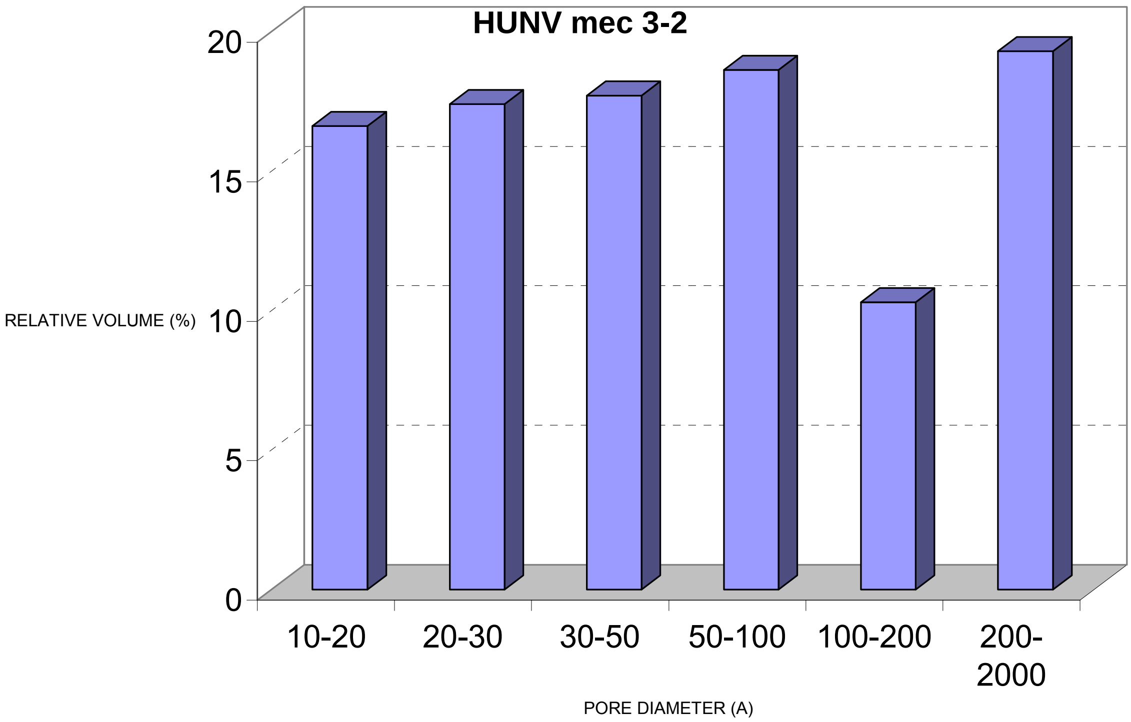


Chart 6 shows that pores of different sizes are present in the material, with no particular prevalence of certain diameter.

Chart 6. Porosimetry tests on building stone samples HUNVmec4-1

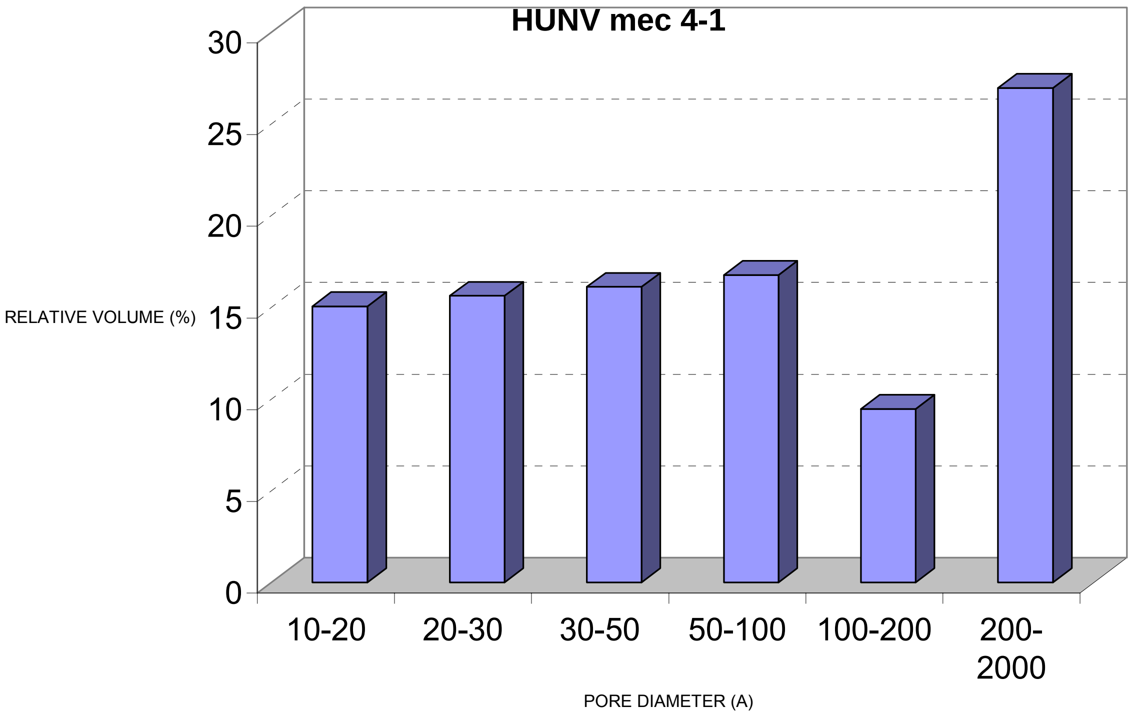
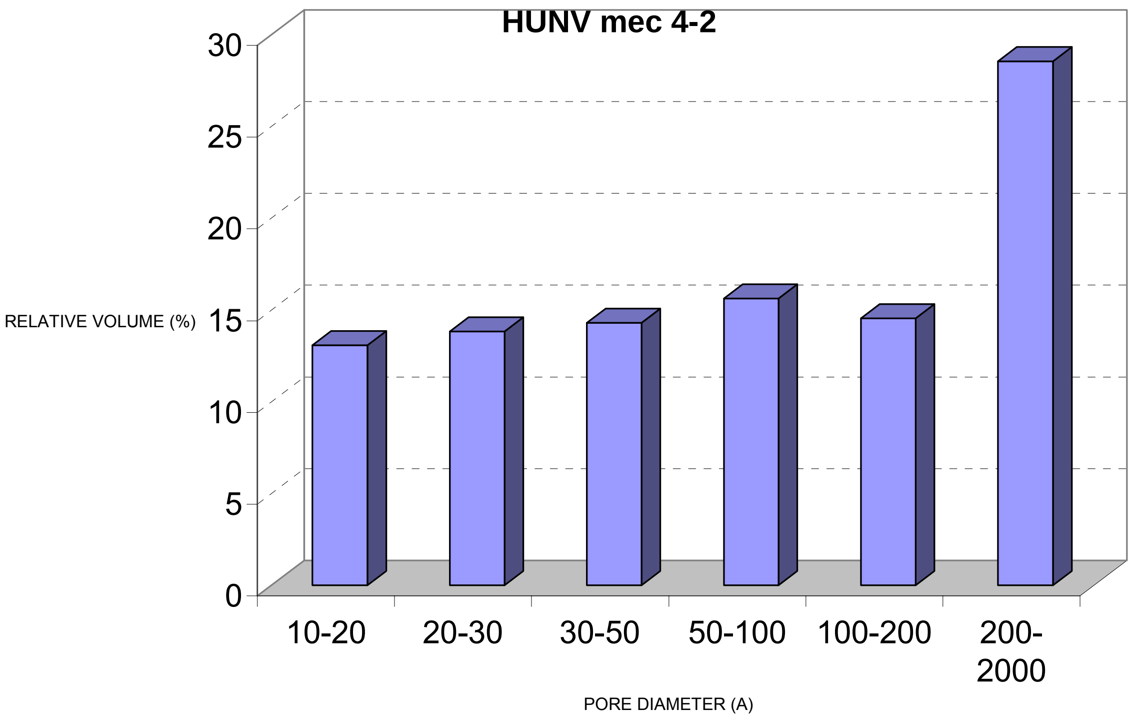


Chart 7 shows that pores of different sizes are present in the material, with no particular prevalence of certain diameter.

Chart 7. Porosimetry tests on building stone samples HUNVmec4-2



Mortars

Petrographical observations

Both structural and decorative mortars were included in the study. Petrographical observations were carried out only on samples from Nagyharsány villa, while granulometry tests and chemical analyses were performed also on samples of structural mortar from Aquincum (HUAQ1 and HUAQ2).

In some cases the quantity of material didn't allow a proper performing of the tests.

Structural mortars are lime-based, resulting from a mixing of slaked lime and sand (approximately in a 1:2 ratio). They appear pale yellow or whitish in colour and quite resistant where well preserved, and brittle where the weathering effects most occurred. There is a substantial presence of straw remnants, which is not surprising since it is known to were usually added to the mixtures in order to improve their properties (Fig.34). (Saturno et al., 2001)

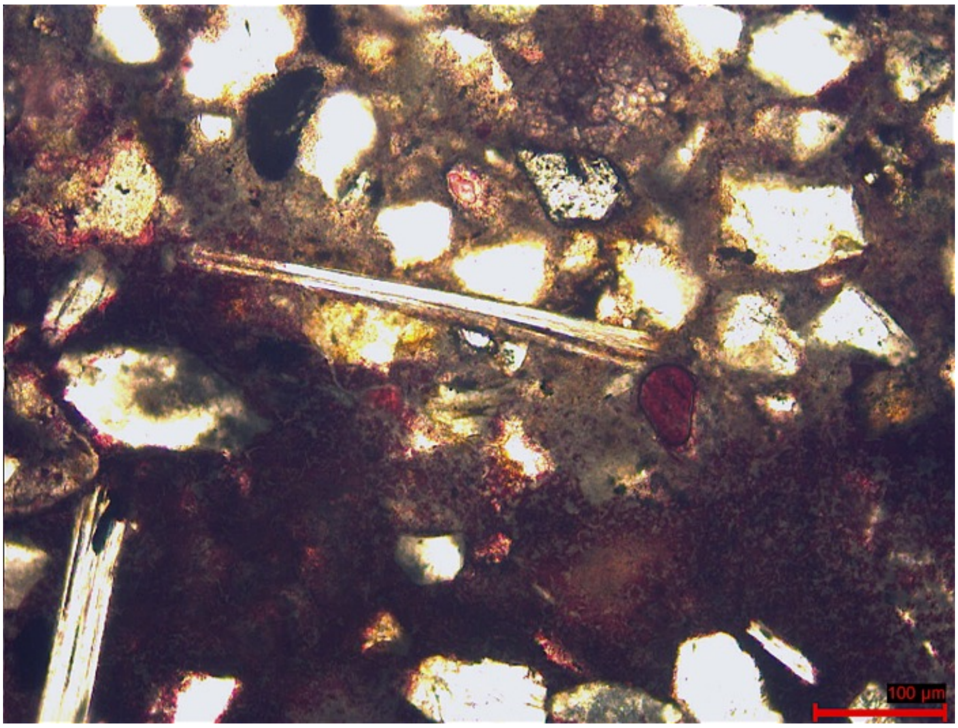


Fig.34 Detail of sample HUNV1, Nagyharsány villa. Remnants of straw in structural mortar.

Grains and aggregates resulted to be rounded and sub-rounded, and quite homogeneous in the granulometrical distribution. Main components are Quartz and Feldspaths, for the most part Plagioclase, recognizable by their polysynthetic twinning (Fig.35-38).

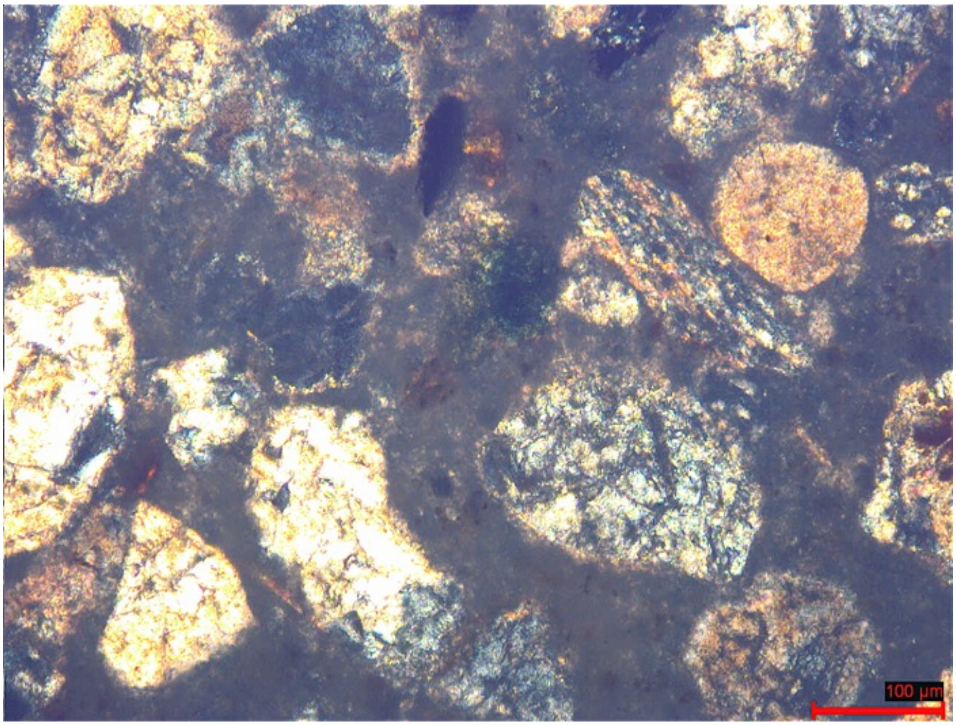


Fig.35 Detail of sample HUNV3, Nagyharsány villa. Quartz crystals, crossed N.

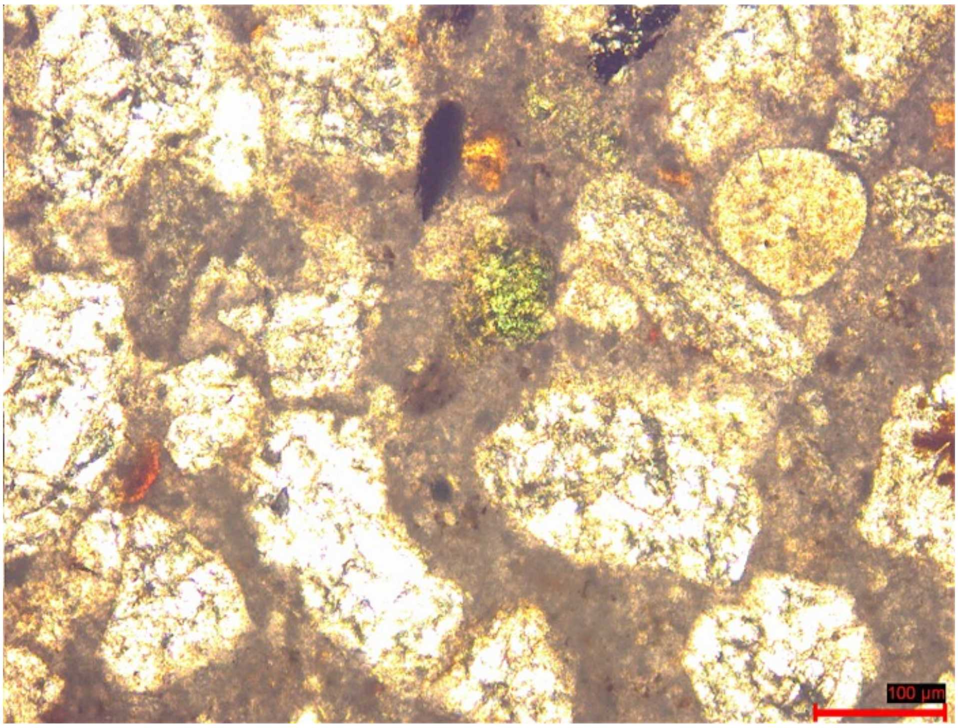


Fig.36 Detail of sample HUNV3, Nagyharsány villa. One N.

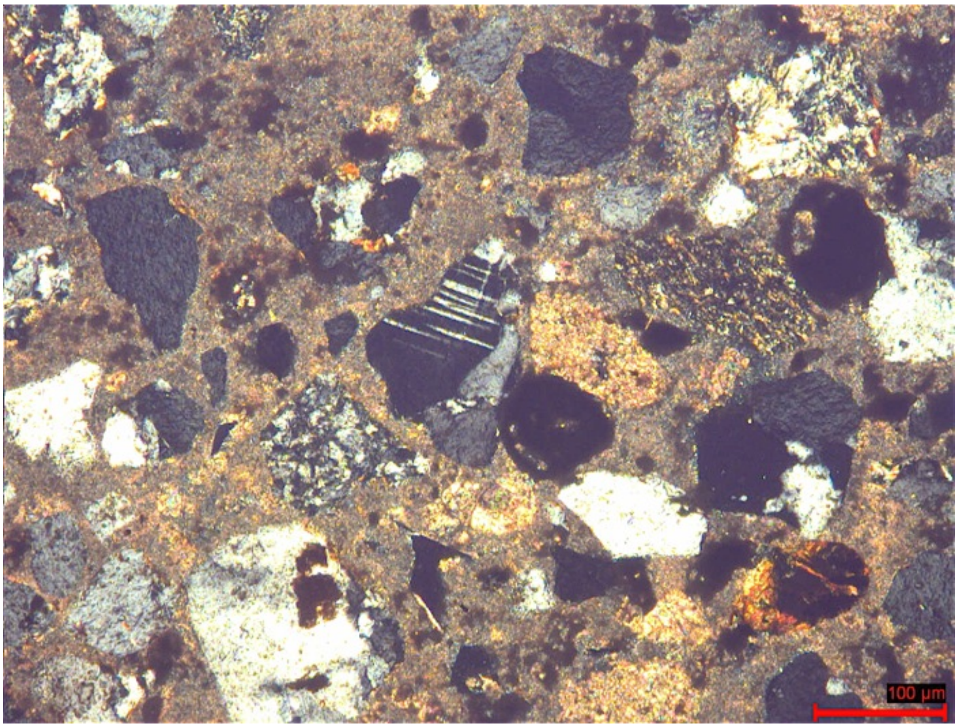


Fig.37 Detail of sample HUNV5, Nagyharsány villa. Quartz-arenite grains, Quartz and Plagioclase crystals, crossed N.

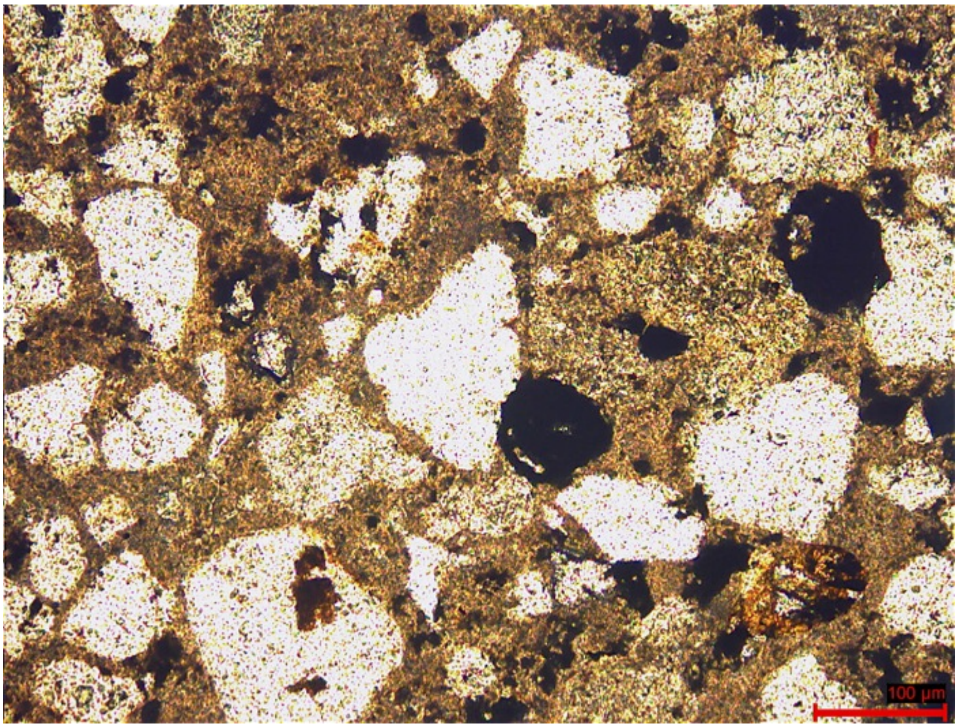


Fig.38 Detail of sample HUNV5, Nagyharsány villa. One N.

The calcitic matrix doesn't appear homogeneous as expected, it looks instead affected by a strong silicatic presence, probably connected to silicatization processes due to the existence of pozzolanic compounds or silicic material like sand diatomea.

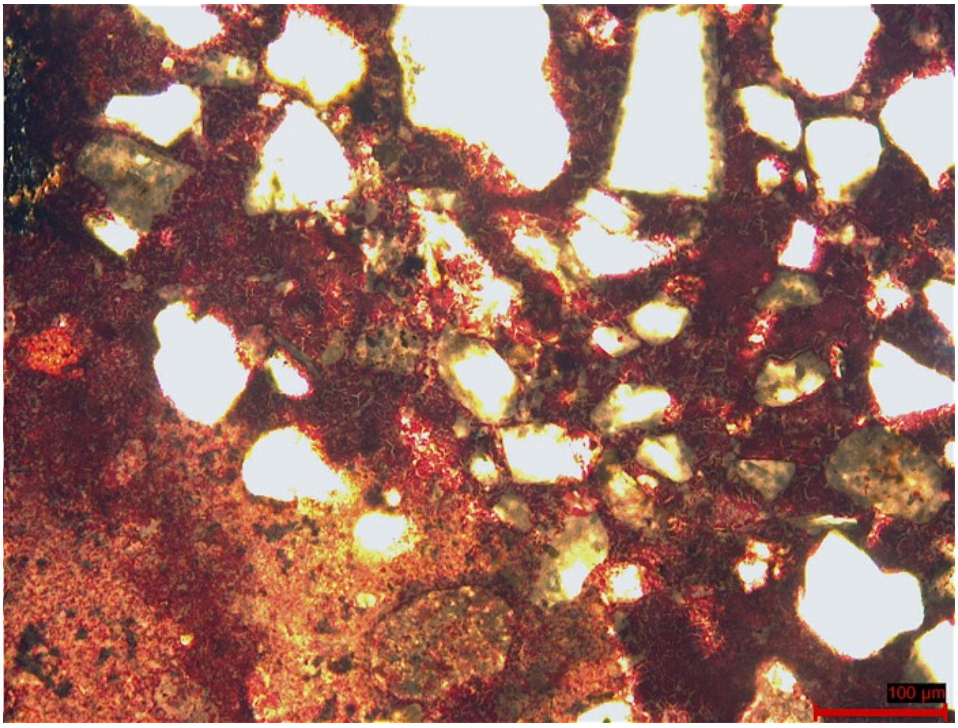


Fig.39 Detail of sample HUNV1 after the Alizarin red treatment. One N.

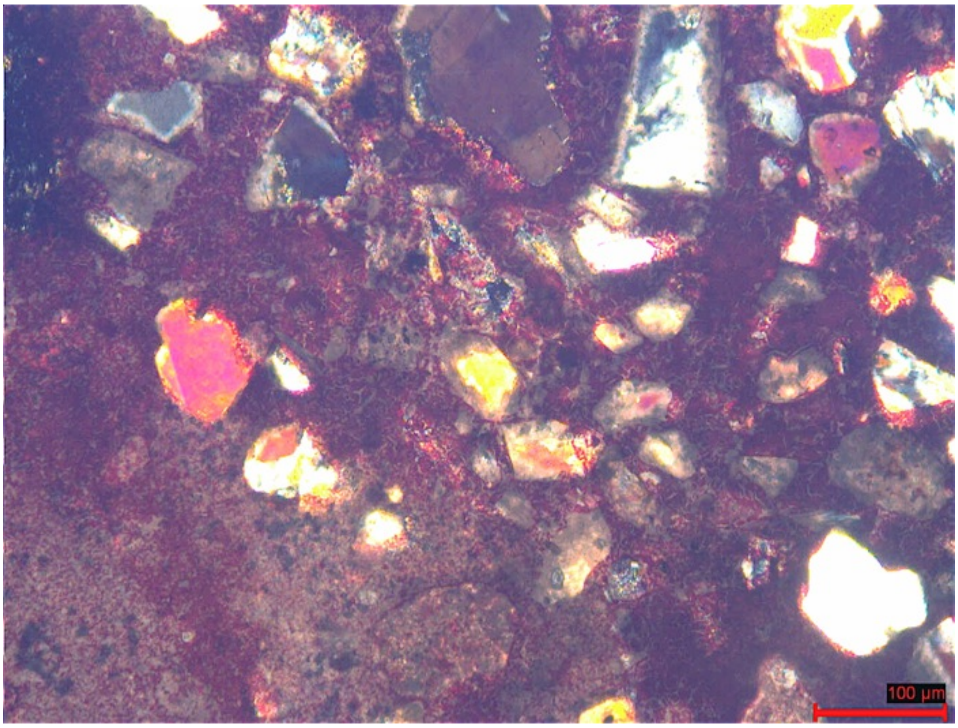


Fig.40 Detail of sample HUNV1 after the Alizarin red treatment. Crossed N.

The Alizarin red treatment could not indicate any univocal evidence of silicatic compounds (Fig.39-40).

It was suggested that evidence of pozzolanic compounds in a mortar would be given by the presence of particular crystals with incomplete filling in of the faces, called "skeleton crystals" (Prof. Gratziu, University of Pisa, personal communication).

For this reason, mortars from the Basilica of San Piero a Grado in Pisa (Italy) and from the Basilica of San Crisogono in Rome (Italy), where pozzolanic presence was already established, were taken into consideration in order to make a comparison with the one collected in Nagyharsány.

The first basilica was erected in the XI century but it includes, in the inner part, some traces of early Christian cult sites (IV century). The second is one of the most ancient church in Rome, built during the IV century. The analyses by polarizing microscope showed the presence of "skeleton crystals", well recognizable for their typical shape (Fig.41-45).

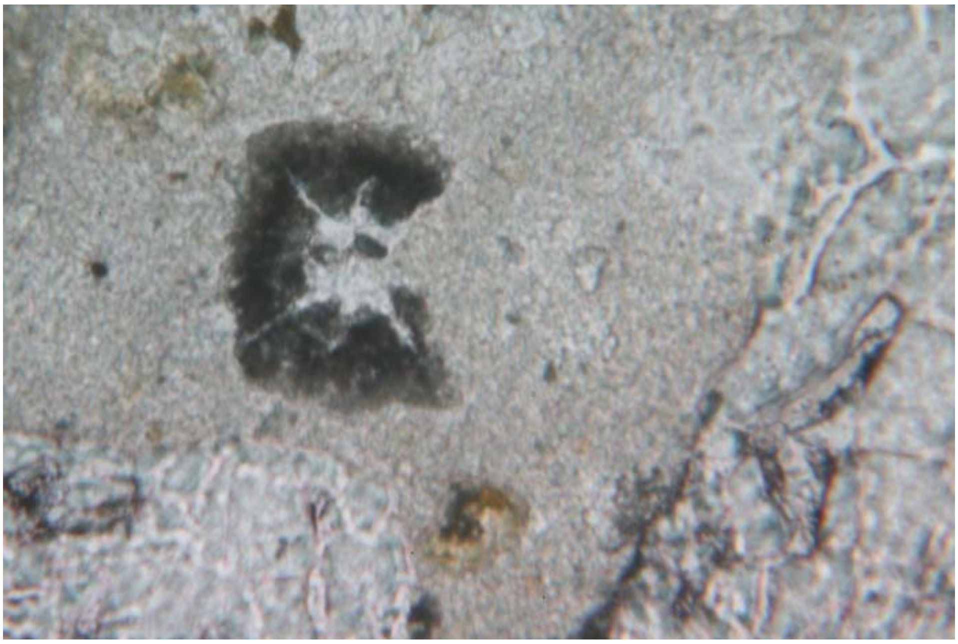


Fig.41 Detail of a pozzolanic nucleous with the typical star structure of the skeleton crystal in a modern mortar from the restoring intervention (1960) on the walls of the Basilica of San Piero a Grado (magnification 10x, one N).

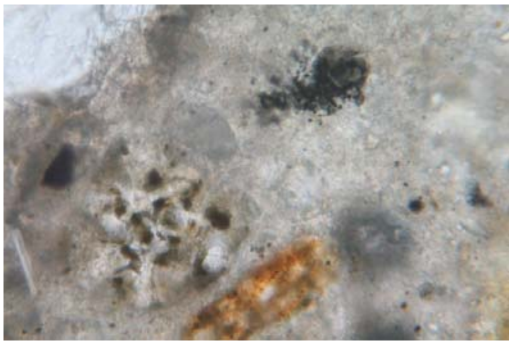
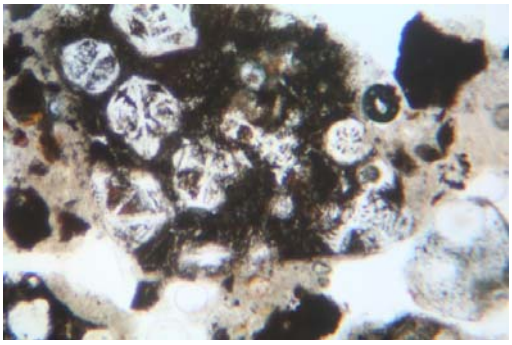


Fig.42-43 From the same mortar, on the right side picture it is visible a pozzolanic nucleous (magnification 10x, one N). On the left side picture it is visible a grain of Portland cement in bottom left and a dark pozzolanic nucleous at the top right (magnification 25x, one N).



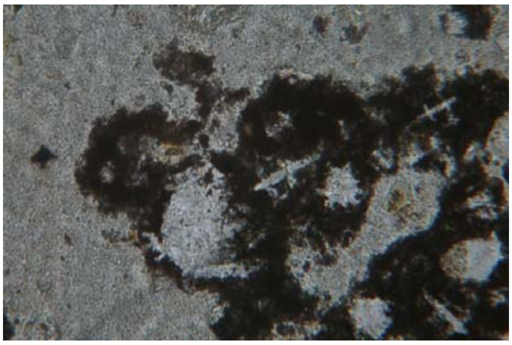


Fig.44 a) and b)Further examples of pozzolanic crystals and relicts from the same mortar (magnification 10x, one N).

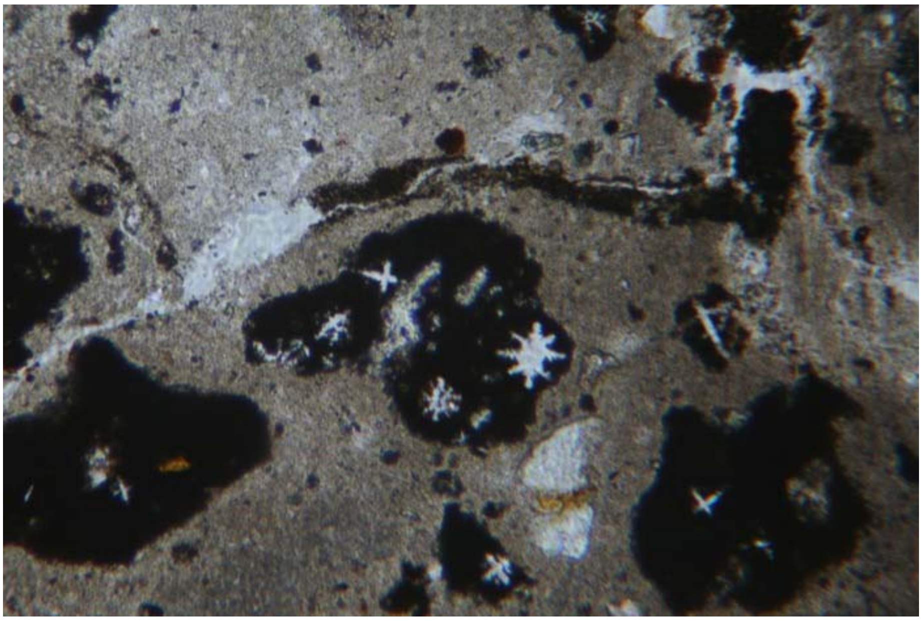


Fig.45 Pozzolanic crystals from the mortar from the Basilica of San Crisogono (magnification 10x, one N).

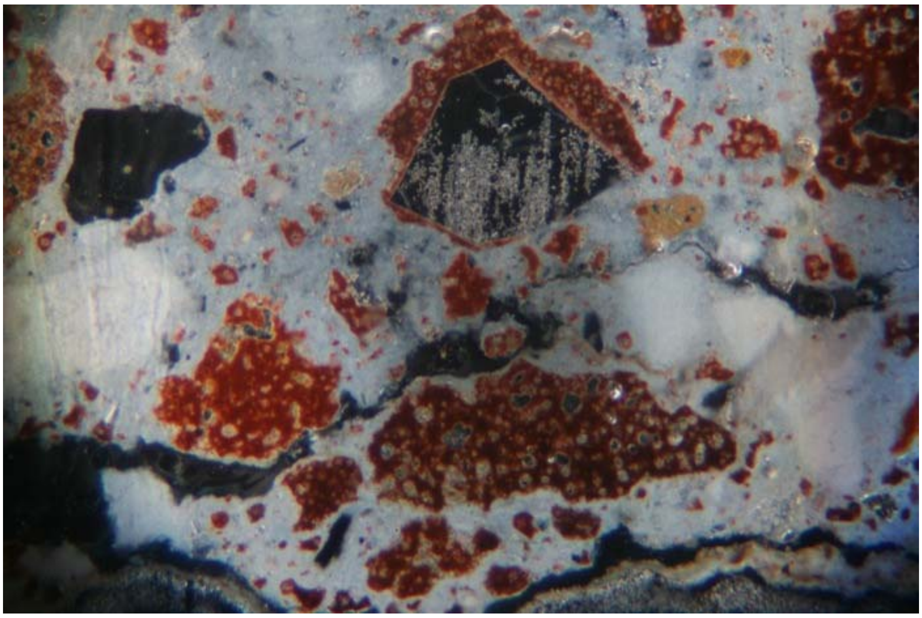
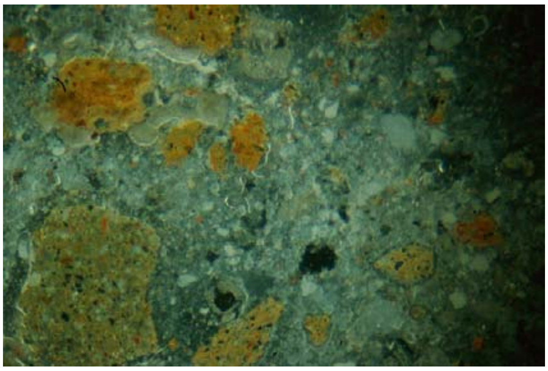


Fig.46 Detail of mortar from the Basilica of San Crisogono. Feldspath crystal surrounded by red pozzolan (magnification 2,5x, lightened from the top).

Unfortunately, neither "skeleton crystals" nor other petrographical evidences of pozzolanic components were found in the mortars from Nagyharsány villa. Therefore, although the presence of silicatic material is certain, it cannot be connected and explained in terms of pozzolanic reactions.
Mortars used as support for decorative elements, sampled from the basement of the Museum, are quite different from the structural.
Mortars for mosaics support are compact and quite hard, usually composed by two layers (Fig. 47-49). In the first layer, 3,5- 4 cm thick, big pebbles are present in a lime-based mortar, grey in colour for the presence of impurities. The main difference with the structural one is the presence of a large amount of big brick fragments.

Fig.47 The back side of a mosaic fragment from Nagyharsány during the sampling in the Museum's basement. Pebbles and brick fragments maximum size is 2 cm.



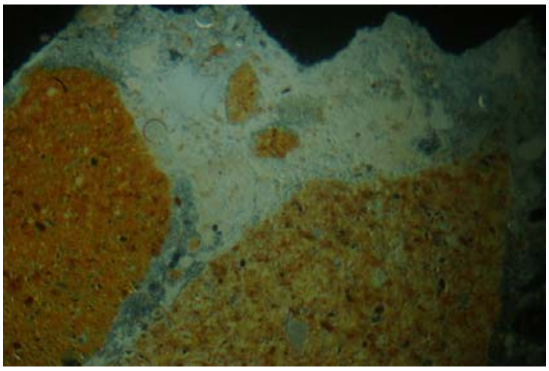


Fig.48-49 Detail of sample HUMT5. Mortars with brick fragments (magnification 2,5x and 5x, one N, lightened from the top)

The second layer, 2 cm thick, is composed by a finer mortar, whitish in colour, characterized by the presence of pebbles and brick fragments with a size distribution between 200 µm and 0,5 cm. Drilling tests were performed on several different mortar from mosaic fragments (Fig.50-51). The tests took in account four fragments of geometrical mosaics and six fragments of figurative pattern mosaics. For each samples, three different holes were drilled and the average calculated accordingly.

Fig.50-51 Two moments of the drilling test.

Charts 8-11 refer to the drilling tests performed on mortars from mosaic with geometrical patterns. Although maximum values are rather different, varying from 80 N to 15 N, average curves show a rather homogeneous patterns and quite stable in the range 5 and 10 N.
The subsequent six charts (charts 12-17) refer to drilling tests performed on mortars from mosaic with figurative patterns. Maximum values vary from 90 to 12 N and the patterns show less homogeneous trends.

Chart 8. Drilling resistance profile of mosaic fragment number 1 with geometrical patterns.

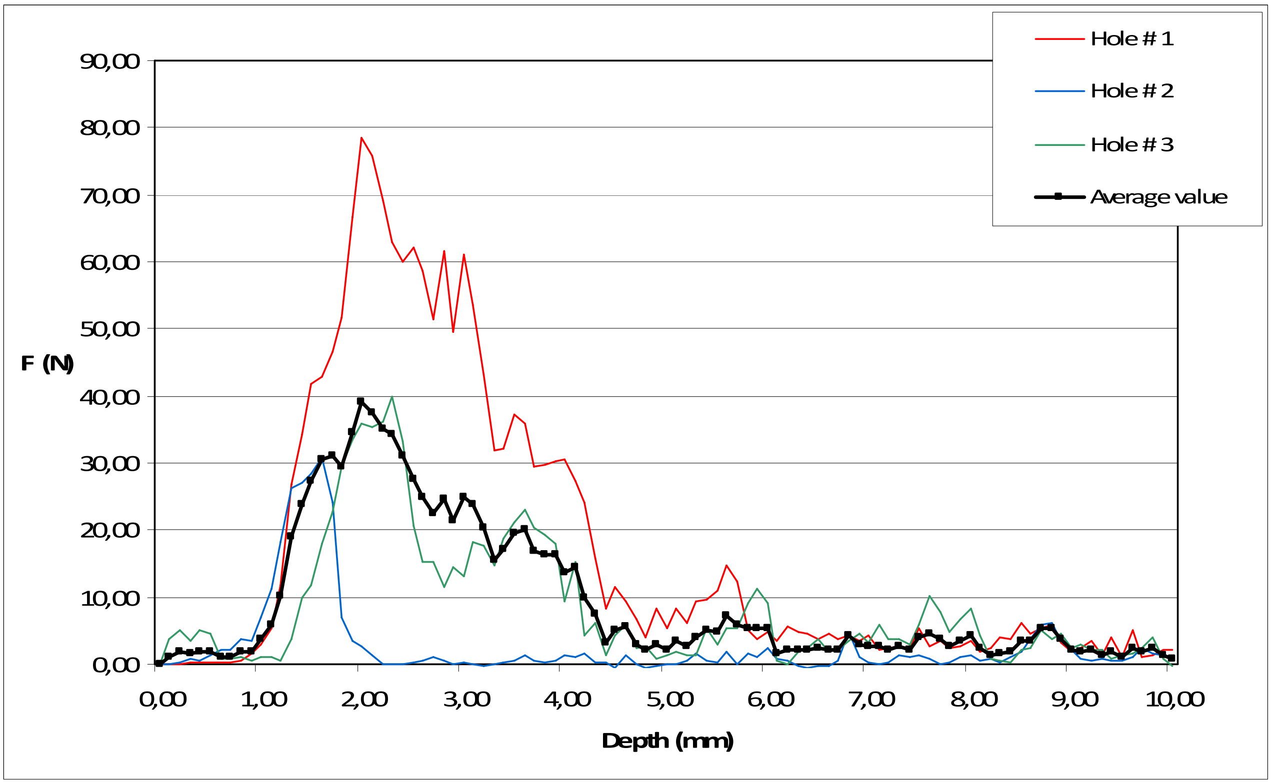


Chart 9. Drilling resistance profile of mosaic fragment number 2 with geometrical patterns.

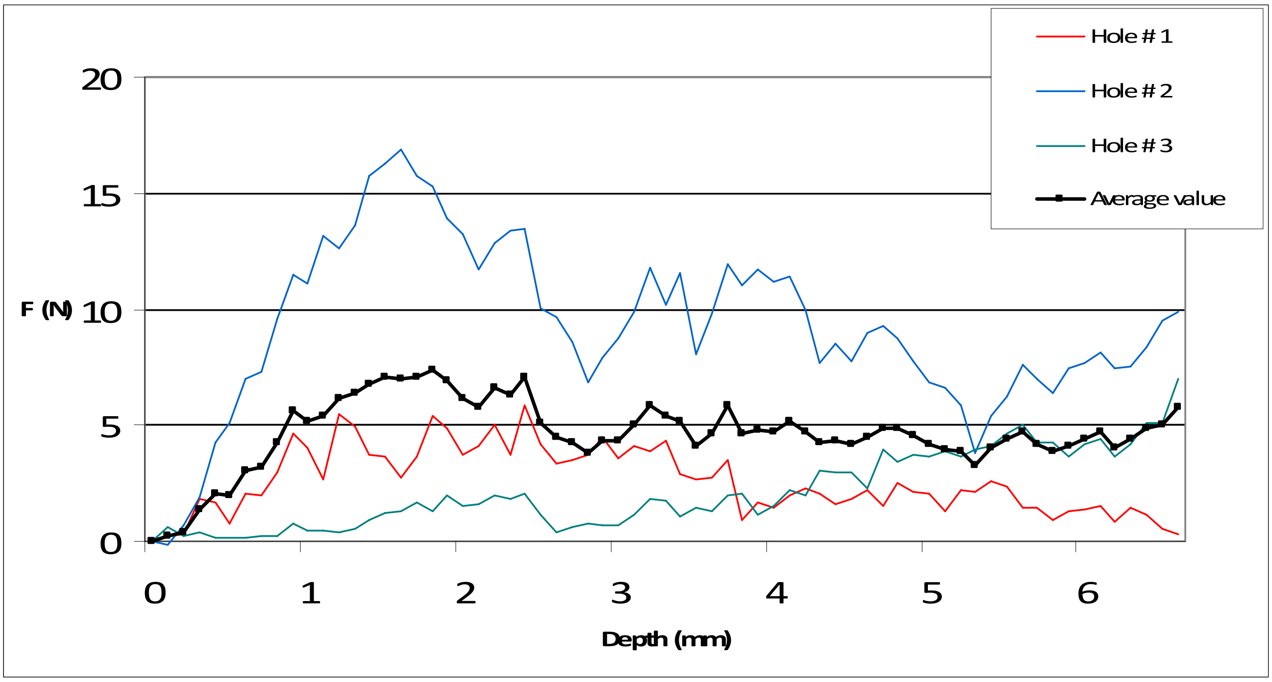


Chart 10. Drilling resistance profile of mosaic fragment number 3 with geometrical patterns.

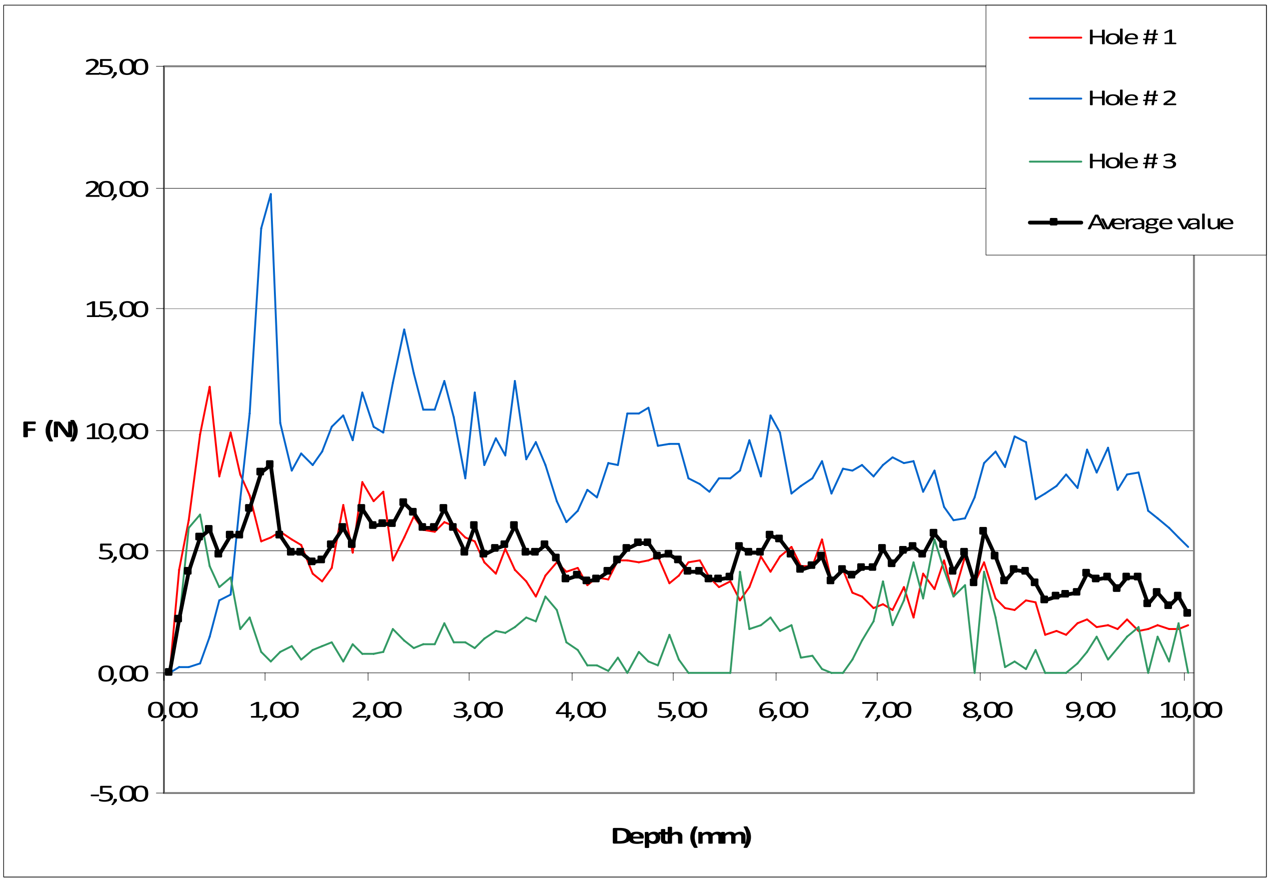


Chart 11. Drilling resistance profile of mosaic fragment number 4 with geometrical patterns.

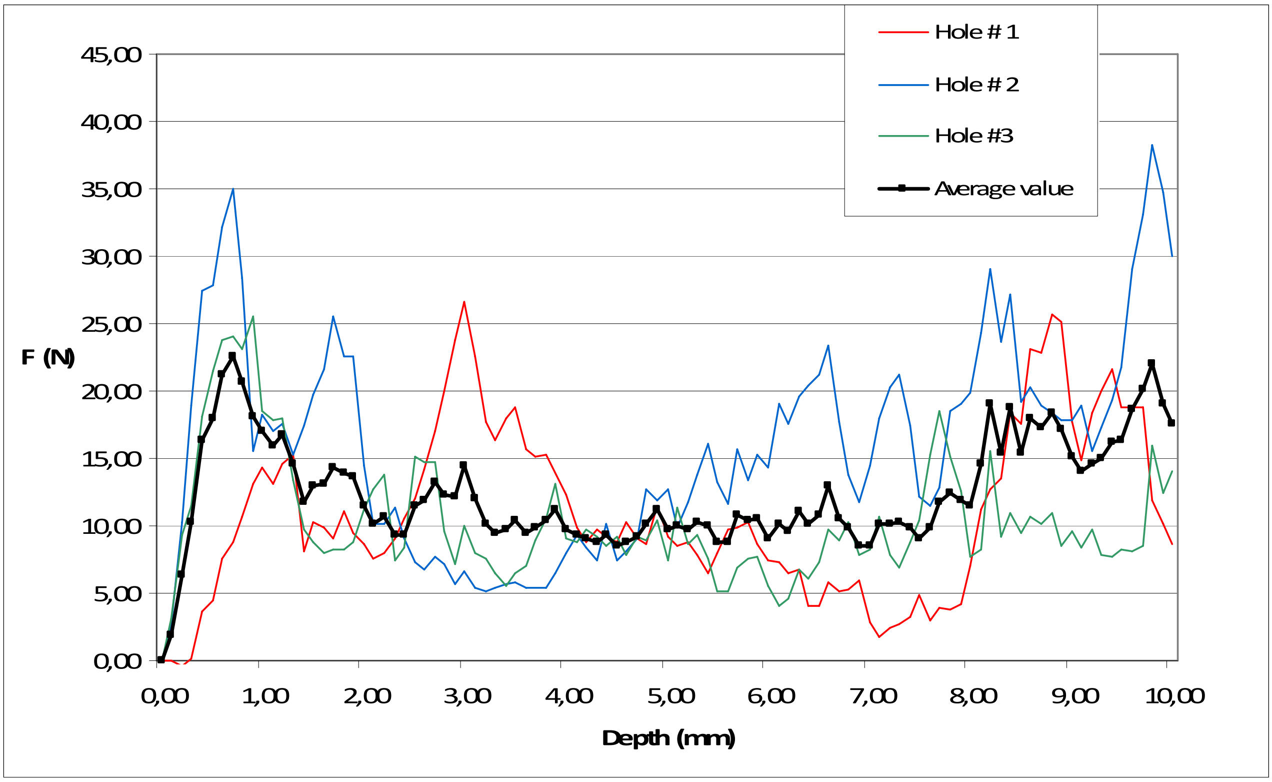


Chart 12. Drilling resistance profile of mosaic fragment number 5 with figurative patterns

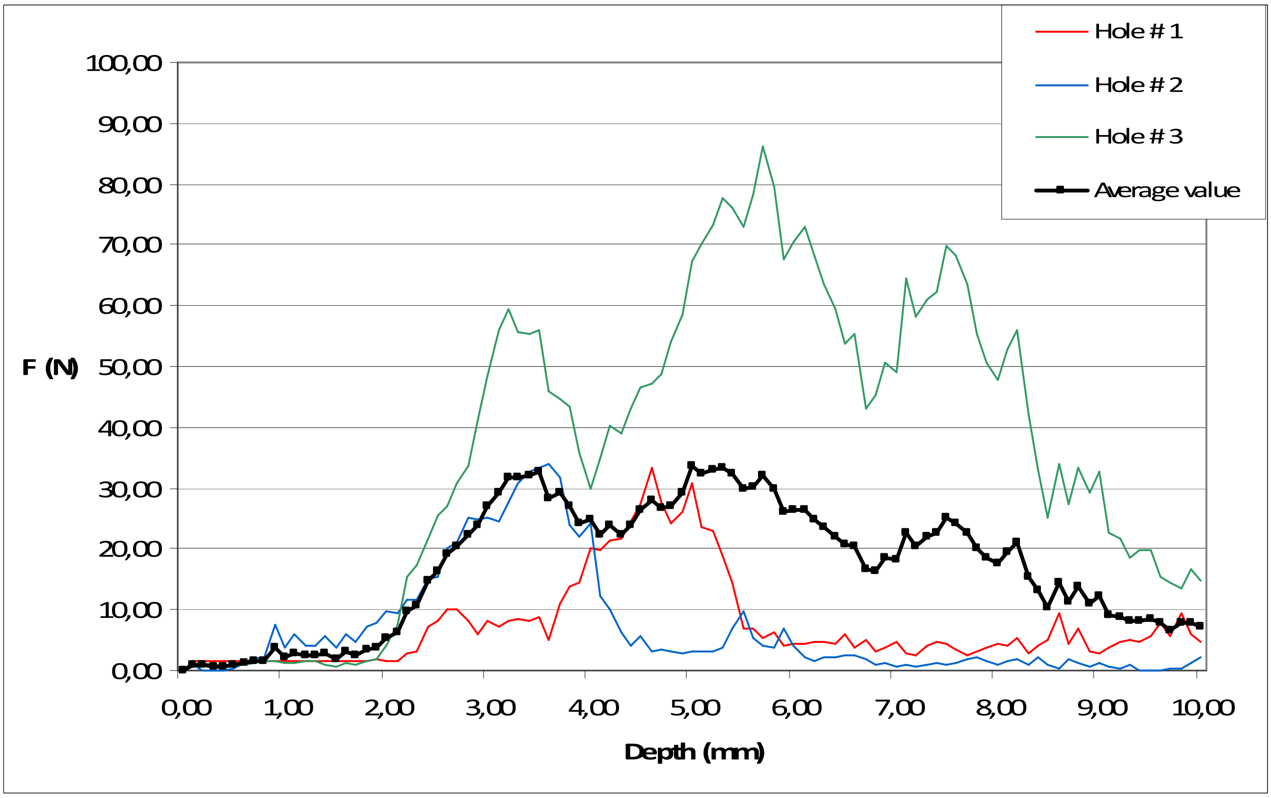


Chart13. Drilling resistance profile of mosaic fragment number 6 with figurative patterns.

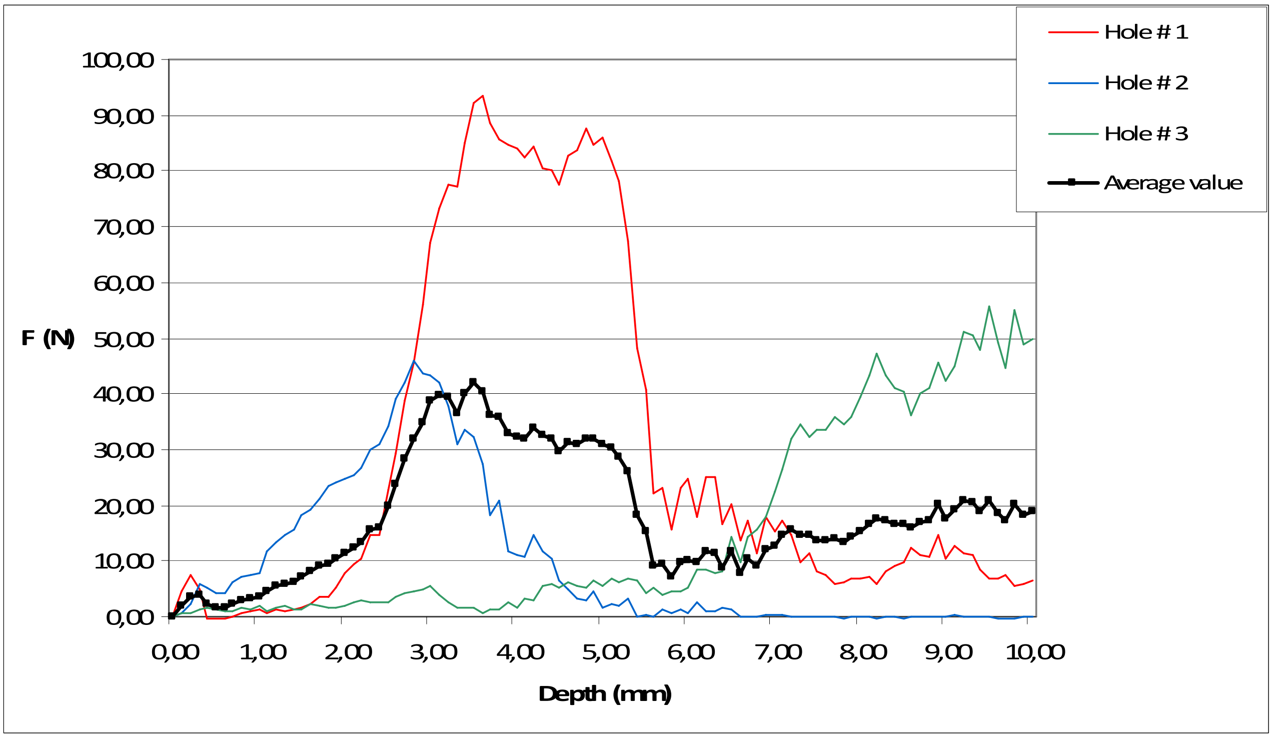


Chart14. Drilling resistance profile of mosaic fragment number 7 with figurative patterns.

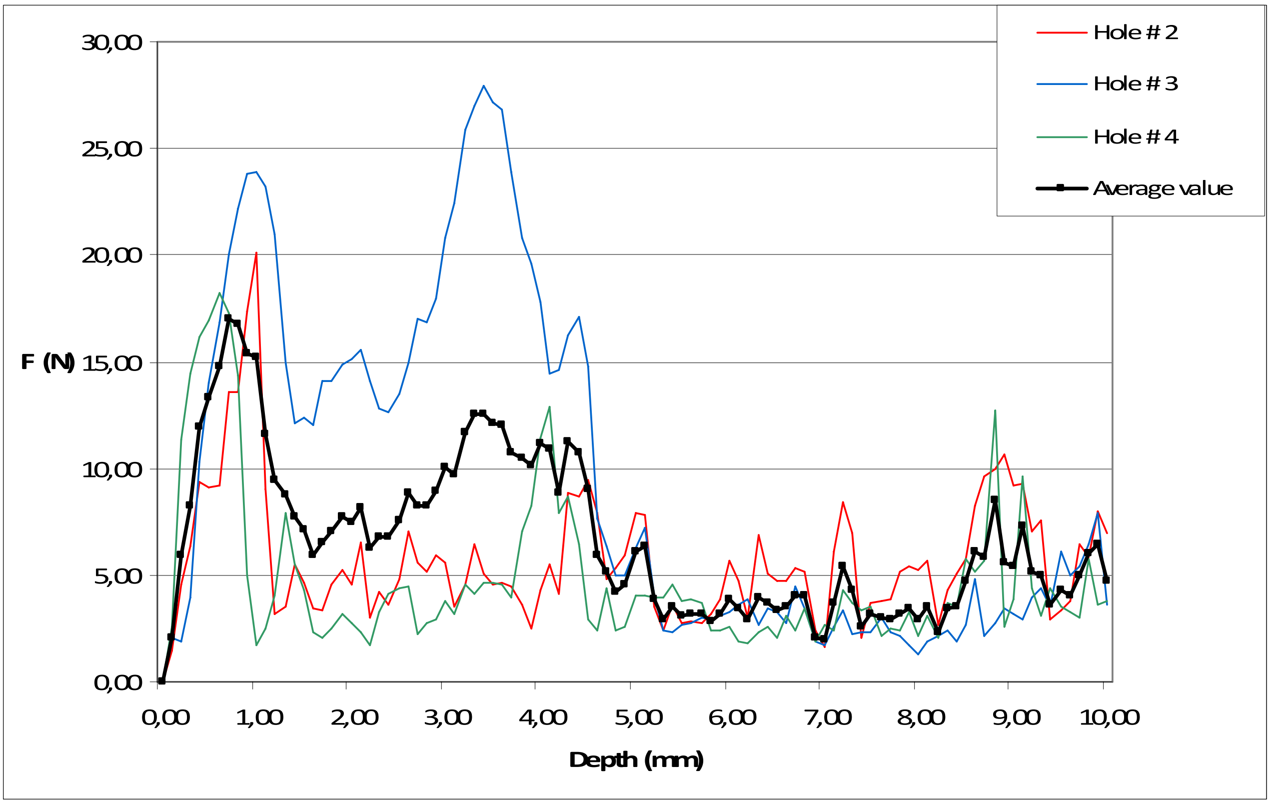
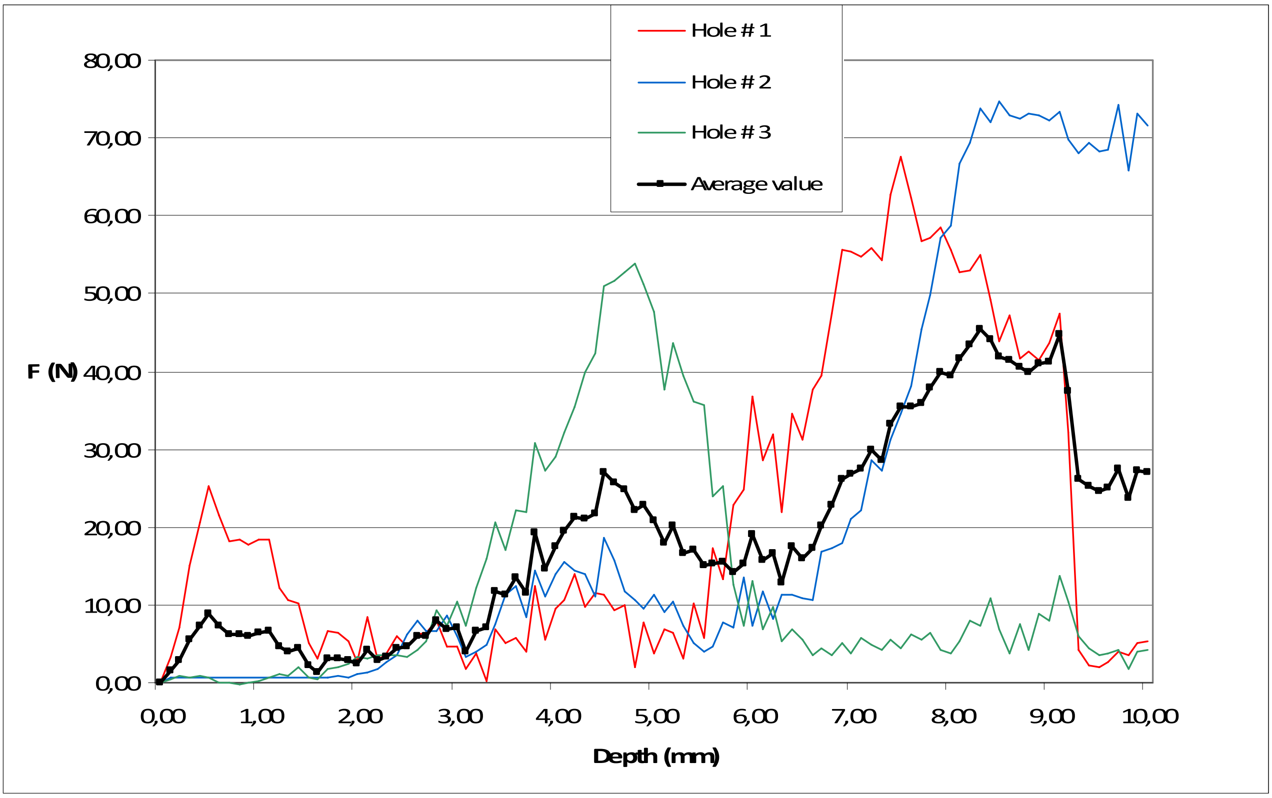


Chart 15. Drilling resistance profile of mosaic fragment number 8 with figurative patterns



Mortars used as support for mural paintings (Fig.52 a) and b)) are usually composed by two different layers: one layer of mortar and one layer of plaster.

Fig.52 a) and b) The two different layers composing the structure of a mural painting fragment.

The mortar layer is thick, 4,5 cm, grey or pinkish in colour depending on the abudance of brick and tiles fragments (*cocciopesto*) and other aggregates (sand and gravels). The aggregates are rather coarse as size (between 1 and 2 mm) and includes Quartz crystals and Quartz-arenite grains. The mortar is resistant and quite compact. It is noticeable also the presence of some voids, clearly due to the presence of vegetable material, most probably straw remnants, added, as in the structural mortars, during the preparation of the mixture to avoid cracking processes.
The plaster layer has a very constant thickness, 1 cm, and it is white in colour. The binder is a cryptocrystalline matrix of lime mixed with a large amount of fragments of romboedric crystal of calcite, visible by naked eyes and confirmed by the petrographical study (Fig.53-55).

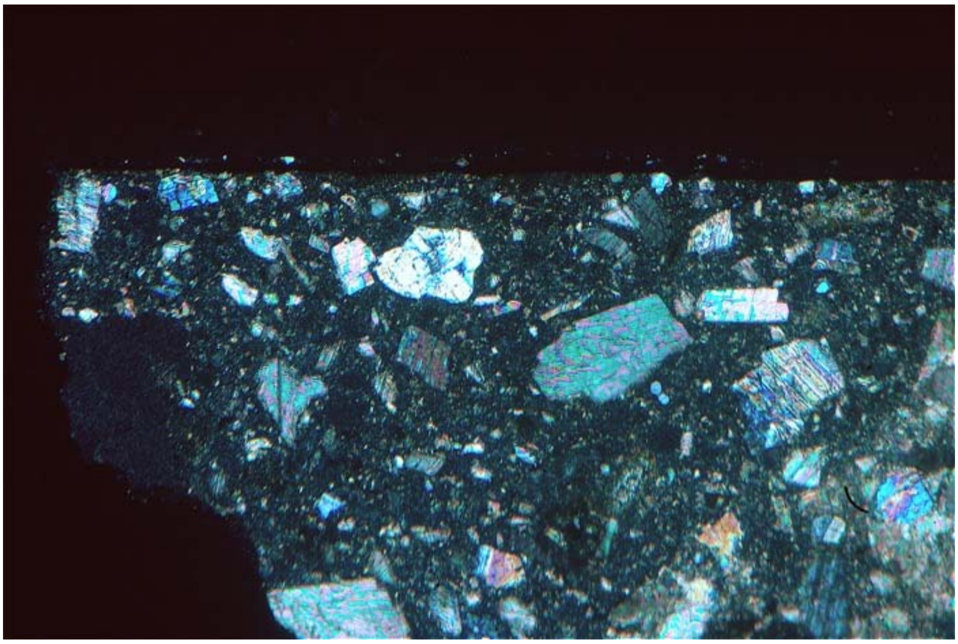


Fig.53 Detail of sample HUMP1. Fragments of romboedric crystal of calcite (magnification 10x, crossed N, lightened from the top, blue filter)

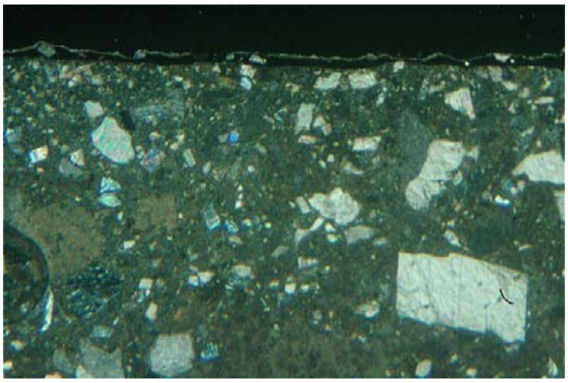
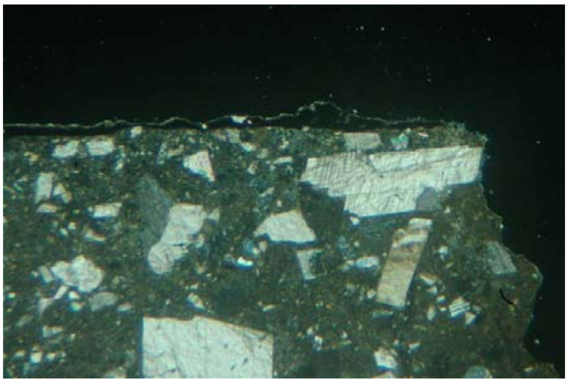
 

Fig.54-55 Further details of sample HUMP1 (magnification 10x, one N, lightened from the top).

Charts 16 summarized the granulometrical and the chemical analyses performed. Results concerning the granulometry tests of mortars are shown by diagrams which have ASTM standard curves as reference, according to the current greek regulation (ASTM, E.L.O.T. 408.). Reference curves represent the granulometrical distribution of aggregates of ideal mortar mixtures which, according to the standards, are characterised by the best strength (low percentage of pores and vacues). Charts 17-21 show the curves of granulometrical distribution of samples from Nagyharsány; they are not in the range of the standards curves taken as reference, except for two samples, HUNA3 and HUNA5a.
The following table shows the list of samples subjected to the analyses.

Code nr	Granulometry	Chemical Analyses
HUNA1	X	X
HUNA2	X	
HUNA3	X	X
HUNA4	X	
HUNA5a	X	X
HUNA5b	Not sufficient	X
HUNA7	Not sufficient	X
HUNA8	Not sufficient	X
HUAQ1	X	
HUAQ2	X	X

Chart 16. Summary of granumometrical and chemical analyses

Chart 17. Table and graph relative to the granulometrical test on sample HUNA1

sieve	0	0,20	0,5	1,0	2,5	4,0	8,0	16,0	31,5
upper limit		23	40	58	67	76	86	96	100
middle limit		13	21	30	40	52	68	87	100
lower limit		2	6	10	18	30	45	70	100
sample	0,00	15,380	37,360	72,530	96,700	98,900	100,000	100,000	100,000

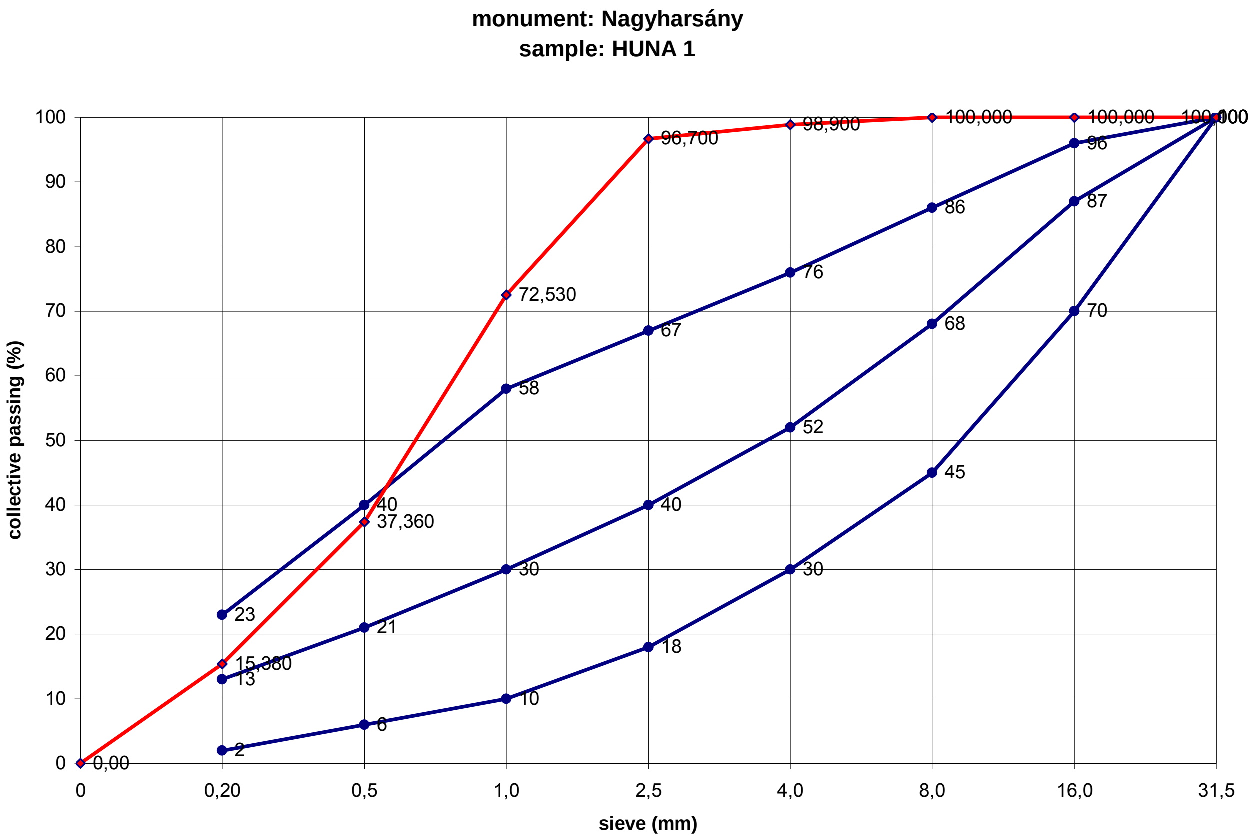


Chart 18. Table and graph relative to the granulometrical test on sample HUNA2

sieve	0	0,20	0,5	1,0	2,5	4,0	8,0	16,0	31,5
upper limit		23	40	58	67	76	86	96	100
middle limit		13	21	30	40	52	68	87	100
lower limit		2	6	10	18	30	45	70	100
sample	0,00	15,280	36,960	72,830	96,370	99,120	100,000	100,000	100,000

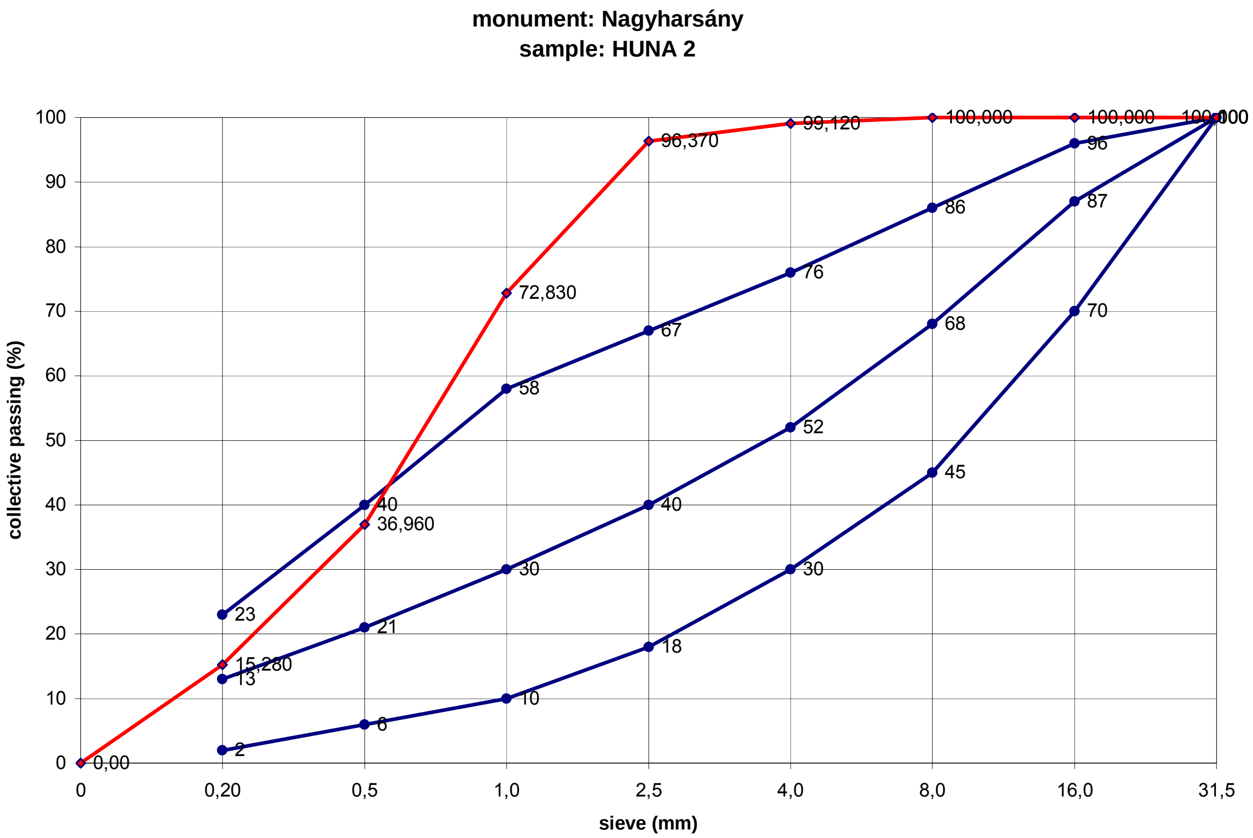


Chart 19. Table and graph relative to the granulometrical test on sample HUNA3

sieve	0	0,20	0,5	1,0	2,5	4,0	8,0	16,0	31,5
upper limit		23	40	58	67	76	86	96	100
middle limit		13	21	30	40	52	68	87	100
lower limit		2	6	10	18	30	45	70	100
sample	0,00	14,880	17,960	22,650	30,120	39,100	66,780	100,000	100,000

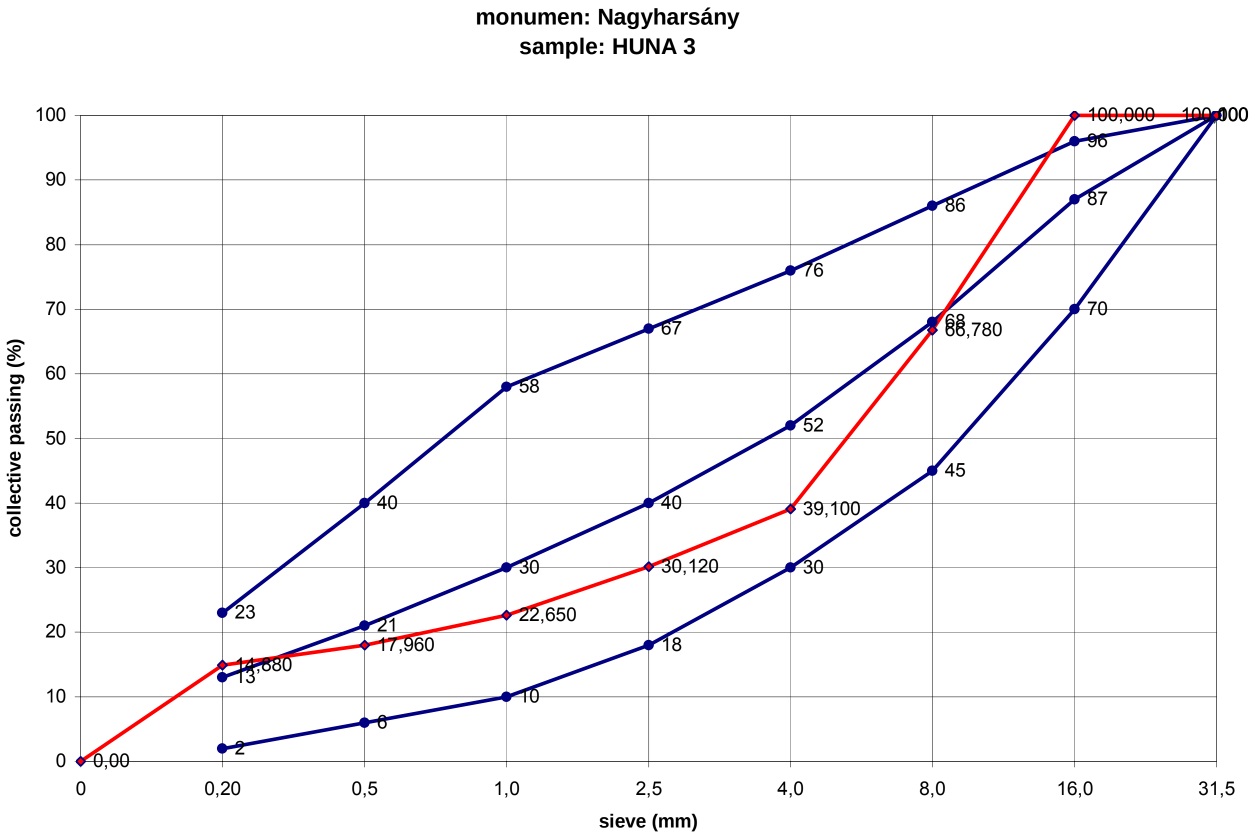


Chart 20. Table and graph relative to the granulometrical test on sample HUNA4

sieve	0	0,20	0,5	1,0	2,5	4,0	8,0	16,0	31,5
upper limit		23	40	58	67	76	86	96	100
middle limit		13	21	30	40	52	68	87	100
lower limit		2	6	10	18	30	45	70	100
sample	0,00	15,380	37,360	72,530	96,700	98,900	100,000	100,000	100,000

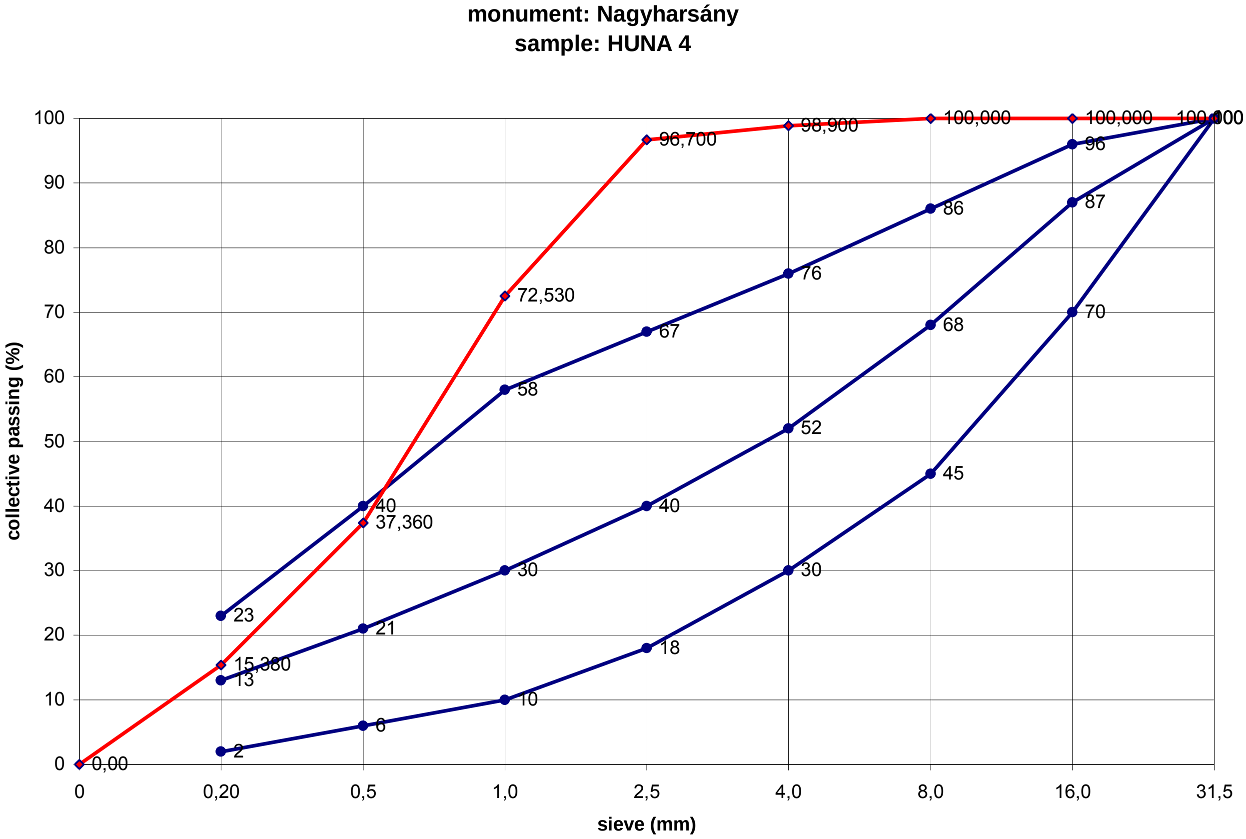
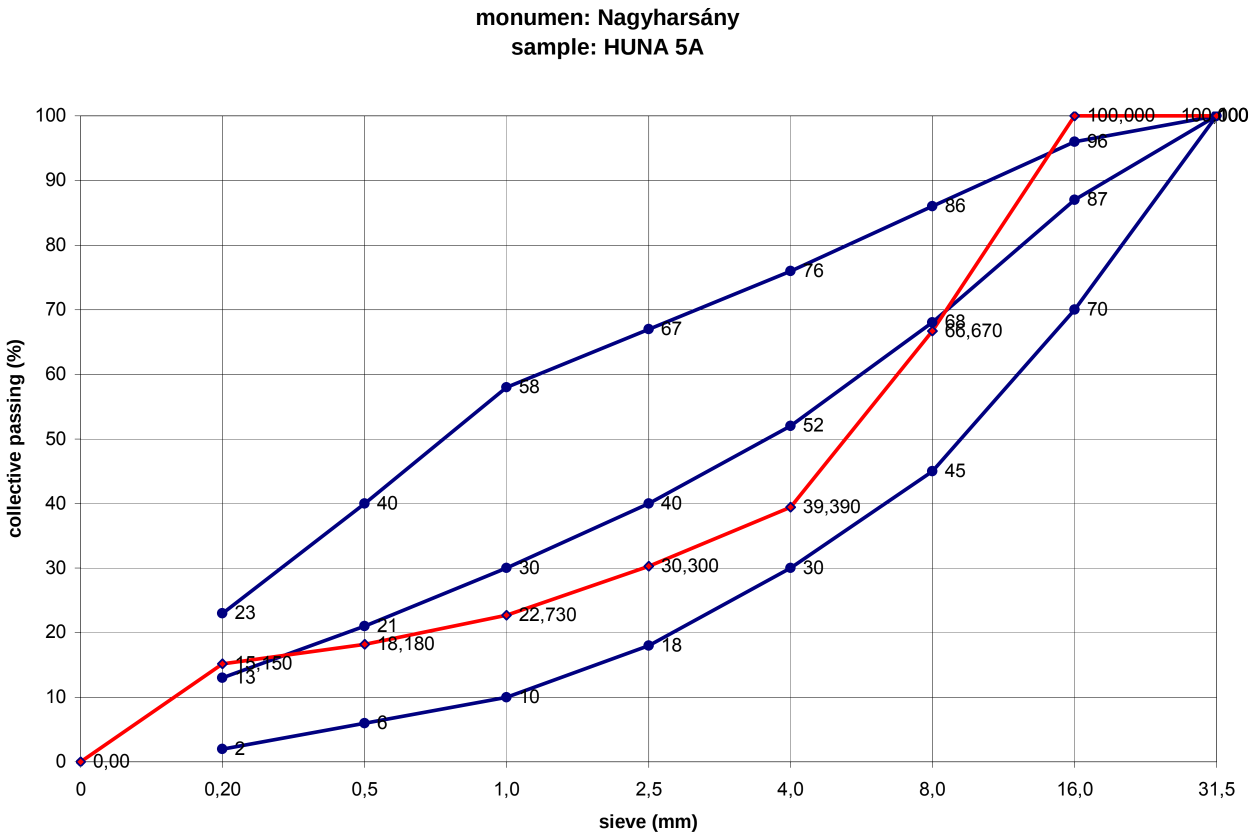


Chart 21. Table and graph relative to the granulometrical test on sample HUNA 5A

sieve	0	0,20	0,5	1,0	2,5	4,0	8,0	16,0	31,5
upper limit		23	40	58	67	76	86	96	100
middle limit		13	21	30	40	52	68	87	100
lower limit		2	6	10	18	30	45	70	100
sample	0,00	15,150	18,180	22,730	30,300	39,390	66,670	100,000	100,000



Chemical analyses are shown in chart 22: all the mortars have a rather high content of CaO (between 46,73 and 30,22 % w.t.). The content of silica is variable but in some cases quite high (42.87 % w.t.). In one case (HUNA5a) the content in MgO is surprisingly high. Generally there is no evidence of presence of soluble salts.

Chart 22. Summary of results of chemical analyses

	SOLUBLE IN ACIDS % w.t.								SOLUBLE IN HCl 0.1 N % w.t.							SOLUBLE SALTS % w.t.		
SAMPLE	Na_2O	K_2O	CaO	MgO	Fe_2O_3	Al_2O_3	SiO_2	L.I.%	Na_2O	K_2O	CaO	MgO	Fe_2O_3	Al_2O_3	SiO_2	Cl^-	NO_3^-	SO_4^{2-}
HUNA 1	0.78	0.87	41.98	0.68	1.32	2.72	42.87	8.79	0.05	0.10	41.84	0.45	0.11	0.02	0.50	0.02	0.01	0.02
HUAQ 2	0.57	0.63	36.24	2.24	1.47	2.99	36.24	19.63	0.11	0.10	36.18	1.19	0.24	0.26	0.45	0.05	0.03	0.10
HUNA 3	0.15	0.53	46.73	0.48	0.74	1.89	39.77	9.71	0.02	0.05	46.17	0.38	0.12	0.02	0.28	0.01	0.01	0.01
HUNA 5A	0.25	0.46	32.04	7.60	1.28	4.23	31.16	22.99	0.08	0.10	31.62	6.38	0.52	2.02	1.35	0.02	0.01	0.03
HUNA 5B	0.20	0.72	44.91	1.01	0.86	2.23	28.12	21.94	0.05	0.19	43.66	0.85	0.20	0.19	0.58	0.02	0.23	0.12
HUNA 7	0.27	0.84	36.24	0.70	1.00	2.87	38.15	19.93	0.05	0.41	36.14	0.44	0.26	0.85	0.38	<0.01	0.01	0.02
HUNA 8	0.21	0.33	30.22	8.31	1.27	3.97	27.78	27.91	0.08	0.11	27.98	7.21	0.57	2.32	1.05	0.01	0.02	0.03

Decorative material

Mosaic and mural paintings fragments are stored in the Hungarian National Museum's basement. According to Museum's Archaeologists and Restorer's categorization, seven different kinds of floor mosaics have been recognized. Most of them are geometric, up to five of colours (black, white, red, yellow and pink) and presenting different patterns and motives, while others present figurative pictures, reproducing human images in 1.5 scale, "still life" patterns and marine scenes. Beside the stone tesserae, the mosaics also comprise some notable glass tesserae, which could not be sampled.
Among the sampled stone tesserae, four different kinds of material were found.
The black tessera was identified as a Calcareous Dolomite, compatible with Dolomitic limestones and Dolomites from the surrounding area or from the close area of the lake Balaton (Fig.56-57).

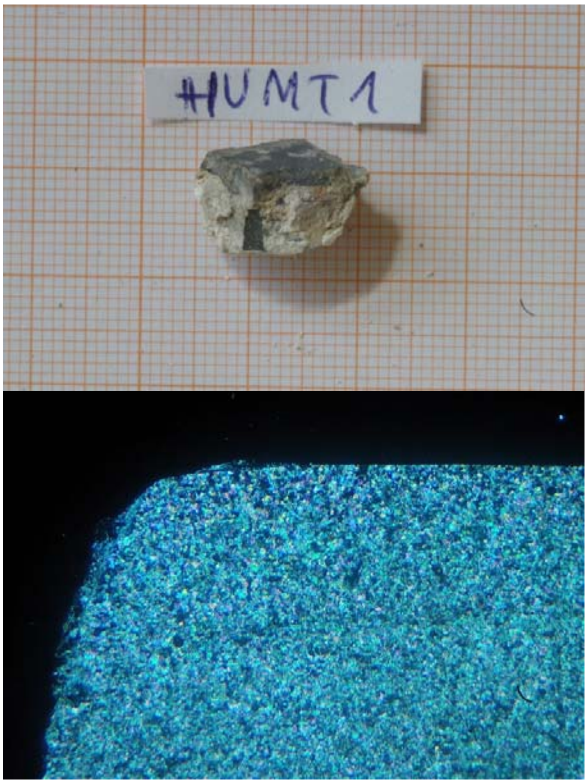


Fig.56-57 Black tessera by the stereomicroscope and with the polarizing microscope (magnification 10x, crossed N)

Red tessera resulted to be a Fossiliferous micritic limestone, compatible with the local "red marble", a biomicrite also characterized by the presence of big fossils and Ammonites (Fig.58-60).

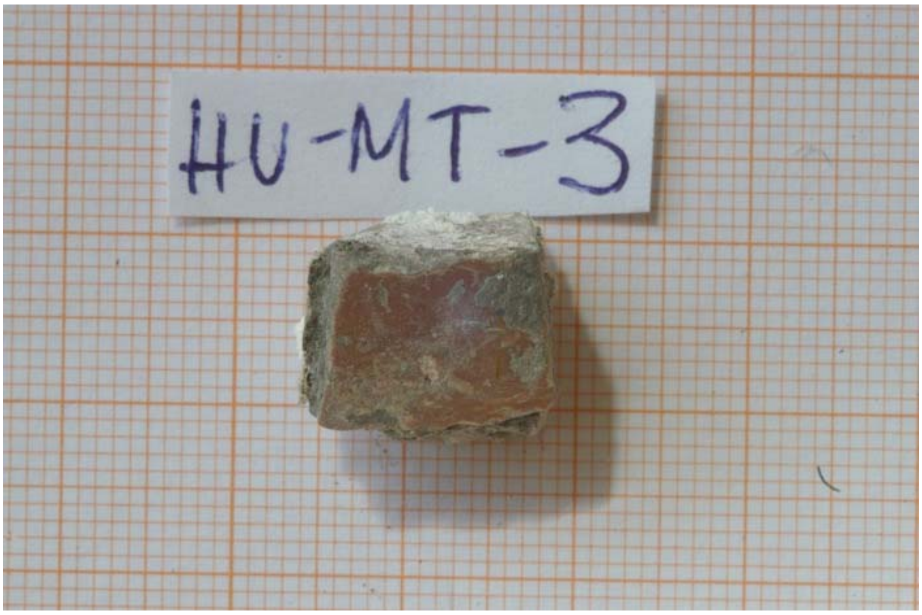


Fig.58 The red tessera by the stereomicroscope

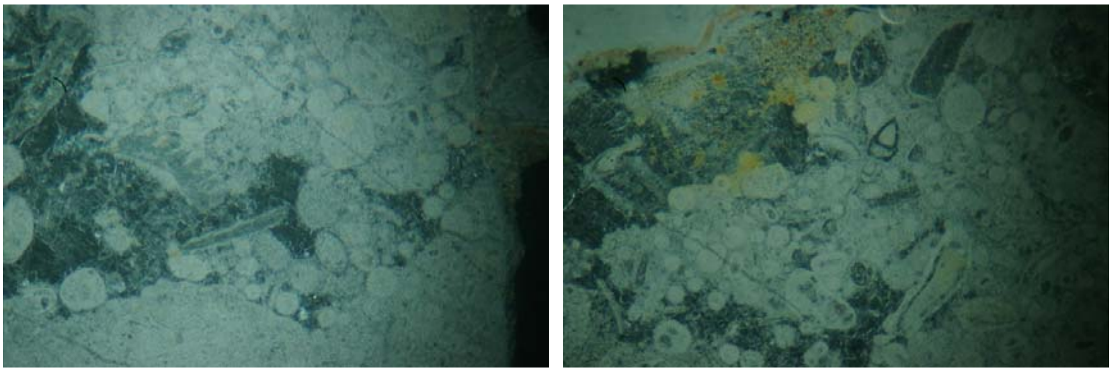


Fig.59-60 Details of the red tessera (magnification 10x, one N, illuminated from the top).

The pink tessera was identified as Oomicritic limestone, compatible with the Upper Jurassic or Low Cretaceous Formation from the Nagyharsány surrounding areas (Fig.61-62).

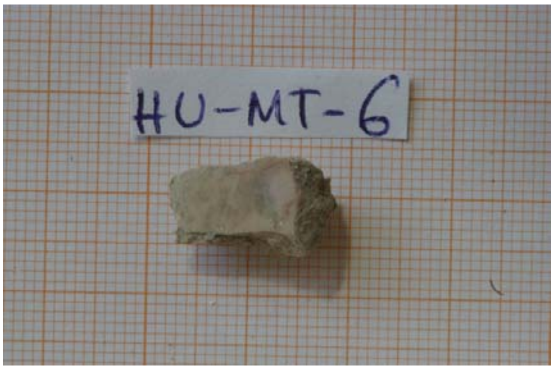


Fig.61-62 Pink tessera by the stereomicroscope and with the polarizing microscope (magnification 10x, one N, illuminated from the top)

The white tessera was identified as a coarse-grained marble. Although the tessera was too small and so poorly representative, the material seems not to be affected by veins (Fig.63-64).

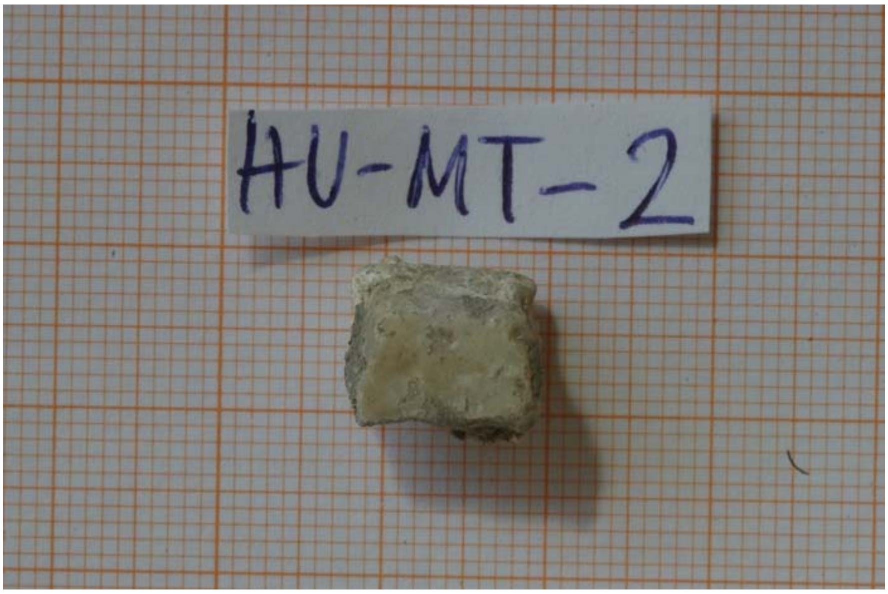


Fig.63 A white tessera by the stereomicroscope

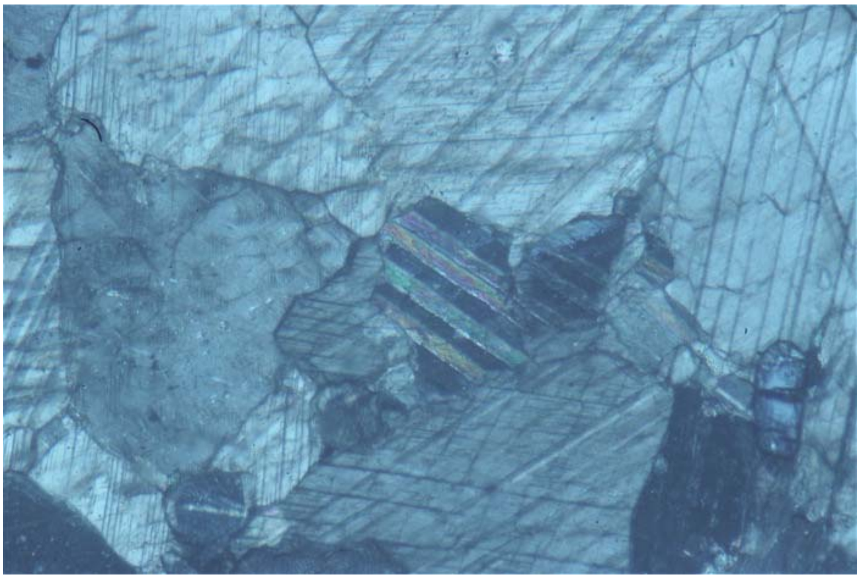


Fig.64 Details of the marble of the white tessera (magnification 10x, crossed N, illuminated from the top).

The peculiarity of this marble is the presence of unusual, elongated round shaped inclusions with high birefringence and the high relief effect (Fig.65-70).

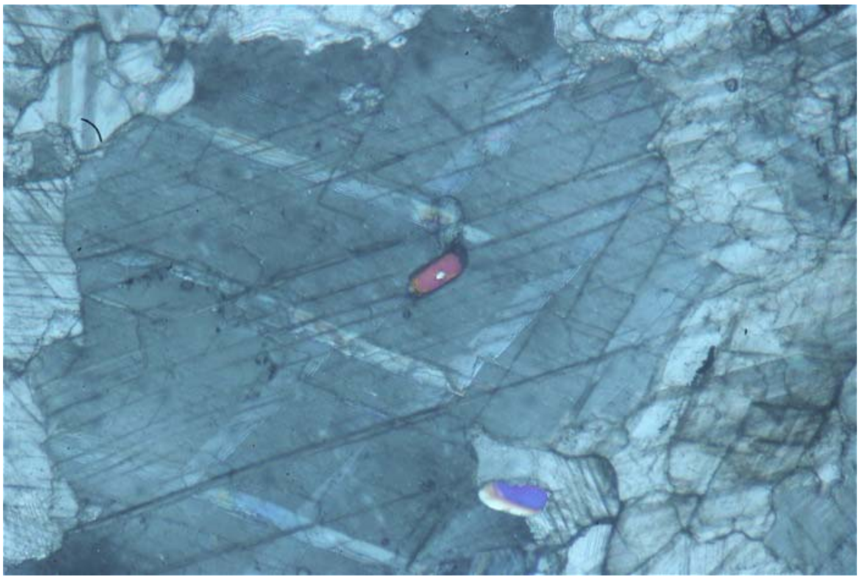
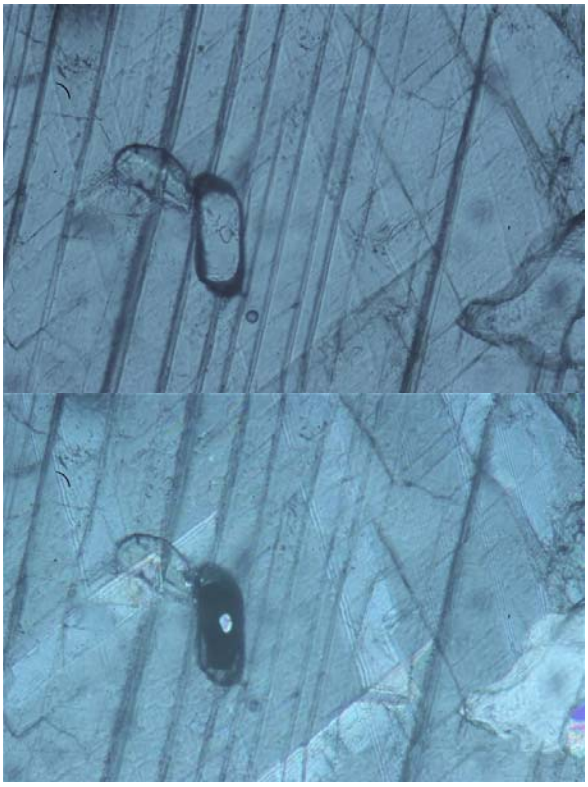


Fig.65 Details of the inclusions of the marble of the white tessera (magnification 20x, crossed N, illuminated from the top).



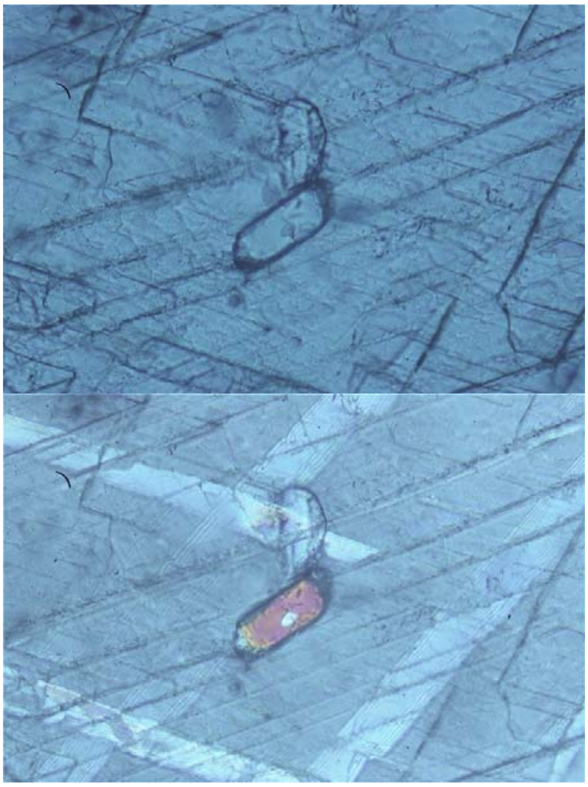


Fig.66-70 Four details of the inclusions of the marble of the white tessera (magnification 60x, crossed N on the right, one N on the left, illuminated from the top). It is visible the high birefringence and the high relief effect.

The identification of these inclusions could be a crucial detail in the definition of the provenance of the marble: according to this, it doesn't seem to belong to local sources, since it is not compatible with any of the marble known in the Carpathian and Transdanubian Basin.

Further studies, such as and Scanning Electron Microscope (SEM) observations and Energy Dispersive Spectrometry (EDS) micro-analyses would be useful to better define the characteristics of the inclusions and identify their nature.

The study of the stratigraphy of mural paintings revealed that they are composed of three layers: two mortars layers and the painting layer; in some cases it was possible also to recognize two different painting layers, lying one on the other (Fig.73-74). (Járó et al.1987). XRD analyses carried out on the pigments showed the presence of Hematite (Fig.71-72) in both red and black pigments, while Celadonite (Fig.75-76)characterized the green one. (Baraldi, P. et al. 2005)

In some cases it was possible to recognize a brownish line between the pigment layer and the substratum. It might be the evidence of carbonization reactions. (Bulgarelli et al. 1997)

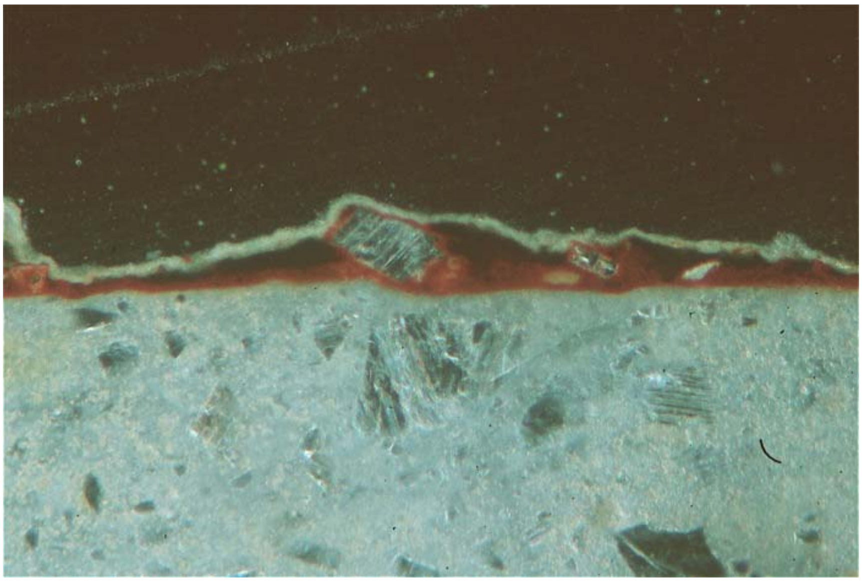


Fig.71 Details of mural painting (HUMP3), with dark red pigment layer including a fragment of romboedric calcite (magnification 20x, one N, illuminated from the top).

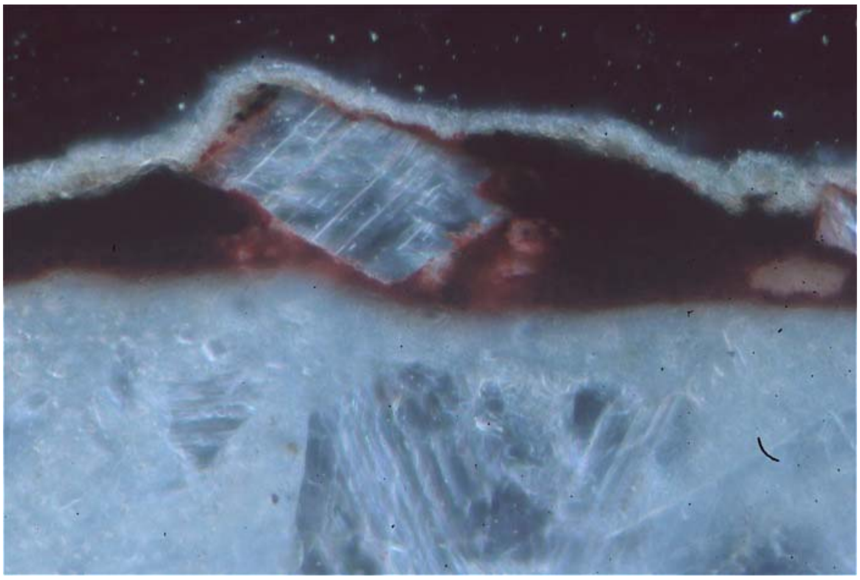


Fig.72 Details of mural painting (HUMP3). An external calcitic layer, lying on the painting surface, is here visible. (magnification 60x, one N, illuminated from the top).

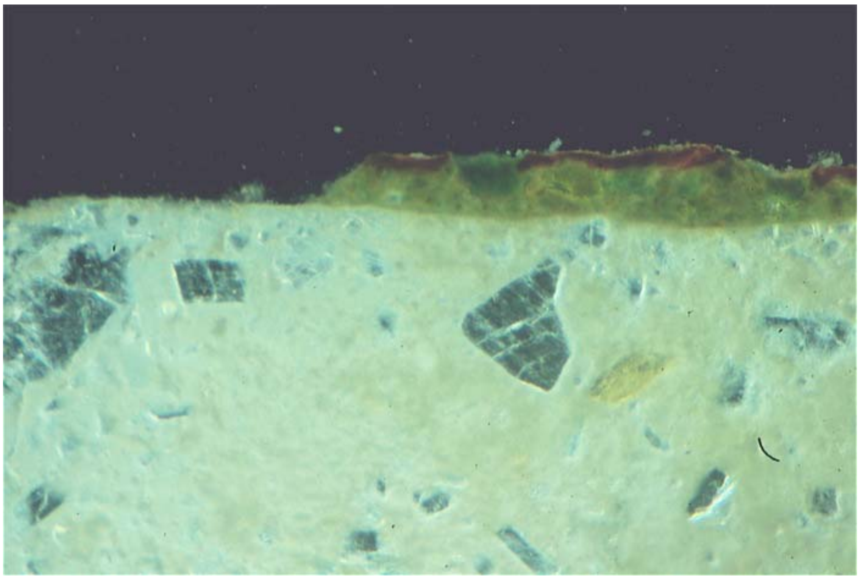


Fig.73 Details of mural painting (HUMP4), red pigment layer lying on olive green pigment layer (magnification 20x, one N, illuminated from the top).

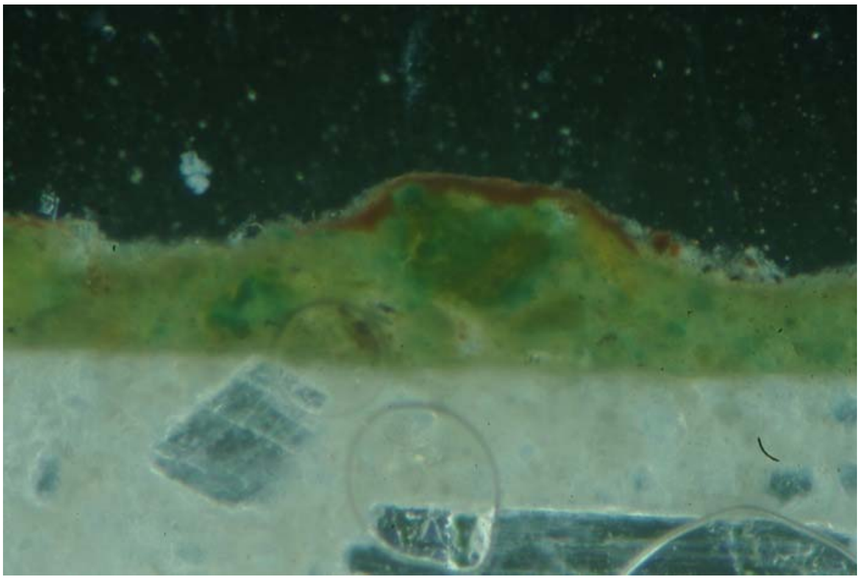


Fig.74 Details of mural painting (HUMP4), Celadonite grain; slightly visible a brownish line between the green pigment and the substratum (magnification 60x, one N, illuminated from the top).

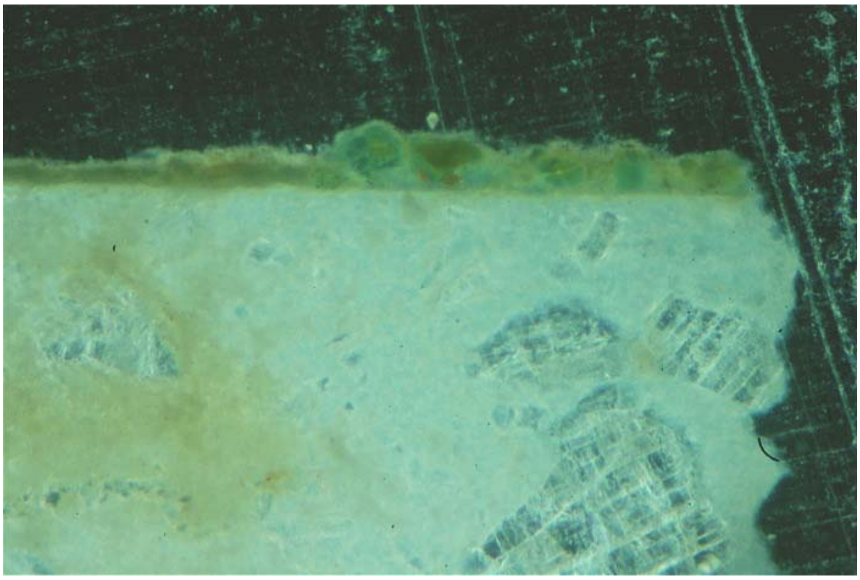


Fig.75 Details of HUMP4 (magnification 20x, one N, illuminated from the top).

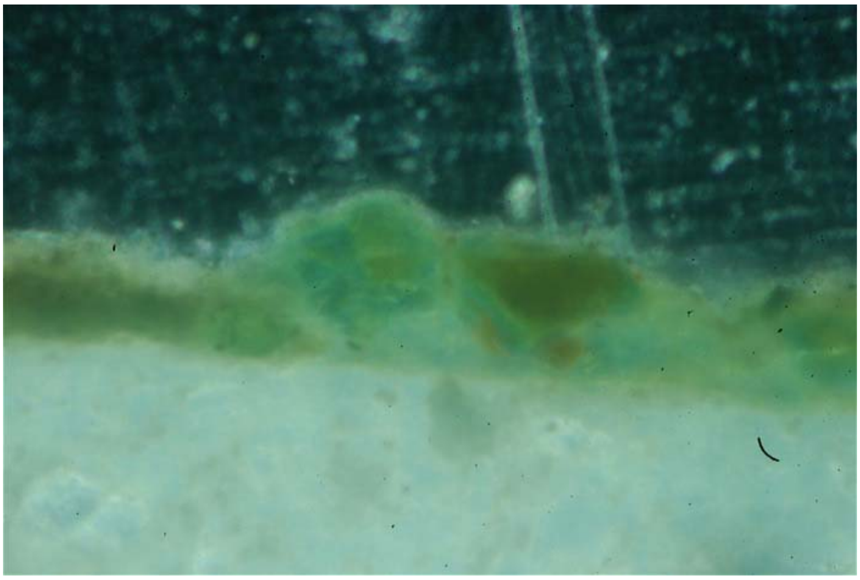


Fig.76 Details of mural painting (HUMP4), Celadonite grain (bright green) with a probable Glauconite grain (olive hues) (magnification 60x, one N, illuminated from the top).

Aquincum archaeological site

Fig. 78 shows the map of Aquincum archaeological site, available to the public at the entrance of the site, while Fig. 80-81 show two views of the site as it is nowadays.

Two samples of mortar were collected from two different sides of the original walls of the ruin garden of Aquincum: one from the southward part of the craftsmen houses, in the western wall, the second from the south wall of the courtyard.

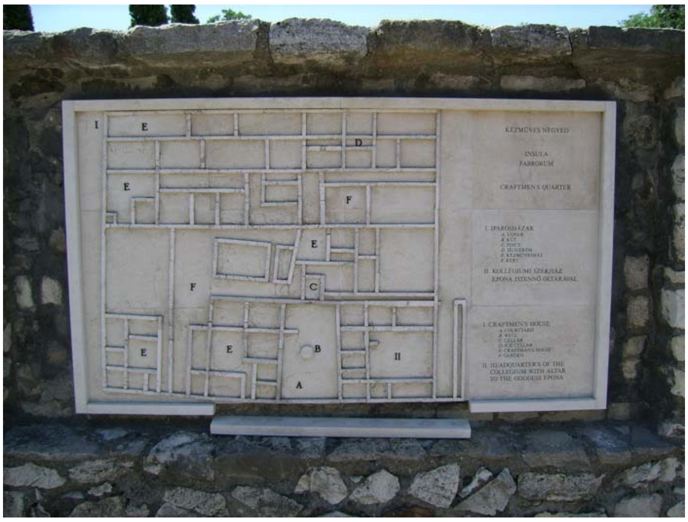


Fig.78 The map of the archaeological site represented for the public.

Fig.79 Detail of mortar during the sampling. Presence of brick as elements of the structure but not brick's fragments as aggregate in the mortar.

Fig.80-81 Two different views of the site. In the first the reconstructed walls are visible, in the second the partially reconstructed Roman road.

Fig.82 The use of travertine for structural elements.

Fig. 82 shows the use of Travertine as architectonical element.

Mortars are lime-based, with a low content of MgO (see chart 22), with a variety of different pebbles, no evidence of presence of brick fragments was detected.

The granulometrical analyses (charts 23-24) shows that the size distribution of the two kinds of mortars appear very similar, and they are both into the range classified by the standards as high quality mortars (ASTM, E.L.O.T. 408.).

Fig.83 Sample HUAQ1

Chart 23 Table and graph relative to the granulometrical analyses of sample HUAQ1

sieve	0	0,20	0,5	1,0	2,5	4,0	8,0	16,0	31,5
upper limit		23	40	58	67	76	86	96	100
middle limit		13	21	30	40	52	68	87	100
lower limit		2	6	10	18	30	45	70	100
sample	0,00	10,120	25,460	38,000	54,100	60,580	81,540	100,000	100,000

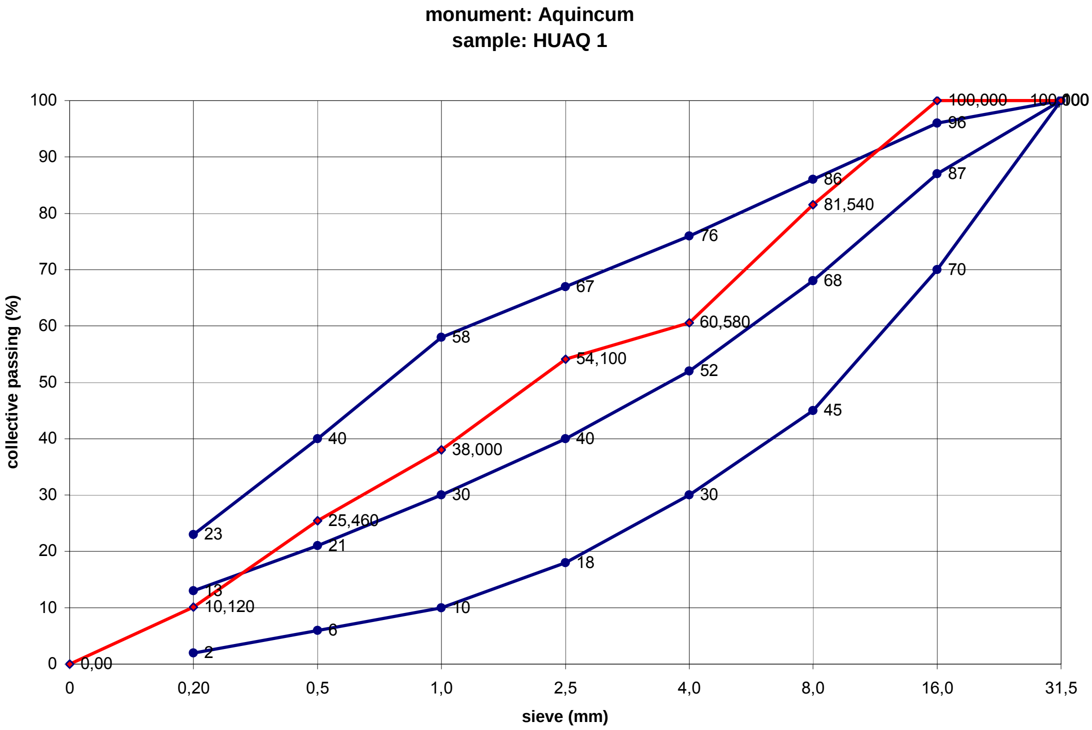
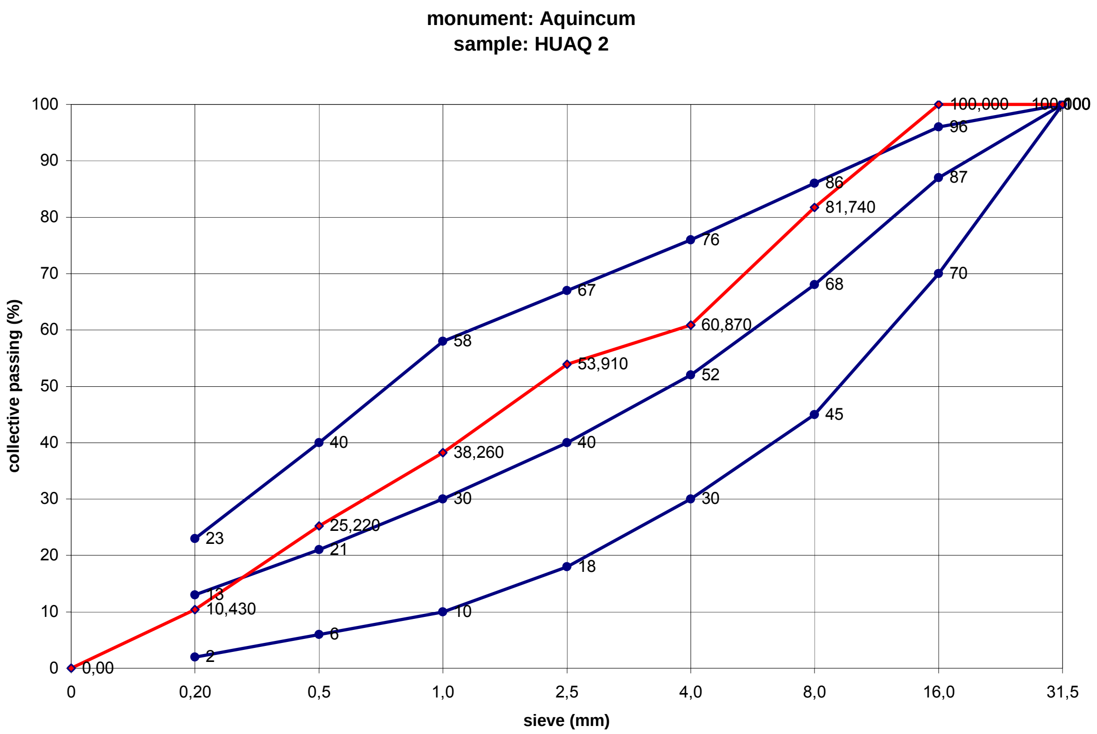


Chart 24 Table and graph relative to the granulometrical analyses of sample HUAQ2

sieve	0	0,20	0,5	1,0	2,5	4,0	8,0	16,0	31,5
upper limit		23	40	58	67	76	86	96	100
middle limit		13	21	30	40	52	68	87	100
lower limit		2	6	10	18	30	45	70	100
sample	0,00	10,430	25,220	38,260	53,910	60,870	81,740	100,000	100,000



Baláca archaeological site

Fig.84 shows a view of the site as it appears nowadays. While Fig.85-86 show two interesting details of the frescoes decorations, Fig.87 a) and b) show the entrance and an original a wall, showing the red line used as marker of the restoring intervention.

Fig.84 A view of the site in the middle of the country side

Fig.85-86 Two different details of the frescoes mural decorations

Fig.87 A view of the entrance of the site and the reconstructed walls. In the second picture a detail of the lowest part of the wall, supposed to be original. The red line (cement) is the marker of the replacing and restoring intervention.

Samples of building stone were collected from the detached material at the base of walls. Physical properties, such as density, the dynamic modulus of elasticity (through ultrasound velocity tests) and compressive strength were investigated. Results are shown in the previous chart 2 together with the results from Nagyharsány archaeological site.

Observing the structure of the site through the remnants of walls, it was possible to notice that, despite of a large use of bricks as structural elements alternated to building stone, there are areas still showing the presence of original mortar, characterized by the lack of brick fragments as aggregates in the mixture.

Fig. 88-89 show two details of original walls, where it is visible the use of bricks for the structure.

Fig.90-91 show the original structural mortar where it was noticed the absence of brick's fragment.

Fig.88-89 First picture is an example of remnants of the original wall approached for the sampling. Second one shows the presence of brick elements in the wall structures.

Fig.90 Example of structural mortars without the presence of brick fragments as aggregates, from walls in open air conditions. Fig.91 Detail of walls preserved in the covered area of the site (at the top of the picture the red line marker).

5. An attempt of comparison between Hungarian and Greek Roman sites: the Galerius Palace of Thessaloniki and Dion Archaeological site

Beside the study of the material, observations on the techniques applied by Romans in masonry for building and decorating their residences was also a goal of of this study. The examination of architectonical features, although each detail could not be included here, was crucial in drawing differences and similarities in the several visited sites, belonging to different region of the Empire. The research, starting from Nagyharsány archaeological site, took into account other main Hungarian Roman sites and two Roman sites situated in Greece. The goal of this kind of analyses was to start a definition of the characteristics in common between different and far regions in order to better understand the ability of Romans in managing exchanges of knowledge and transfers of material from the centre to the borders of the Empire, and to build up a structure of knowledge useful for the archaeologist of the Roman period in Hungary.

As it is well known, building techniques varied a lot during centuries, and in most of cases they were also adjusted according to local environmental condition, availability of material, costs, tastes.

According to what observed in Nagyharsány, walls were erected by the use of unshaped stone bound together by lime based mortars, the so called *opus incertum,* which started to be used in Rome since the beginning of the II century (Lugli, 1957). There are no evidences of the use of bricks for the walling, probably due to the costs of their manufacture. Internal walls were covered by plaster decorated by mural paintings or parietal mosaic, even though less frequently then the floor mosaics. Decoration were rather fine and accurate, characterized by geometrical patterns but also figurative ones, showing human representations and leaves, fruits motifs.

In Aquincum the use of shaped and unshaped stones was alternated with the use of bricks (*opus mixtum*), and, while in the Civil town stones still prevailed on bricks, especially in the Military town they were equally distributed. In the Civil town, secondary walls were erected also in *opus caementicium*, where the core of the wall was constituted by a mixture of mortar and big stone and gravel fragments, fixed into two stone surfaces. Fine and sophisticated mosaics and mural paintings decorated the inner walls of the residences, rooms and chambers, with the use of precious material.

In Nemesvámos-Baláca walls were built in *opus mixtum* and *opus incertum* but styles like *opus spicatum* (rectangular bricks set in a herringbone shape) were present as well. Pavements were decorated by mosaics with both coarse tessera (*opus tessellatum*) and fine tessera (*opus vermiculatum*), or by the use of slabs of different marbles of different colours set in geometrical patterns (*opus sectile*) (Adam, 1984). Internal walls were decorated by accurate frescoes, recalling mythological scenes, animals and flowers.

Additional structures like baths and hypocausts were present in all the three sites but, while in Aquincum and Baláca they are visible, in Nagyharsány they are only mentioned in the archaeological reports.

<u>Galerius Palace: Navarino Square archaeological site</u>

The Navarino Square archaeological site (Fig.92-93) is situated in the centre of Thessaloniki and shows a part of the ruins of a large complex known as the Galerius Palace, which was the official residence of the emperor Galerius and his court since the beginning of the IV century AD. The palace was continuously used by several emperors during the IV and V century AD. The complex, not completely excavated yet, comprised the imperial quarters, interior courtyards, halls and audience chambers (called *Basilica,* Fig.94-95) with interior rich decorations. Operation Programmes (1994-2000 and 2002-2006), with funding from Greek Ministry of Culture and the European Union, implemented the conservation and the presentation of the site. Last excavations brought to light an earlier construction phase (II –III century AD), characterized by the presence of very fine mosaics, belonging to a luxurious residence which had been destroyed during the III century, and covered by marble, coarse mosaic and brick pavements in the second half of the V century AD.

Part of the earlier mosaics are now visible protected by glass shelters (Fig.96-97).

Baths had at least three chambers for bathing in cold, warm and hot water (*frigidarium*, *tepidarium* and *caldarium)*, furnaces heated water (*praefurnium*) while hot air was channelled by a system of ducts (*hypocaust*) into the wall and under the floor.

Wall structure is built alternating courses of stones and bricks (*opus mixtum*) held together by mortar (lime-based with pozzolanic compounds and pebbles and gravel as aggregates). The use of bricks is limited to courses of walling, doorways, pillars and vaults (Fig.98-101).

Construction phases results from a change in the form and use of the different units of the complex, and are revealed by discontinuities in the masonry, a change in the building materials, and a change in the proportions and measures used.


Fig.92-93 View of Navarino Square archaeological site from an aerial picture and from the entrance

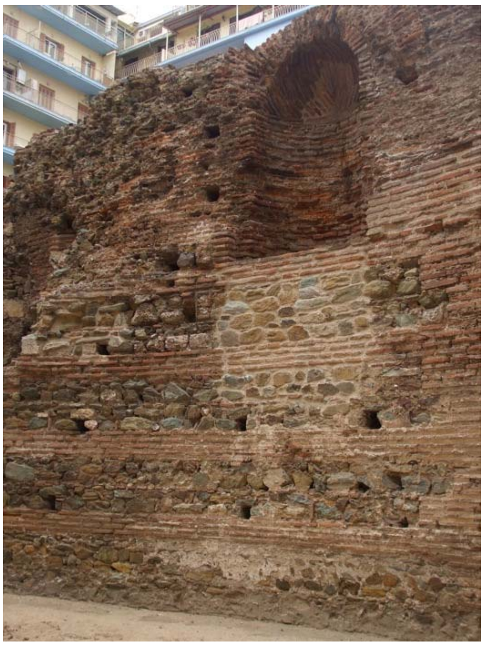
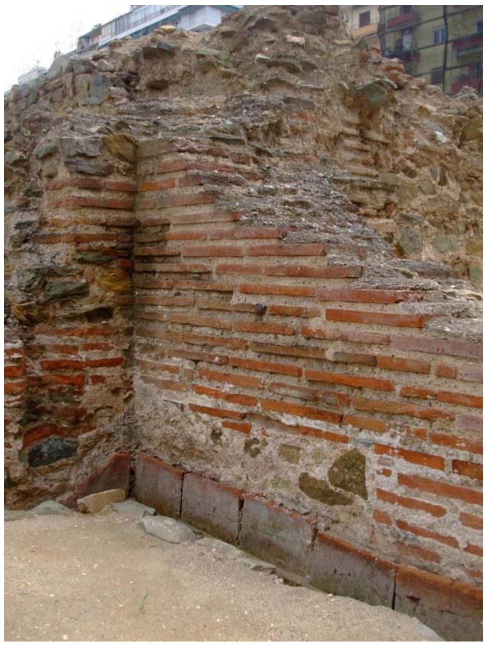



Fig.94-95 On the left a detail of a wall of the Basilica in *opus mixtum* (Galerius Palace in Thessaloniki) on the right bricks wall in *opus signinum* (lime based mortar with brick fragments as aggregates, *cocciopesto*)

Fig.96-97 Details of floor mosaics, fine and coarse tessera (Galerius Palace in Thessaloniki)

Fig.98-99 Details of the mortar strip used as marker of the reconstructive intervention (Galerius Palace in Thessaloniki)

Fig.100-101 On the right a detail of wall in *opus caementicium*, on the right a detail of structural mortar with brick's fragments of different sizes (*cocciopesto)* (Galerius Palace in Thessaloniki)

Dion

Dion was a small city, dated from end of the V century BC, embraced by defensive walls, situated at the northern foothills of the Mount Olympus. The city comprised public baths, rich houses, shops and workshops, two theatres outside from the city walls, sanctuaries as well as cemeteries, dated by the archaeologists as remnants belonging to the V century BC to the V century AD. Most part of the site is nowadays excavated. From the first century AD it became a Roman colony. The walls were essentially built with shaped and unshaped stones, alternated with the use of bricks (*opus mixtum*) (Fig.104-105) as in Aquincum.

Fig. 106-107 show that decorative elements as mosaics and paintings were common, while Fig.108-111 show details of mortars and walls also erected in *opus caementicium*, tipical of a Roman civil town.

Fig.102-103 Views of the site showing the walls in *opus incertum, opus mixtum*.

Fig.104 Detail of walls in opus mixtum, Fig.105 Detail of well shaped building stones constituting the wall without the use of any binder


Fig.106-107 Detail of decorative elements: on the left coarse tessera mosaics, on the right mural paintings


Fig.108-109 Details of different mortars: on the left a detail of structural mortar showing the absence of brick's fragments as aggregate, on the right a specimen of mortar used as support of mosaics, containing a large amount of brick's fragments of different sizes (*cocciopesto)*

Fig.110-111 Details of *opus caementicium*: on the left detail from Dion, on the right detail from the Galerius Palace.

6. Conservation in Hungary: an overview of main strategies

Here it will be describe a short history of conservation and maintenance of Roman ruin monuments in Hungary after 1949 with special regard to the causes of further deterioration. (Mezős, 1999; Zádor, 1999; Zsidy, 1993)

After the 2nd World War, in order to create a common sense in the management of the Hungarian cultural heritage, the National Center of Monuments and Museums founded, in 1957, the National Inspectorate of Monuments (OMF). The OMF as an institute for research was responsible for the conservation and protection of the monumental remains of the country. Although innumerous interventions on monuments have been carried out during the past 50 years, in this study the focus is on the activities regarding the Roman ruins.

Concerning the cleaning interventions on stone surfaces of ruin monuments, references can hardly be found, especially for those actions belonging to the past decades (60's-80's) . The most commonly used methods were the mechanical cleaning and the rinsing with pure water. (oral information from conservators Vilmos Osgyányi and Istvan Bóna, Horváth, 1998).

Conservation and completion

The principles used in conservation of monuments were posed by the Monument Protection Commettee of the Ministry of Architecture. These principles state, as a general rule, that the reconstruction of ruins should be avoided. Unique exception are the interventions aimed at the reconstruction of monuments which have partially or totally collapsed. In these cases, the reconstruction is made by using elements from the original material, trying, at least in theory, to place them back to the original position. The use of modern (cement, synthetic resins, ferroconcrete, portlandcement) material is limited to those parts which are completely missing (*anastylosis*), but sometimes their use is also allowed for missing details and architectural decorative elements. This kind of practise opens a wide range of questions dealing with the compatibility of materials, the respect of autenticity and the need of proper pre-interventions studies to face the consequences of not reversible actions.

In some cases the replacement of the missing original stone masonry was made of bricks. Scarved stones were completed by stone or artificial stone pulps with different types of binding media (lime, gypsum, kazein, resin, portland cement and even synthetic resins) (Szakál, 1977). As adhesives epoxy-resins were used usually (Nyulasiné Sztrányai, 1980) In the 1970's interesting researches were carried out on the consolidation of porous limestones with water taken from natural springs with high mineral content. (Kőfalvi, 1979).

In some cases some extra low walls were added as a protection of the original one. In that case the original and the reconstructed walls were marked either by a different method of walling or by employing a completely different material (normally portland cement). To distinguish the old from the new wall, a strip was prepared between them, as a marker of the intervention. This strip was usually a thick, red layer of mortar (containing iron oxide) (Hajnóczy, 1987, Mezős, 1999), but also made of brick. In the 1980's there were examples of the use of the so called *monument mortar* which was especially developed as portland cement free for monument conservation (Kaba, 1986). Mosaics excavated in the 1950's were often imbedded in concrete. (Kaba, 1986) Some of them were re-conserved in the 1980's using synthetic resins. (Szalay, 1983) Mosaics and mural paintings were mostly removed from the place of the excavation and conserved in a conservation workshop (Báthy, 1984).

Consequences of the early conservation practice

The extra walling and the use of the strip caused several damages to the ruin monuments. In most cases cement mortar was used instead of mixtures compatible with the original lime mortar. The incompatibility of the materials causes, and has caused, several well known problems in Hungarian monuments, such as the damaging effetcs connencted with the raising water, consequence in winter due to freeze-thaw cycles (Mezős, 1999) and the dissolution of salts contained in the cement with the resulting effects like color changes, salt recristallization, stresses in the stone. (Kertész, 1990)

The ferroconcrete elements used as supports or completions can become dangerous as well. Since their dilatation is different from that of the original masonry, and their strength is much higher the movement due to the changes in the temperature leads to the weakening of the structure. The increasing air pollution can make faster the decay of ferroconcrete speeding up the corrosion of the iron. (Mezős, 2002, Zádor, 1999; Bellanca, 1995)

Fig.112 shows a detail from Aquincum archaeological site of repearing mortar, which includes, accordin the common use in the country, brick fragments as aggregates.

Fig.113 shows an example from of the wide use of cement in the repearing of walls.

Fig.114 shows an attempt of restoring intervention and presentation to the public of floor mosaic in Nemesvámos-Balácapuszta Roman villa (Baláca). Despite the fact that polysterole resulted to be a too soft and not durable material, its advantages are the low cost, the easy and practical setting and the possibilities to be easily decorated.

Fig.115 shows a detail of a well preserved frescoes in Baláca.

Fig.116 shows the restored frescoes of Brigetio where a mixture of limestone dust, calcite crystals and dolomite powder have been used to create a support of plaster 1,5 mm thick (Bóna, 1997, 2000, 2003).

Fig.112 Detail showing the use of brick's fragments as aggregates in a repearing mortars. Aquincum.

Fig.113 The large use og cement in the restoration of walls. Aquincum.

Fig.114 An attempt of restoring intervention and presentation to the public of a mosaic floors. Nemesvámos-Balácapuszta Roman villa (Baláca)


Fig.115 Restoring intervention and presentation to the public of frescoes walls. Nemesvámos-Balácapuszta Roman villa (Baláca)


Fig.116 Frescoes in Brigetio

7. Discussion

Building stone

For the first time, by petrographical and mineralogical observations in situ material and from surrounding quarries, it can be concluded that limestone used as building stone in the construction of Nagyharsány villa resulted to have local origin.

Unfortunately, since only a few traces of walls are accessible, surely information are still missing. Therefore further sampling campaigns will be crucial to complete the study of the site.

Mortars

Different mortar compositions were found. A first obvious differentiation is between the mortar used during the 80's repearing interventions and the Roman one. The first shows the presence of Ettringite, which is known to be a product of the decay of modern cement-mortar, while it is absent in the Roman mortars.

Differences are also present among the Roman mortars that have been collected. All mortars can be defined as lime-based. While the content of CaO is quite stable in mortars used as a support for mosaic or paintings (32,04 - 35,06 % w.t.), there is a large variability in the mortars used for building (30,22 - 46,73 % w.t.). This might simply mean that the builders paid more attention to the selection of lime during the preparation of the mixture for mortars with a special function, such as the one used for decorative elements, in order to better control characteristics like the thickness or the strengh.

On the contrary, the content of MgO in building mortars is stable and, as expected, very low (0,68 - 1,01 % w.t.) while in the mortars used for decorations, it shows a certain variability and it is quite high (5,60 - 7,60 % w.t.). This seems to prove that Romans already knew of the plastic properties of dolomite, and used to add it to the mortar in order to apply it as mural painting support in an easier and more efficient way.

In all kinds of mortar there is a quite high and similar content of SiO_2. This seems a strong indication that all mortars have pozzolanic properties, due to the probable addition of either vulcanic ashes or also fine fluvial sands or clay with high content of alumina and silica, although no definitive petrographical evidences were found. For this reason a further sampling campaign and a new series of analyses (XRD and petrographical) is strongly recommended.

As expected, there is a different range of size distribution of the aggregates (mainly pebbles) in the two kinds of mortars. In the decorative mortar, the main grain size varies from 1 to 3mm while in the building one from 2mm to 2cm. The finest size of aggregates is also associated with the presence of small brick fragments ("*cocciopesto*"), which are on the contrary missing in the mortar used for building. (Bruni, et al., 1996)

All these results indicate differences in the procedure of mortars production, in the selection of the compounds, in the techniques used for building and the changes occurred during the centuries.

It is possible to make an attempt to correlate the archaeological and historical knowledge of Archaeologists with the analytical results on mortars achieved during the present research.

The petrographical observations, supported by chemical analyses, lead to define at least three types of building mortars, which differ for the content and type of pebbles as aggregates, their size distribution and the content of the main oxides. The drilling tests showed that they also have different average patterns of resistance.

Previous the archaeological data suggested that mosaic fragments with geometrical and figurative decorative patterns dated back to different periods. The results of this work show that the two different kinds of mosaic's patterns correspond to different mortars mixtures. Although such tests are usually performed with other purposes, here, they resulted to be a useful and fast tool as a further support to differentiate and categorize the materials. Thus drilling resistance tests, combined to petrographical-mineralogical and chemical analyses, can be useful as a further way to distinguish different kinds of mortars, belonging to different kinds of mosaic, related to different construction phases or position in the complex of the several annexed units constituting the site.

Matching all the historical information with the one collected "in situ" and in the laboratory, it was possible to elaborate a possible sequence of construction phases. The Fig. 91 shows by different colours the supposed chronological order based on the chronology provided by the Archaeologists (Chart 25).

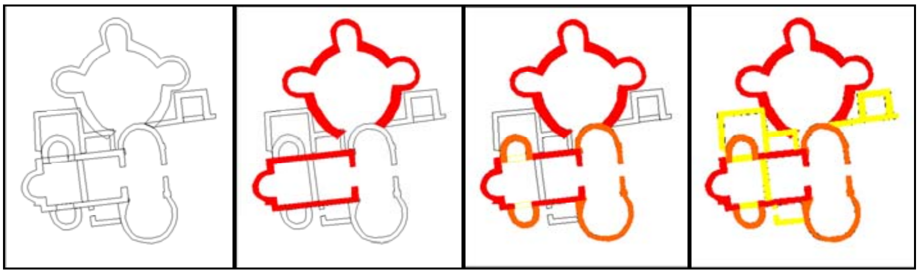


Fig.91 Drawing of the map of the site showing by different colours the possible interpretation of the construction phases: beginning of the III century shown in red, the end of the III century in orange, beginning of the IV century in yellow.

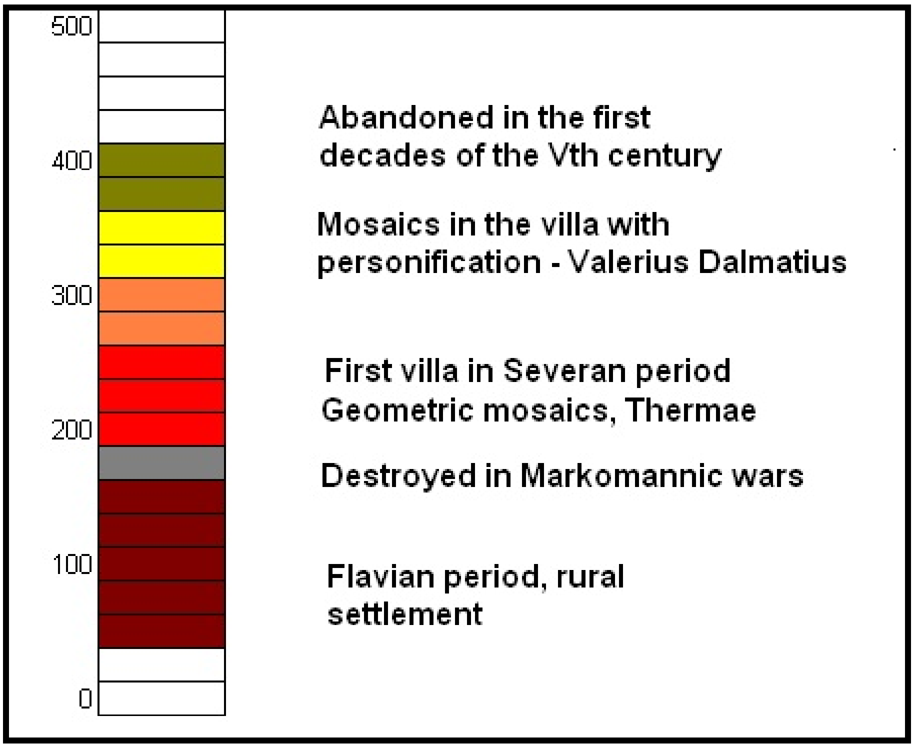


Chart25. Chronological table based on historical data provided by the Budapest Museum's Archaeologist in charge for the site.

Further investigations on the building and decorative material is necessary to provide a conclusive interpretation of Nagyharsány archaeological site structures. New sampling campaigns are strongly needed, especially on the areas which are not excavated yet.

Furthermore, from chemical analyses it can be argued that all mortars analyzed so far don't show any relevant content of soluble salts. This unexpected data reveals that, although the open-air condition surely had and still have an impact on the state of the site, there is no evidences of a severe damage due to re-crystallization of salts.

In conclusion, up to know, the most dangerous risk affecting the few walls monument exposed to the environment is the effect of the freeze-thaw cycles and the action of bushes and tree's roots and branches on the structure of the walls.

The presence of fragments of romboedric Calcite, revealed by the petrographical study, recalls an open question concerning Roman mortars and plasters, and the definition of their aggregates. (Daniele, et al.,1993; Daniele et al.,1996)

According to the literature, especially the one concerning mural paintings, the *tectorium* (Latin term to indicate the overlaying structure supporting the painting layer) usually consisted of three mortar layers (lime and sand), followed by one or two thin layers of mortar containing finely ground marble, the so called *marmatum* or *opus marmatum.* (Barbaro, (*ed.*), 1993). The surface was then worked, when still moist, until it became strong and perfectly smooth. (Adam, 1984; Ward Perkins, 1974; Giovannoni, 1925)

This ancient decorative technique was mentioned by Vitruvius in his book:

"*…incernatur marmor, et supra loricae ex calce et arena inducantur..*" (Vitruvius, Marcus Pollio, VII book, chapter 1, p.511-512)

meaning to "apply marble dust and a coat of lime and sand", and it is known to be used by Romans also when they wanted a polished surface to have a "marble appearance". Nevertheless, in the same book, a few pages after, it is also mentioned the use of another kind of dust:

"*Marmor non eodem genere omnibus regionibus procreator, sed quibusdam locis glebae* *ut salis micas perlucidas habentes nascuntur, quae contusae aet mollitae praestant (tectoriis et coronariis) operibus utilitatem. Quibus autem locis eae copiae non sunt, caementa marmorea, sive assulae dicuntur, quae marmorarii ex operibus deiciunt, contunduntur et moluntur, et subcretum et subcretum in operibus utuntur* " (Vitruvius, Marcus Pollio, VII book, chapter 6, p.552)

meaning "the quality of marble is not the same in all countries: in certain places, in fact, masses similar to salt crystalline lumps are born, with some little transparent and bright fragments; these masses, after grinding, are very useful for plasters and frames. But, where it is not possible to find this kind of material, it is used to grind marble fragments, remnants of the workmanship of marble, after a proper sieving".

This description by Vitruvius makes clear that he refers to those hydrothermal carbonatic crystals (salt like) available in veins or hydrothermal deposit, far from being similar to the marble dust properly said, but corresponding instead to the spatic Calcite in fact, here meaning well rhombahedron shaped big crystals, with evident planes of cleavage (Venturini Papari, 1901; Daniele et al., 1996). Thus, the ancient author recommended, for the preparation of plasters and mortars, the use of this "*marmor*", referring univocally to the spatic Calcite, available in veins or concretions, and mentioned the use of marble dust only as a secondary solution.

The use of this kind of aggregate in Roman plasters indicates a more elaborate technique than the one with travertine, rare but documented for example in the study of the Domus Aurea in Rome (Marchi,, 2008), or with marble dust. Although the availability of such a kind of Calcite was not that easy, the resulting plaster was very appreciated by the Romans because of its shine and brightness.

It seems that, although in the literature these different kinds of aggregates are quite often confused and mistaken one for the other, a distinction is actually possible and demanded, since it is a marker of the authenticity of plasters and mortars of the Roman period. It has been also suggested that fragments of rhombahedron Calcite as aggregate added to the mortars do improve its physical properties (Daniele., Gratziu, 1993).

Through the petrographic study it is possible to discriminate between a ground marble dust and a ground rhombahedron Calcite. In order to be able to distinguish between the two, marble fragments were ground and observed by stereomicroscope and optical microscope. The grains maintained the rounded shape of Calcite crystals constituting typically the marble structure, while when grinding rhombahedron Calcite they break according to the planes of cleavage and they maintain that particular and recognizable shape.

In the case of Nagyharsány, the petrographical study confirmed that in both mortar layers present as support of mosaic the aggregate is represented by such kind not well-sorted fragments of rhombahedron spatic Calcite and not by marble dust.

Decorative material

According to the characteristics of the three typologies of black, red and pink tesserae, and taken into account some of the limestone characterizing the area, which is one of the richest in such kind of material, their origin seems to be definitely connected with local sources.

Concerning the white tessera, it was identified as marble. On the base of petrographical study, it resulted to be a coarse-grained marble, apparently not affected by the presence of veins. Peculiar inclusions were found, characterizing the material as a unambiguous marker. No match could be found with marbles from Transdanubian Basin. For this reason, and according to the literature on Roman mosaics in Hungary (Kiss, 1973), it is reasonable to consider the marble constituting the tessera coming from distant regions, (Corsi,., 1991; Fiora, et al. 2005; Paparati, 1990) as the result of the trades that Romans were able to establish and maintain all over their Empire. Marbles coming from far Portuguese regions have been reported (Prof. Gratziu, University of Pisa, personal communication; Ling, Apr 2005), but further and more specific analyses (SEM and EDS analyses) are necessary to univocally define possible matches and to identify the origin.

Macroscopic and microscopic observations of samples from mural paintings reveal that they are composed of three layers.

The main surface of all samples results to be very smooth and, generally, every single layer is plane and well worked, testifying a good attention in the creation and the smoothing of the sequence of overlying levels. The stratigraphy results to be very uniform.

The finding of an external calcitic layer, lying on the painting surface, could be the result of re-crystallization processes occurring on the surface, which would attest a not very healthy environment for the state of conservations of the painting fragments. Anyway, such a layer was found only in one sample; could be due to the environmental conditions in the storage room of the Museum's basement which can vary also depending on the location of that fragment since there is no monitoring system for humidity or temperature and no equipment to keep conditions stable.

8. Conclusions

In Nagyharsány site:

- Building material has local origin while more precious material (mosaics) is probably imported from distant region of the Roman Empire;
- By a non obvious use of investigation techniques at least three construction phases were identified, thus confirm the chronological interpretation provided by the Archaeologists;
- Walls were erected with the Roman *opus incertum* technique. There are no evidences of the use of bricks for the walling, probably due to the costs of their manufacture;
- Mortars used as support for mural paintings show the presence of rhombahedron fragments of spatic Calcite, and not finely ground marble (*marmatum)*.

In Aquincum:

- Masonries follow the *opus mixtum* and *opus caementicium* technique;

In Nemesvámos-Baláca:

- Wide use of Roman building techniques (*opus mixtum*, *opus incertum* and *opus spicatum)*

In the Galerius Palace and in Dion:

- *opus caementicium, opus incertum, opus mixtum* techniques were observed

Roman *cocciopesto*

- Brick fragments used as aggregates in the mortars were found in mortars used as support for mosaics, although not in the structural one.

Building and decorating techniques in Hungary strongly refer to Roman knowledge and practise, with a wide use of local materials.

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