POSTERSESSION

About the use of latest technologies for determining the metal composition of archaeological jewellery

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Abstract: This study is devoted to investigation of origin source of jewellery and metallic items stored in the National Museum of Azerbaijan History at the National Academy of Sciences. The results of analyzes made by the XRF methods identified the chemical composition of archaeological monuments and showed that, the majority of jewellery are made from the local raw materials by Azerbaijanian jewelers.

Keywords: jewellery, archaeological findings, element content, XRF analysis.

As a result of archaeological excavations on the territory of Azerbaijan there were collected a large number of artifacts indicating the presence of ancient knowledge in the field of metallurgy and jewellery. As we know, the territory of Azerbaijan from V millennium BC was one of the most important metallurgical centers of the Caucasus (ASLANOV et al. 1966: 64; HASANOV 2011), played an important role in the development of ancient industry in the region. Many different attributes of metallurgy (slag’s, fragments, molds, crucibles residues of metallurgical furnaces) proved their local production (SEYIDOV and HASANOV 2005: 275). The copper-bronze objects and their chemical composition have been investigated, at that time the gold and silver artifacts of antiquity have not been studied. For the first time the chemical composition of the jewellery was investigated and identified that artifacts of the Museum had a similar composition to the ores of gold fields in Azerbaijan.

The source for this study is a unique collection of archaeological specimens of jewelry made of precious metals in amount of 120 pcs. of the Special Fund of the National Museum of the History of AzNAS. These artifacts are the most vivid and authentic archaeological sources, allowing investigating the certain aspects of material culture of ancient Azerbaijan. The aim of this study is to determine the chemical composition of samples of the types of jewelry alloys, which will allow us to show the degree of development of metalworking and manufacturing methods of that period. Investigation of the chemical composition of non-ferrous metal jewelry helps to identify characteristics of raw materials and possible sources of non-ferrous metals from I BC to the XII–XIII centuries and estimates the local non-ferrous metal. All this in a wider context will make it possible to reconstruct the source of production, organization of craft activities in different historical periods and to monitor changes in the level of craft skills in a particular area.

Techniques

Most of the archaeological objects from the museum's collection are not subject to pilot testing, and many entries in the inventory books of the Museum maintained a visual description of archaeological materials. Therefore, for the first time in Azerbaijan latest technology Portable X-ray fluorescence spectrometer, this belongs to a new generation of non-destructive technology that allowed us to determine the concentration of elements in % in metals for 35 seconds. Used equipment has follow parameters: Excitation Source Xray tube, Ta anode, 10-40 keV, 5-50 μA, five filter positions. This technology allows to quickly exploring a large number of archaeological objects to determine their chemical composition and creation of a single database, "Non-ferrous metals and their alloys in the territory of Azerbaijan."

I. The oldest gold in Azerbaijan. Bronze Age archaeological material brought to us the image of an ancient civilization, represented by three bronze cultures, the Kura-Araks, Nakhichevan and Khojaly-Gedabek regions. During this period, there is a significant increase in the population, the emergence of large tribal unions, increased military clashes, the increase in the number of settlements, and most importantly, strengthening ties with the urban civilizations of Mesopotamia, Asia Minor and Iran, etc. The process of folding of early urban civilization and state formation begins to occur in the most developed regions of Azerbaijan (end of the III–beginning of the II millennium BC). Judging by the nature of the archaeological finds of the population in the settlements of the Bronze Age is beginning to lead a sedentary life, and among the peasants, farmers are allocated specialized craftsmen, mainly in industries such as pottery and metal. The economic development of mountainous areas of Azerbaijan took place not only for the purpose of breeding, and metallurgy. So rich deposit of iron, titanium, gold, silver, copper, cobalt, chromite ore and other base metals territory of Azerbaijan has become a source for the early development of mines and folding crafts.

Information on the availability of gold in the Caucasus in ancient times is found in the writings of ancient authors of I–II cent. (JAFAROV 1984: 106 ff.). “Behind the gates of the Caucasus, as claimed by Pliny, on the mountains of Gordie, forming a valley, the barbarians have developed gold mines.” In the XVI century, Georg Agricola, known as the “father of the industry”, in his work “De Re Metallica” fairly describes in detail the high-tech and complex process of extracting metal from ore (SEYIDOV and HASANOV 2005: 275) where it says: “In the Caucasus, large and small rivers that carry the golden sand. As local residents collected gold dust on the perforated plates and sheep skins, placing them on the bottom of the river, perhaps, was the source of the legend of the Golden Fleece” (http://geoman.ru/books/item/f00/s00/z0000039/st025.shtml).

In addition to the availability of local raw material base for future economic development played an important role and proximity to the ancient civilizations of mankind.

In 1987 in the village of Sheki Kudurlu of Azerbaijan, the archaeologists found gold plates of the finest jewelry XX–XVIII centuries. BC: necklace (218) in the form of a shell (Fig. 1), two round pendants decorated with rows of ornamental point (220) and two hollow beads (219), covered with a convex pattern (Fig. 2). These products, age about 4,000 years, affecting not only the elegance of form, technique, finishing, but the purity of gold alloy.

Fig. 1 – XF 268 - fragment of necklace, gold, machinery casting, found in v. Kudurlu of Sheki region of Azerbaijan, XX–XVIII centuries. BC, weight - 10.2 g. Composition: Fe-0.0739; Cu-1.9093; Ag-16.1228; Au-81.8940.

Fig. 2 – XF 219 - Beads, Gold, casting technique, found in v. Kudurlu of Sheki region of Azerbaijan, XX–XVIII century BC. Composition: Ti-0.3206; Fe-0.3978; Cu-1.7054; Ag-15.8363; Au-81.7856.

The study of the structure of gold and silver in the most ancient archaeological jewelry shows that its contain in the oldest gold in Azerbaijan 81% and silver more than 15% with a natural mixture of titanium, iron and copper. Jewelers for the manufacture of these products from the finest gold used the technology of casting and soldering. In more recent times things have invasion of the Huns (IV–V centuries.) Observed a similar chemical composition with the percentage of gold - 81.7399 where silver increased in the amount - 28, 7314% (Fig. 3).

Fig. 3 – XF 118 - tiara (ASLANOV et al. 1966: 11) of a sheet of gold coinage with 192 garnet inlays and two obsidian. Hynysly Shamakhi district of Azerbaijan, IV–V centuries. Composition: Ti-0.1294; Fe-0.1125; Cu-3.9613; Ag-28.7314; Au-81.7399. In the Middle Ages XII–XIII centuries purity of gold was observed - 87.5%. Impurity composition is different, there was found vanadium.

Fig. 4 – XF 280 - piece of jewelry, gold, Lankaran region, XII–XIII centuries. Composition: Ti-0.0970%; V-0.1221%; Cu-3.0628%; Ag-9.1689%; Au-87.5492%.

This model is particularly interesting because it allows to detect changes in the formulation of alloys and allow to identify correlation between chemical composition with historical time from the I millennium BC until the middle of I millennium BC, that can be evidence of using of the same source local gold mine. Archaeological findings stored in the collection of the Museum, show that the II millennium BC Azerbaijan was not only hunted, but were able to extract valuable metals from ores, processing raw materials into precious metal in a sufficiently pure form and were able to make high quality stuff. Perhaps there is a selection from the community groups dealing with only the steel industry. Already from recycled metal artisans create beautiful jewellery designs, jewels for the Arts and compositional properties, which can judge the level of aesthetic needs and tastes, technical, professional knowledge and capabilities of jeweler’s era. So many archaeological jewels of mid-first millennium from the vaults of the Museum, shows that about 3000 years ago making jewelry was a popular profession among the population not only of Egypt, and the cities of Sumer and Azerbaijan.

During this period, the ancient jewelers of Azerbaijan was casting technique quadrupeds «tükmə», crimping «çaxma», soldering «lehimləmə» (SADIKHZADE 1971: 76). The greatest difficulty of execution and reception of distinguished decorative beading jewelry «dənəcik» (from the VII century BC), when the tiny balls of equal size of the noble metals, soldered on a hot surface to hide the soldering, or combined with each other, forming bunches of grapes (GUMEL).

The results of analyzes

Application of this method of research has helped characterize the jewelry types of alloys, which are indicators of the dynamics of the metalworking and manufacturing methods. Based on our results of analyzes of the chemical composition of metals, it can be stated that the Azerbaijani jewelers know their ratio in the alloys to obtain sufficient strength and colors. Investigating the chemical composition of the metal can be judged on the availability of raw materials to Azerbaijan and possible sources of releases of non-ferrous metals in the country. Conduct in the broader context of similar analyzes of archaeological material in adjacent areas would the comparative historical method to reconstruct the path of cultural activities and relationships going through the dissemination of technological advances in certain historical periods. In conclusion, it should be emphasized that these results indicate that the precious legacy left by people who knew many secrets of metal. The presence of a large number of steel alloys in the metals studied can be explained by the existence of various technological recipes. It is assumed that the establishment and operation of the information system will enable a new level of understanding of the formation of metal and jewellery business in Azerbaijan and neighbouring countries. The results of an analytical study of gold products identified in the archaeological monuments of Azerbaijan have shown that the parsing of the local product production. This is evidenced by the chemical composition of the investigated products. Almost all of the products along with the increased of the content both gold contain higher impurity of silver and copper. The gold content comes to 99.7595%. The copper content in the range is from 0.7494 to 36.1655%, silver is from 0.815 to 33.7840%. We know that in Gadabay gold deposits in the radical associated with copper and silver. Therefore, the probability of Gadabay field to manufacture products under study are not excludes. Other products are silver objects, as well as provide an alloy of silver and gold. The results of analyzes of

silver goods shown in their composition increased admixture of gold, copper and minor impurities of other elements. It should be noted that all the impurities in gold and in silver products are natural impurities of the original ore, of which-pared from these products. A natural alloy of gold and silver called electrum and is often found in nature in the territory of Azerbaijan. Silver products containing gold and copper are likely to be domestic products on the basis of occurrences Gadabay district, because the natural impurities of gold and silver to copper occurrences are inherent in this. Therefore, the use of Gadabay ores for the manufacture of these products is more likely. Investigating the chemical composition of metal jewellery, we found the presence of not only raw material base in Azerbaijan, but also received non-ferrous metals in the country. An example of a product containing 99.7595% gold, there is no silver and copper. It is, apparently, made of native gold, which is not the previously mentioned item. This product can be brought in, and do not exclude the possibility of its local production. The discovery by archaeologists as the imported jewellery is not accidental, because in the investigated time, the population of Azerbaijan was ethnic different and its territory was on the route of the Silk Way, so there were common things not only made here, but got from the outside. Gold, tin, mother of pearl and others were here anciently objects of barter (GUMEL). Conduct in the broader context of similar analyzes of archaeological material in adjacent areas would the comparative historical method to reconstruct the path of cultural activities and relationships, going through the dissemination of technological advances in certain historical periods. In conclusion, it should be emphasized that these results indicate the precious legacy left by people who knew many secrets of metal. The presence of a large number of steel alloys in the metals studied can be explained by the existence of various technological recipes. We assume that the establishment and operation of the information system in neighbouring countries, will allow us to move to a new level of understanding of the formation and interaction of metal and jewellery of Azerbaijan and neighbouring countries.

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Abu Simbel

A re-lecture after half a century

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Abstract: In the past century, at the end of the fifties, the project of the Aswan High Dam, put the monuments of Nubia in danger. UNESCO promoted the “Nubian Campaign” to involve western countries in the salvage of the Abu Simbel Temples. The survey of the area, essential for the operations, was made by the Institut Géographique National Français (from 1956 to 1963), using innovative – for those times – technologies like photogrammetry.
As it is well known, the salvage of the monumental area was done cutting the statues and the buildings in parts and moving them to a safe position near their original site where they were reconstructed in the best possible way. After 50 years, it is possible to attempt a new reading of this impressive operation, analyzing the original photographic survey made by IGN and applying the same methodology used in the past with a computer software: through the stereoscopic photographs and the coordinates taken during the survey campaigns it is possible to digitally reconstruct the main parts of the Great Temple façade, into a digital 3d model. This will be an interesting contribution to the knowledge of this monument, offering a reconstructive representation of the original temple. But the research project is intended to go far beyond this step. If in the next months it will be possible to document the monuments by means of laser scanning, there will be the opportunity to compare the old survey made on the original site of the monuments and the new one on the actual dislocation to compute a map of differences, which are due to possible erroneous reconstruction or changes with time, and to investigate the state of the monument in details.
The poster proposed here will show the state of the work in this challenging research.

Keywords: Abu Simbel, Nubia, Unesco, Photogrammetry.

A short history of the monument

The two Abu Simbel Temples were created by King Ramsess II during the 12th century b.C., in Lower Nubia 280 km south of the First Cataract of the Nile, at Aswan. They are two rock temples of different size, situated on two sides of a natural recess of a hill. The Great Temple was officially consecrated to the gods Amun and Re-Horakhty: indeed the Great Temple was executed for the king, as an incarnation of the god Horus. The Small Temple was dedicated to Nefertari, the great royal spouse, identified with the goddess Hathor. Both temples were hewn out of the rock and each consists of an outer façade and of inner rooms, 14 in the Great temple, and 5 in the Small temple. The Great Temple façade has a width of 35 m at the base and 29 m at the top, and a height of 32 m. It is dominated by the four colossal statues of Ramsess II himself, each about 20 m high, and in addition, a great number of smaller statues. The Small Temple, originally located just above the high-water level of the Nile, has a façade 27 m wide and 12 m high, is dominated by six upright statues 9–10 m high, four of Ramsess and two of Nefertari. The temples remained unknown until 19th

century. The Great Temple was located by Ludwig Burckhardt and then released from the hill of sand that covered the façades, by Giovanni Belzoni in 1816. The French-Tuscan survey mission, in 1828, was the first interested in a modern documentation of the temples. Plans, fronts, epigraphs and colours we studied, drawn and collected in publications by architects and archaeologists under the guide of François Champollion.

Fig. 1 – View of the Great Temple Façade (Ph. Elena Fabrizi).

The temples, since their discovery in modern times, have been always an object of interest, and they have left in their original condition until the 20th century, when progress and technology challenges came. The revolution of 1952 aspired to an economic and social renaissance in Egypt and one of its vehicles was the Aswan High Dam. The production of electric energy, the improvement of agricultural land, the prevention of Nile's floods leaded by the dam were urgent facts, more than the sacrifice of Lower Nubia and all his archaeological sites. In 1960, the great works began officially: they have been completed ten years later. A very small number of monuments could be saved from the submersion, and for this reason, in 1954, UNESCO entrusted the inventory and the documentation of the archaeological sites to the new-born “Documentation and Study Center on history of the art and civilization of Ancient Egypt”.
In this way the Nubian antiquities wouldn't have completely lost even if the original couldn't be saved.
The Documentation Center consigned the task of surveying the temples to different groups of specialists and institutions. The missions had their headquarters on boats docked on the Nile shores, supplied with a photographic laboratory, and advanced technical equipment. Every national mission could bring on their surveys on the temples. Every hieroglyph has been copied by a group composed by Egyptian, Italian, British, German egyptologists; the Greek engravings, and inscriptions in any modern language, were studied by Egyptian and French epigraphists. Archaeological descriptions were made by Egyptian, Italian, French

egyptologists; architectonic surveys by an Egyptian and a Swiss architect. Pictures by Egyptian and American photographers; drawings by Egyptian and french drawers; mold and models to Egyptian artists, photogrammetric surveys by french surveyors from IGN “*Institut Géographique National Français*”.
It performed the duty in many photogrammetric survey campaigns done from 1956 to 1963.

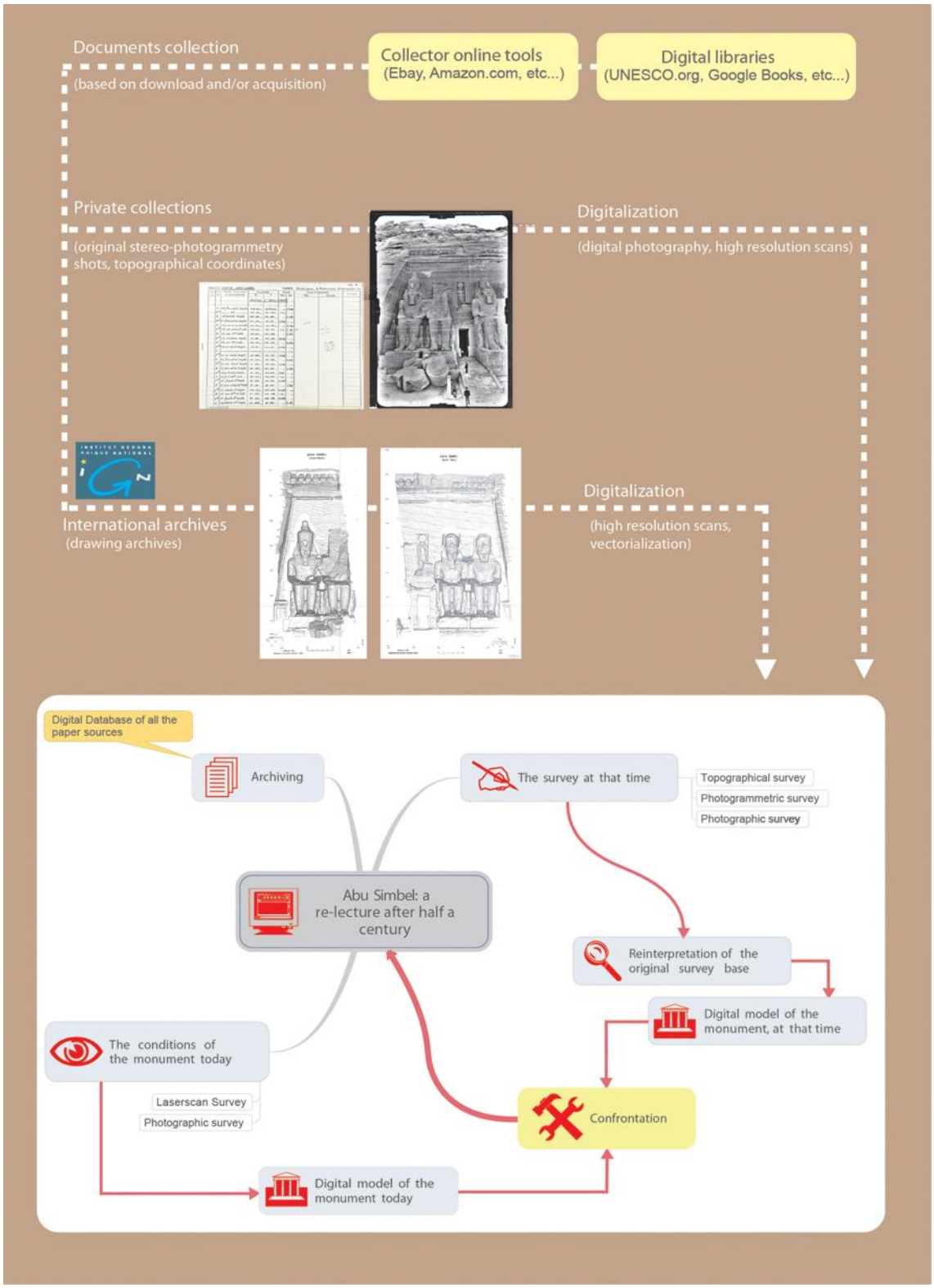

Fig. 2 – Schematic model of the collection of monuments and digitalization process.

The Nubian Campaign to save the monuments, officially began the 8th March 1960 with the appeal of the UNESCO Secretary to the governments, to public and private institutions and foundations to contribute with services, instruments or funds. The salvage operation was an outstanding example of collaboration between people of different categories and professions and also many different nations. Until this time, every monument situated inside the borders of a country was that country's affair. Since the Nubian Campaign a new idea was born: monuments were considered as part of the Cultural Human Heritage and became subject of interest for the entire international community.

Collection of documents

The search for documents has been largely helped by the Internet and particularly by the UNESCO website. The international character of the Salvage project, the press campaign all over the world, the different nationality of the researches done in the field fifty years ago, fragmented the whole documentation. The collection has been easier through on line collector sites and digital libraries. Tools as Google books, Amazon.com and Ebay.com helped us to find paper documents in University libraries or buying them from private collectors (from Italy, UK and USA). To manage the large, enormous amount of documents written around the world about this monument and about its salvation, a specific offline database has been built, it collects all the records about this library and it was developed little by little incorporating each meaningful document. In this way it is possible to quickly investigate all the resources organized inside this research. Obviously it allows a good query inside the whole archive, accelerating the whole retrieve process.
The progressive digitalization of the UNESCO library is giving us a wide panorama of the subjects involved, without necessarily being physically inside the library. This would have requested a really long time, since the material on the subject (newspapers, magazines, books) is huge and written in different languages. Obviously, the easiness of the download really helped making more affordable this phase of the work.
On the other side, the photogrammetric material has been collected from private collectors and IGN archive. The documents, pictures and sheets, both on paper, have been digitalized in high resolution photos and scans. These scans have been converted into vectors using Autodesk Autocad in a long operation of following each path of the contour lines and re-drawing them.
In this way all the drawings has been accurately transferred into the digital age, allowing the use of this data inside a CAD environment and making it possible to use this information for new modeling from the survey data of the original monument. Even if this is a time consuming task, the choice to almost manually redraw every line allows a great control on the accuracy of the resulting digital tracing. Before deciding to complete this task in this way various automatic tracing software were tested (Softsoft Wintopo, Avia Scan2Cad, AlgoLab Raster to Vector Conversion Toolkit), but none of them was capable to offer the same correspondence between the original image and the result if compared to the human drawing process.
It is worth to say that in our research we were mainly interested in the photogrammetric survey done by IGN. We are now completing a digital data-set of the state of the Temples before the moving and in this first phase of our research we concentrated our efforts towards the Great Temple façade. This is due both to the dimensions of the area and to the fact that we easily found a very well preserved drawing of this part of the archaeological site. This part of our work we consider as the first fundamental test of this research.

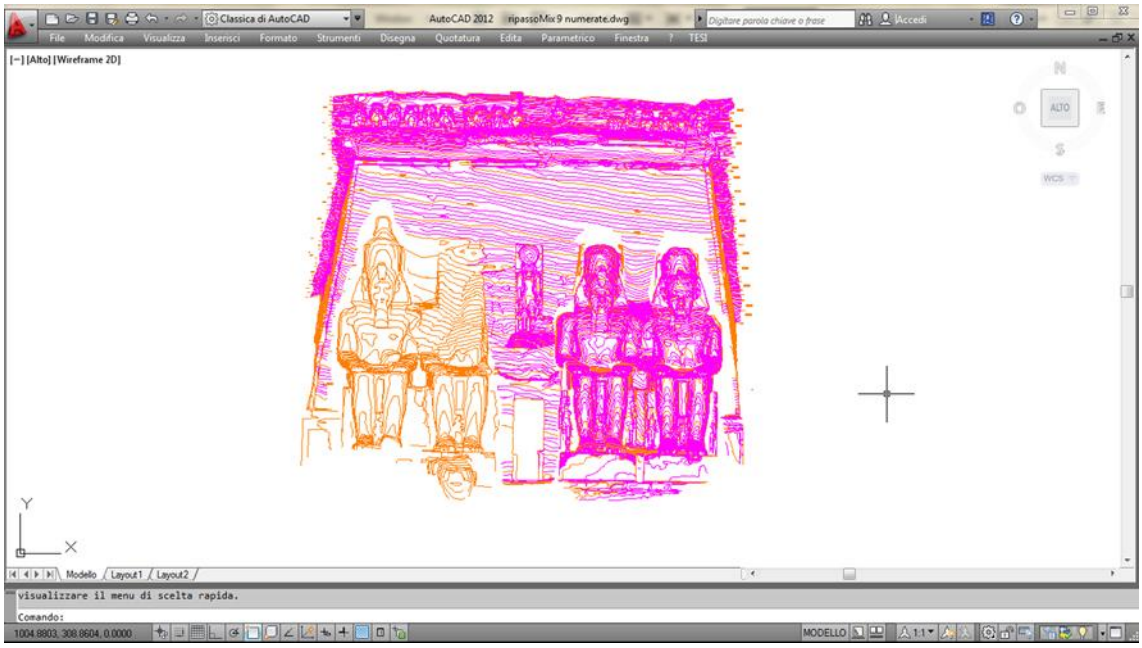

Fig. 3 – Screenshot of the re-drawing process. Contour lines of the Great Temple Façade.

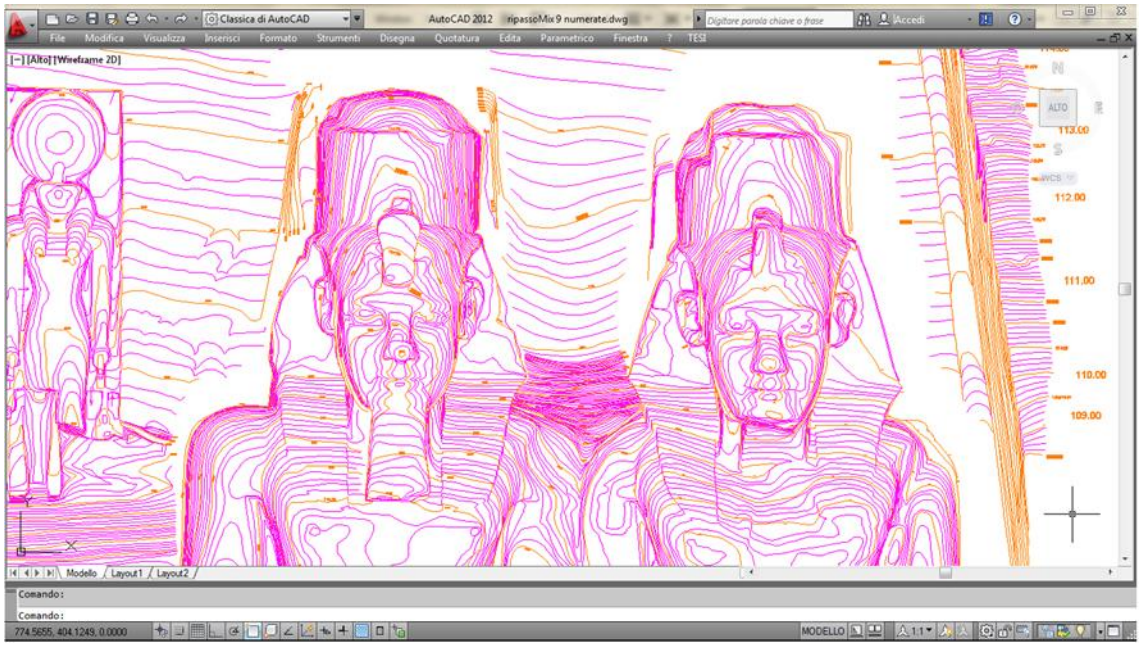

Fig. 4 – Screenshot of the re-drawing process. Contour lines of Pharaoh's heads of the Great Temple Façade.

Photogrammetric survey

The photogrammetric survey of the temples was entrusted to IGN by the “Documentation and Study Center of Ancient Egypt”. Photogrammetry was used to survey monuments since the second half of 19th century, and was born together with photography. It is a science based on perspective laws coded by descriptive geometry. It is commonly used for topographical survey with aerial measuring pictures, for architectural surveys with precise terrestrial measuring photographs, and it was applied to the temples' site in similarity to terrain surveys. In particular, in Abu Simbel, IGN used stereophotogrammetry: a branch of this geometry

based technique that involves two photos of the same object, taken from two different points of view. Through a mechanical, analogical or digital machinery it is possible to have a three dimensional view from the stereo shots, to see the different levels of depth and to draw contour lines of the temples in the same way as for land surveys.
IGN surveyors took the stereo shots of the exterior parts of the monument with a 13x18 cm (5x7") precision view camera (the contact print available from the “Istituto Papirologico” in Florence clearly show this), working inside and outside the temples. It was a very professional solution for that time: glass negatives have been used, in order to minimize negative distortion. Developed with field equipment, and soon being contact printed for security as well as for the fieldwork images.
Within the photographic campaign a series of points in a local XYZ system of coordinates were taken, such which are best visible also in the stereo images. Each of these points was precisely located with a needle in the field-copies and numbered in order to guarantee correspondence between nature and photographs. These so called “passpoints” had to be visible in both perspectives of the stereo pairs.
Today we want to use these photos to have a survey of the monument as it was before the dismantling and the moving. We have the source shots, the system of points and the resulting contour lines, but no correspondence between them. We have couples of shots referenced with coordinates: on every picture there are at least 6 points that, most important thing, don't belong to the same plane. Their position is known in a XYZ system so it is possible to set a relation between the 3D space and the projective plan of the two shots. The real problem to correctly use these shots is the missing data about the orientation of the pictures. Computer technologies help us to provide for it, thank to the modern digital photogrammetry we were able to to get through this lack of knowledge. Using an AutoLISP code it is possible to bypass the problem, through the known point coordinates in a 3D Autocad space. AutoLISP is a programming language, specific for Autocad, it enables group of existing commands to encode procedures. Knowing 6 non-planar points, with their coordinates and their position on each shot, it is possible to determine a projective transformation matrix associated to each picture. Having at least one couple of pictures and their associated projective matrices it is possible to determine the position of a point in coordinates XYZ from his two projections on each shot. In this way it is possible to draw contour lines (using the polyline drawing tool).
This method allows the correlation between the real point in the 3D space and their projection, and may permits also the opposite procedure, the reference of the 3D point to a point on a plane. This verifies the correctness of the process in presence of curved surfaces. As an additional feature, when it will be possible to survey these monuments directly a laser scanner campaign will be planned, it will allow to project the new real condition of the object in the old pictures to compare the new with the old and to see the probable differences after the moving. The comparison will also be possible between each single point in the ancient 3D space and the actual one in form of a point cloud.

Conclusions

The will to investigate, understand and unveil something left inside this meaningful match between humanity, heritage, industrial needs and genius, is the backbone of this research, thus the incoming dramatic Egyptian events have stopped the whole process, the idea to develop a complete analysis about the condition of the

Abu Simbel monument is still at work. This intention is aimed to produce a definitive state of the knowledge about the sense and the real result coming out from this long experience, to bring to light the meaning of the whole operation. Was the monument saved or the transformation went too far off the original one? The following studies and the next steps in this research, now still under development will try to put an answer to this, according to the effective possibilities given by the global situation.

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Vernacular Sustainability at Santorini

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Abstract: The Underground dwellings are most popular in regions where there are many natural caves such as Spain, Italy and Greece. The oldest and most simple form of residence in the Aegean is what we call cave house, meaning the traditional building which is found inside the rocks (like carved grotas) with a domelike roof, a narrow facade and a narrow but long space inside.
According to their form underground dwellings acquire different names as well as aspects. Underground or cave structures in Greece have been used mainly for refuge, religion or dwelling uses such as storage, water reservoirs and industrial activities which included oil presses and wineries, up until this era of touristic boom where now they are mostly used as homes or hotel rooms. Their use and occupation in some areas has been almost continuous from prehistory until today and most of them enabled people to hide from intruders for a long time. The combination of the ground temperature alongside with the architecture of the dwellings provides a 'comforting' environment.
Nonetheless, due to the morphology as well as the constructing materials used for these underground dwellings, the presence of Particulate Matter is ensured.

Keywords: Cave, Underground dwellings, Earth integrated, Microclimate, Temperature, Particulate Matter.

Cave Houses at Santorini

Referring to the evolution of the human \habitat and worship in the Aegean, from the Prehistoric era until today, the cave techniques were applied mainly for housing or storage but also for churches and cemeteries. One of the main reasons for the use of these caves was the protection from the sometimes extreme climatic conditions that prevailed mostly during the summer time (very high temperatures), and in some cases from strong winds that increased due to the lack of sheltering from the steep cliffs. The specific urban fabric form of the Calderas villages of Santorini with the high urban density, the narrow streets and the small buildings, is due to the shortage of proper ground for construction , the need of protection from the strong irradiance and the wind, security reasons and family growth, the economy and the highly communal spirit of the old societies (STASINOPOULOS 2006).
At Santorini cave villages were created alongside the caldera, where the land was easy to work and to shape.
Santorini is a small, circular group of volcanic islands located in the Aegean Sea, about 200 km south-east from the mainland of Greece. It is also known by the name of the largest island in the archipelago, Thira or Thera. The island was the site of one of the largest volcanic eruptions when it erupted cataclysmically about 3,500 years ago. Before the eruption Santorini was known as Stroggili due to its circular shape but after the eruption many parts of the island sank with the formation of small islands. Due to its morphology parts of the island specifically near the cliff provide a good architectural structure for the underground dwellings. The

specific types of dwellings were selected in order to monitor the direct effect of the local architecture and it’s almost “positive” environmental conditions.

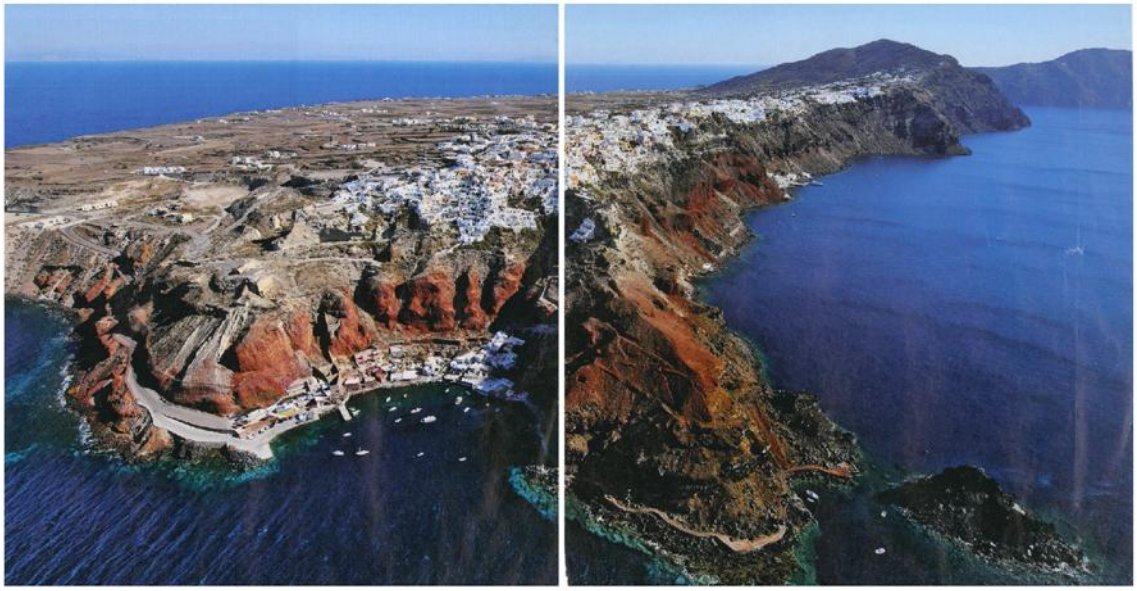

Fig. 1 – Santorini Island (Greek newspaper magazine “K”).

Fig. 2 – Typical view of Santorini Island.

Some of the cave houses were also used as stables for mules and other animals.

Fig. 3 – Cave houses used for animals and for storage.

Most of the ground on the island of Santorini is covered by soft and powder like volcanic soil. It is still used as a constructing material by almost all the local villagers since it is found in abundance on the island. Their homes were shaped as open vaulted caves and that gave them protection both from the pirate raids as well as from the nature elements. Topography and construction economy led to vaulted caves of various sizes and uses (STASINOPOULOS 2006).

The construction works of Santorini are separated in three different types:

- The well known cave houses that are distinct due to the way they are carved in front of the vertical layer of the “Aspa”.
- The typical built construction which is regarded as the neoclassical evolution and was mainly perceived by richer people as the constructing materials where of high value.
- And the third are the semi-built constructions. In this sense the houses are partly built (specifically the access side otherwise known as entry point) whereas the rest of the construction is based on a natural cave.

The architecture of the cave houses is divided into two main parts, the front of the house and the back. On the front the kitchen and the living room are usually accommodated, while in the back one can find in most of the cases the bedroom. It has to be noted that in the architecture of these dwellings the back of the dwelling includes usually the lower ceiling, so it provides easier space for a bedroom rather than any other room. The separation of these two parts is made through a wall with enough openings throughout for the ventilation and daylighting of the back part of the dwelling. In most cases, the dwellings provide only one main opening for

ventilation and lighting and it is through the main entrance at the front of the dwelling (http://www.greek-islands.us/santorini/cave-houses/).

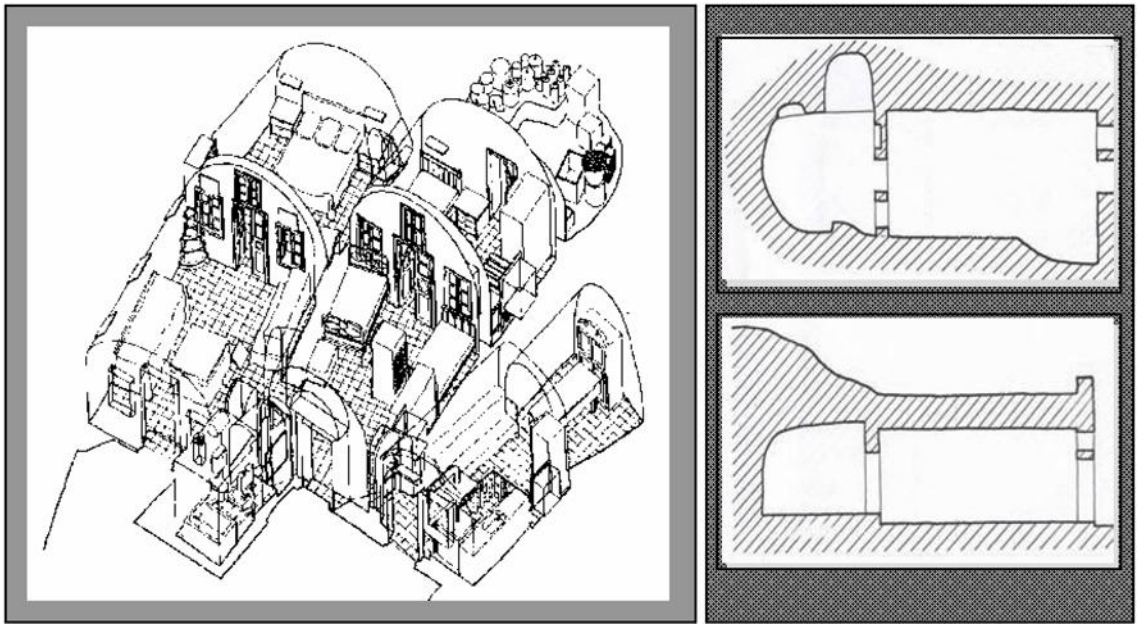

Fig. 4 – Cave house imprint (STASINOPOULOS 2006).

Fig. 5 – The inside of a cave house.

Often one can find a skylight at the top of the roof that helps ventilation for the back part of the house. These openings are very important, especially during the warm days, because due to buoyancy the warm air circulates from the skylight.

Cave houses architecture poses some problems as far as ventilation is concerned. Although these dwellings are usually “cool” and the temperature of their walls is stabilized at about 18Celsius degrees. Problematic ventilation creates a problem of dampness with consequent implications on living standards of the inhabitants.

Fig. 6 – Skylights, air ducts.

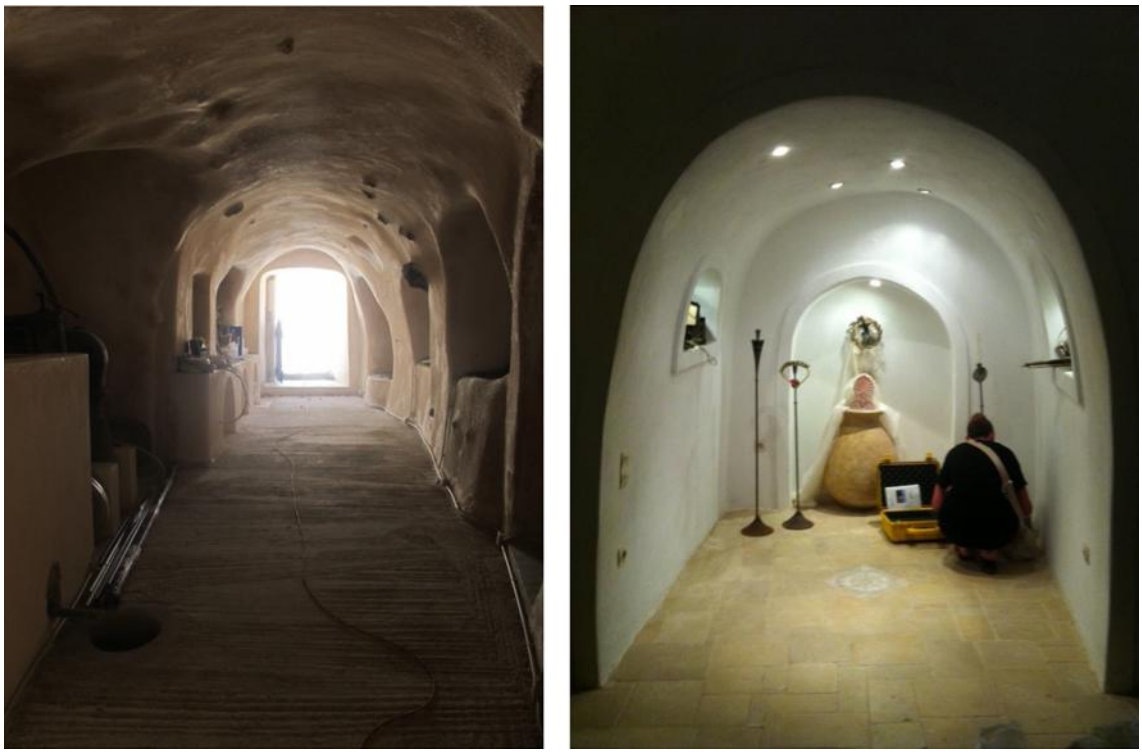

Fig. 7 – Inside the back part of a cave house.

As mentioned, these old types of building constructions are very cool during the hot summers of Santorini but usually suffer from the incomplete and non-existent ventilation combined with the high humidity (MEIER).

Indoor Air Quality

The onset of the interest in Indoor air pollution is stated to be somewhere around the 1900's. The main reason for which IAQ measurements where conducted are:

- To determine the dust balance in houses with or without air purifying systems
- As a background form of investigation of the health status of chronic patients
- As a basis for establishing safe distance of residences from pollution sources.

'1965' is marked as the date that for the first time investigators examined that indoor air pollution might have been responsible for some of the health effects that were attributed to outdoor air pollution for so far.

In order to understand the concept of IAQ one needs to take into serious consideration the following factors:

- The source of the indoor pollutants
- Emission characteristics of the source
- Air exchange between the building and the surrounding environment
- Air movement within the building
- Interaction of the pollutant with the surfaces within the building (i.e. sink effects)
- Chemical or physical interactions affecting the pollutant concentration.

Every building 'produces' problems that are uniquely attributed to its location as well as the climatic conditions that exist in the area. Climatic conditions such as hot or humid, wet or dry, warm or cold, play a very important role in the architectural characteristics when designing a house, or renovating an already existing building. The age of a building may play a very significant role as the deterioration of some constructing materials may be revealed ending in higher levels of pollution factors. Moreover the originally designed air flows in the buildings may not be able to cover the need of the new occupants, since the number of people in a specific zone may have increased and exceed the original criteria.

Infiltration as well as building envelope integrity is very crucial. For example moisture can be drawn into a building's wall cavities through leakage or negative pressurization which will lead in surface mold growths and bio aerosol releases, which are both important IAQ pollutants (SPAUL 1994).

Cave dwellers were perhaps the first exposed to the quality of indoor air, especially when they used to build up fires in their caves to either cook or heat the space. One of the most toxic chemicals they were directly exposed to is formaldehyde. Formaldehyde is emitted by cooking or by heating over open flames. One of the solutions they could have come up with was by building the fire at the entrance of the cave. Nowadays we are confronted with problems of indoor air quality that resemble a lot those of the cave dwellers. For the conservation of energy they now build well-sealed homes and install insulation as well as various materials, which result in the reduction of air movement in the building and simultaneously increase the source of IAQ pollutants (NAMIESNIK et al. 1992).

Recent measurements

The main objective of this work was to perform an indoor environmental study of dwellings with specific architectural characteristics.

The methodology followed to achieve the objective involved two phases. Initially, a detailed climatic audit and monitoring of the area was carried out on some specific cave houses. During the second phase, and in

order to assess the indoor environmental conditions of the underground dwellings, the architectural and bioclimatic characteristics alongside with the indoor air quality of the dwellings were monitored. The monitoring campaign included measurements performed in underground dwellings which were situated at Oia, Foinikia and Imerovigli village at the island of Santorini. The dwellings selection took into consideration the historic use of these dwellings and their use today in respect with the population density of the study area. At least one of the dwellings was situated in the city centre (densely built area).
Data collection for the case of Santorini, took place during one of the hottest months of the year, as the scope of this study was to identify the natural cooling potential of such spaces under hot arid conditions.
The inspection covers all accessible internal areas of the underground dwelling.
The type and location of specific indoor sources of pollution and other peculiarities were taken under consideration in order to avoid biasing or influencing the measurements.
Finally samples of the construction materials as well as natural stones were collected in order to assess their reflectance in the visual and infrared spectra. This aimed at estimating the impact of the specific materials in the air temperature and in particular the thermal comfort of the area under investigation.
Three buildings in Santorini were inspected. The first one was at the village of Imerovigli and it was a cave room in a hotel called Heliotopos. This space is used as a conference room and also for the breakfast and the afternoon drinks by the guests of the hotel. The measurements took place inside the cave dwelling.
The second one was a traditional house in Oia village and was occupied by a single resident. The inner part of the dwelling hadn’t been restored for quite some time and the needs for restoration are evident as seen from the relevant results.
The third and last was a hotel in the traditional village of Foinikes. The cave room was occupied by the owner of the hotel and the restorations in the materials used on the walls of the dwellings had been very recent. In this part of the study outside measurements so as to compare the climatic measurements that took place indoor and outdoor we also collected.

Meteorological and Air Quality Measurements

The equipment used for the measurements where portable, automatic and are owned by the Laboratory of Indoor Environmental Quality Measurements of the National Kapodistrian University of Athens. All equipment were connected to data loggers (either internal or external) and treated by specially designed software so that a high quality data set was formed. Some of the data collected may need further processing in order to extract useful information regarding the distribution of certain pollutants and indoor atmospheric chemistry kinetics. More specifically for the monitoring of PMs the instrument used was Osiris by Turkney, for the temperature and humidity the collectors are Tiny Tag and finally in the case of the CO2 the instrument used is IAQ-calc Model 8732 by TSI.
Indicative results of the measurement campaign in Santorini are presented in this section.

Date	Place	Average Temperature	Average Humidity
18/06/2011	Heliotopos Hotel (Imerovigli Santorini) (day measurements)	22.51 °C	94.0 %RH
19/06/2011 20/06/2011	Traditional House in Oia Santorini (continuous 24 hours measurement)	23.95 °C	88.5 %RH
20/06/2011 21/06/2011	Heliophos Hotel in Traditional Village Foinikies Internal Measurements (night measurement)	24.4 °C	79.4 %RH
21/06/2011	Heliophos Hotel in Traditional Village Foinikies External Measurements (day measurement)	34.74 °C	45.6 %RH

Table 1: Average values of the measuring campaign.

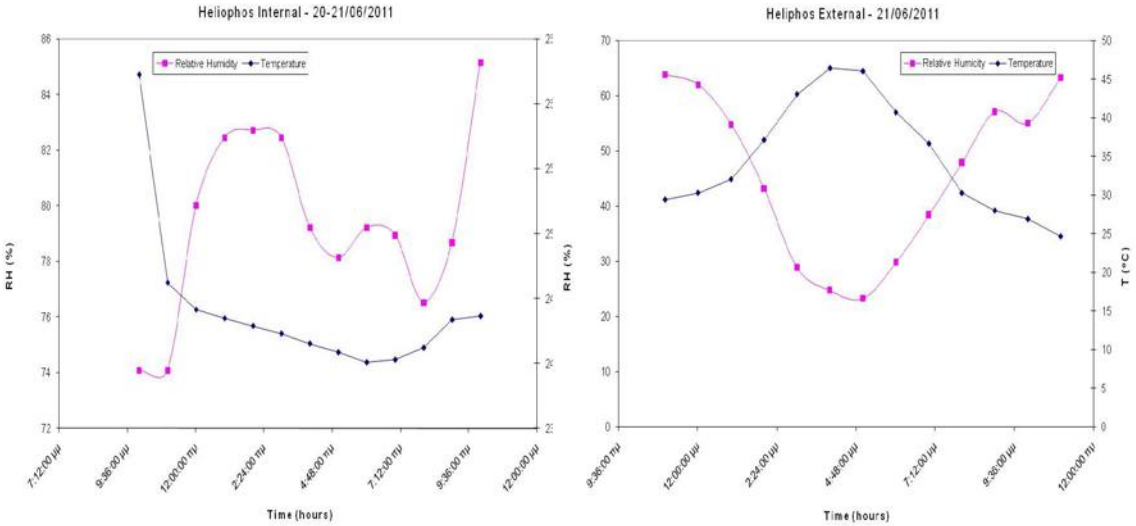

Fig. 8 – Temperature and relative humidity in Santorini Greece.

Figure 8 presents the measurements obtained in all 3 locations in the Santorini Island of Greece.
It is quite obvious that even though the temperature is close to the "comfort" levels during the summer season, it is not the case for the relative humidity. In all buildings measured in Santorini the levels of relative humidity could be accounted as "extreme" placing the term of "thermal comfort" out of reach for the residents and guests of these dwellings. Nonetheless, before attributing any behavioural or constructional patterns to those levels, it has to be taken into serious consideration the effect of the sea as a major contributor in the elevated values of humidity. So, no matter what materials are used, or dehumidifiers, or numbers of ventilation shafts, the problem of humidity will always be present due to the topography of the island .and the vicinity of the sea In order to maintain humidity levels as low as possible new and highly technological advanced constructing materials as well as adequate ventilation should be used. In all of the underground dwellings that were measured the concrete materials that prevailed were the natural stones of the area. The thermometers and the humidity monitors were usually placed in the back rooms of the dwellings that is the bedroom in most cases. In the case of Santorini two out of the three buildings had air ducts for the

rejuvenation of air and the provision of day light. The air ducts are usually placed on the front part of the dwelling. Moreover, the measuring campaign in Santorini included measurements of Particulate Matter in order to observe the level of pollution of the indoor environment of the dwellings.
Figure 9 clearly indicates that the PM10 concentrations are in most cases not exceeding the legislative daily limit values (PM10 - 50μg/m3) set by U.S EPA. The only building presenting higher PM10 concentrations was the conference room of a hotel and in particular the breakfast room which served cafe as well during the day. PM2.5 concentrations are much lower than the PM2.5 limit set by US EPA.

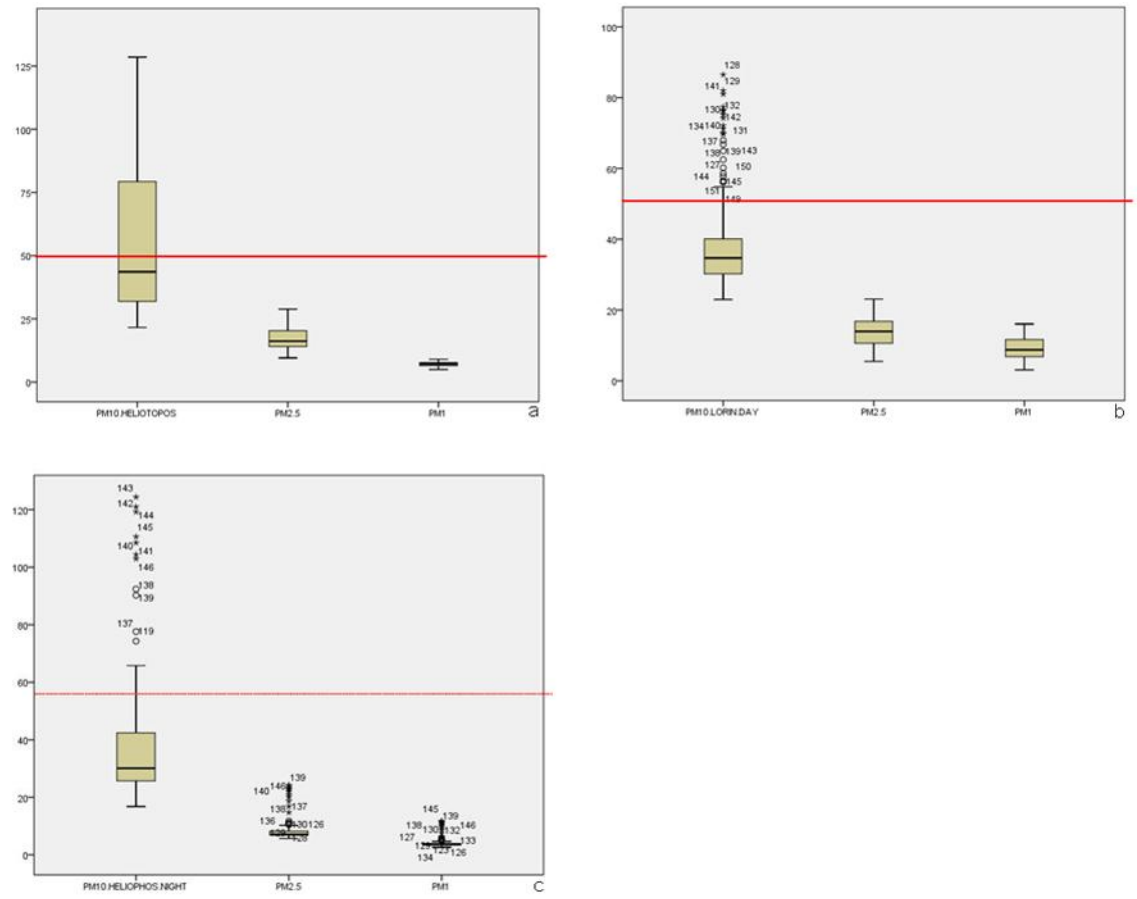

Fig. 9 – Box Plot of buildings in Santorini. The red line indicates the EU PM10 limit.

In figure 9b the PM10 concentrations exceeded the limit value of 50 μg/m3. It has to be noted though, that the house in this case did not have a ventilation (skylight, or air duct) as well as the fact that the kitchen, living room and bedroom where all one common area, meaning that the process of food preparation and cooking could increase dramatically the numbers, as well as the smoking habit of the particular resident.
In the case were the PMs concentrations in all three chosen dwellings were exceeding the limit values there was indication of activities such as smoking, cooking, cleaning. In that case the owner was absent most of the day time whereas during evening and the night the owner was present and sometimes accompanied by other guests as well. The main activities taking place where smoking and cooking. Taking into consideration these two activities, alongside the fact that there was inadequate ventilation one can easily understand the very high levels of Particulate Matter.

Finally figure 9c presents the measurements in the Foinikies traditional village Heliophos hotel where the owner of the hotel and resident of the particular dwelling had fully restored all rooms with material that prevented humidity and dampness as much as possible.
The measurements in this case took place during the night where the owner and resident were indoor and smoked occasionally. The kitchen was in a separate room linked with an outside door, so any effect from cooking could be eliminated.

Thermography and Reflectance Measurements

In an environment such as the Santorini Island solar energy is absorbed by concrete and paved surfaces, causing the surface temperature of urban structures to rise several degrees higher than ambient air temperatures. As surfaces become warmer, overall ambient temperature increases. This phenomenon, called “urban heat island”, has as natural consequence the increase of energy demand, accelerating the formation of harmful smog and causing human thermal discomfort and health problems by intensifying heat waves over cities (OKE et al. 1991; SANTAMOURIS 2001; CARTALIS et al. 2001; BURKHART et al. 2001; SYNNEFA et al. 2007).
The Solar Reflective Index (SRI) is the ability of a material to reject solar energy, so the ability of a material to contribute to the heat island effect decreases when the solar reflex index of the material increases. In more simple terms when the shade of a material is darker, the SRI of this material is reduced, but in order to be more accurate one has to test the material in order to be sure of the concluding results received.
In most cases natural stone is used as a building or landscaping material and in the case where it has a high SRI it contributes in the reduction of the heat island effect. Stones and other products that exhibit a high SRI index are considered as advantageous materials in regions that have short periods of cold weather like in the Mediterranean. For example in the energy savings factor, when a roof has a high SRI index, it can offer energy savings up to 10–30% for an average daily summer load. The major benefit of the natural stone is that usually it maintains the same colour throughout the whole of the structure, thus meaning that the reflectance index remains the same and no extra cost is needed for either maintaining, or adding reflective paints.
The SRI is directly affected by three factors: the material composition, the surface texture and finally the orientation of the material. Nonetheless it has to be taken under serious consideration that variables such as materials aging, weathering and discoloration can affect the long term SRI index (University of Tennessee Center for Clean Products 2009).
It is obvious that materials with lighter surfaces have high reflectance, and thus smaller surface temperatures. The small temperature range measured is mainly due to the lack of direct solar daylight as well as the direct contact with the soil that helps them keep a stable temperature.
Specifically, the lowest daily temperature values that were displayed for the white plastered walls, in the deep part of the Cave, are due to the fact that the sunlight doesn’t reach the interior. On the other hand the highest daily values of surface temperatures, appear at the entrance (front-facade) as well as on the "wells-surface" used for the natural ventilation and lighting. High surface temperatures also appear on surfaces where we have artificial lighting.

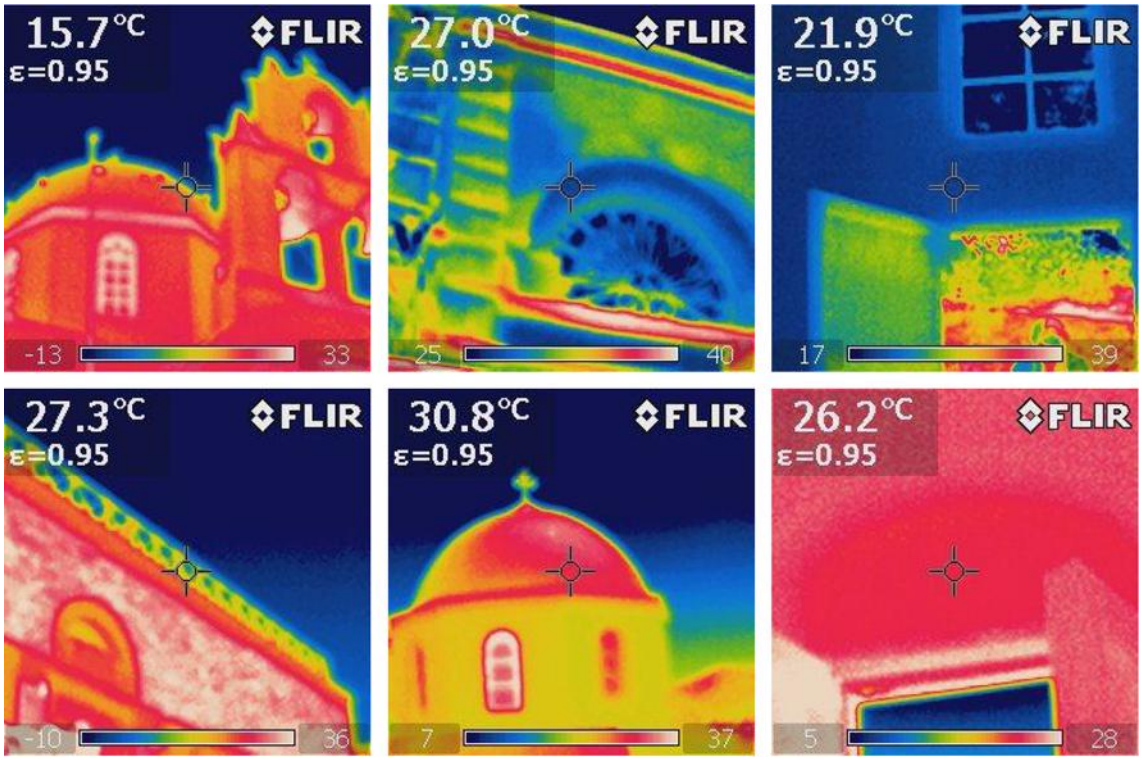

Fig. 10 – Infrared camera readings.

In the framework of this study samples such as plaster, volcanic stone, volcanic beach sand and stone from the Santorini island were collected (figure 11) and brought back to the laboratory for testing. The optical properties of the samples were measured. More specifically the spectral reflectance of the samples was measured using UV/VIS/NIR spectrophotometer (Varian Carry 5000) fitted with a 150mm diameter, integrating sphere (Labsphere DRA 2500) that collects both specular and diffuse radiation. The reference standard reflectance material used for the measurement was a PTFE plate (Labsphere).

Figure 12 depicts the spectrophotometric measurements of the samples. In the visible range the reflectance curves present practically the colour of each sample. This means that the lighter the colour of a sample is, the more it reflects in the visible range. More specifically, plaster which is white has a very high reflectance while volcanic sand, which is darker, is strongly absorptive.

However, in the NIR range it can be easily seen that the samples with the darker colour present high reflectance.

The high quality database was related to the energy consumption of the dwellings and some other special characteristics (construction materials, age, indoor materials, usage etc.), so that useful conclusions were drawn. Energy is directly related to the architectural structure of the dwellings since the bioclimatic structure may lead to less energy consumption in comparison with the conventional architecture. The location of a building, as well as the structural-building materials used is directly related to the energy used by the residents. In the case where an “eco friendly design” took place, the need of air conditioning during the warmest periods can be significantly deducted.

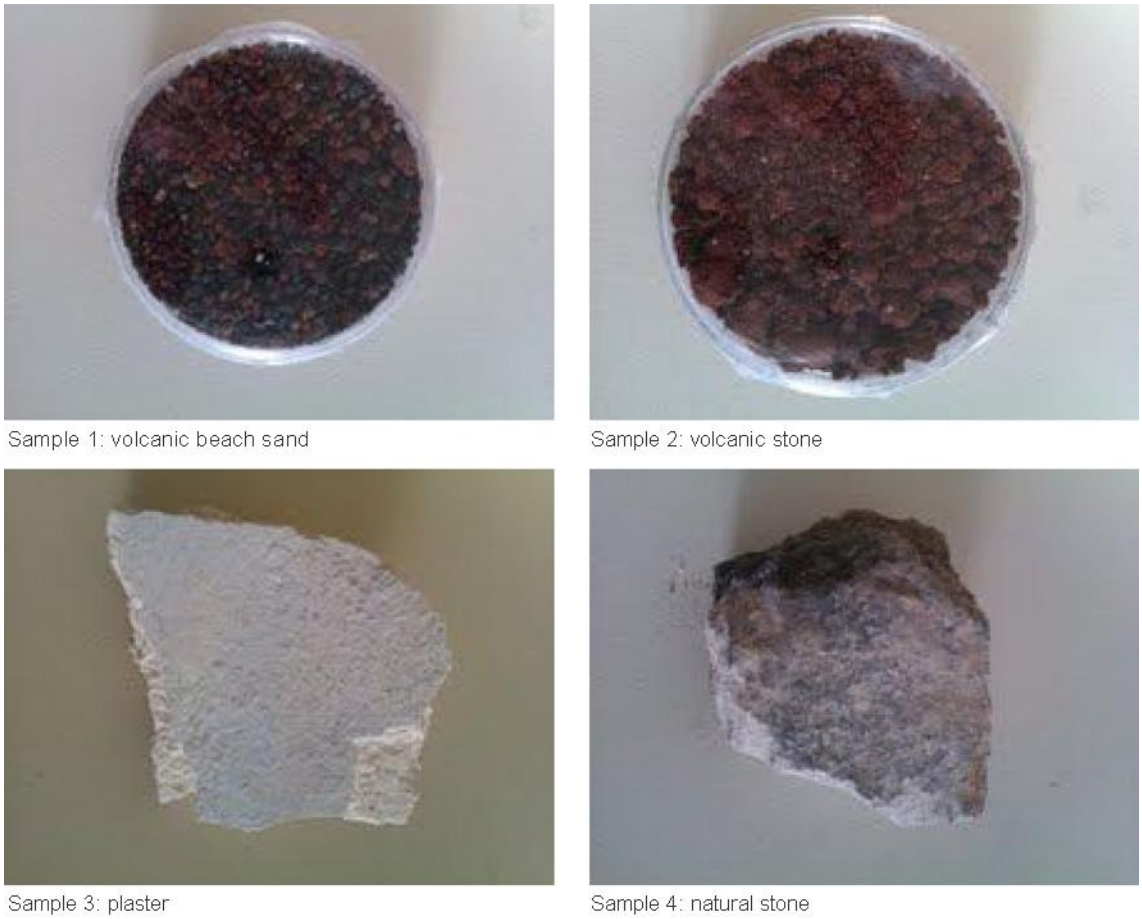

Fig. 11 – Stone samples.

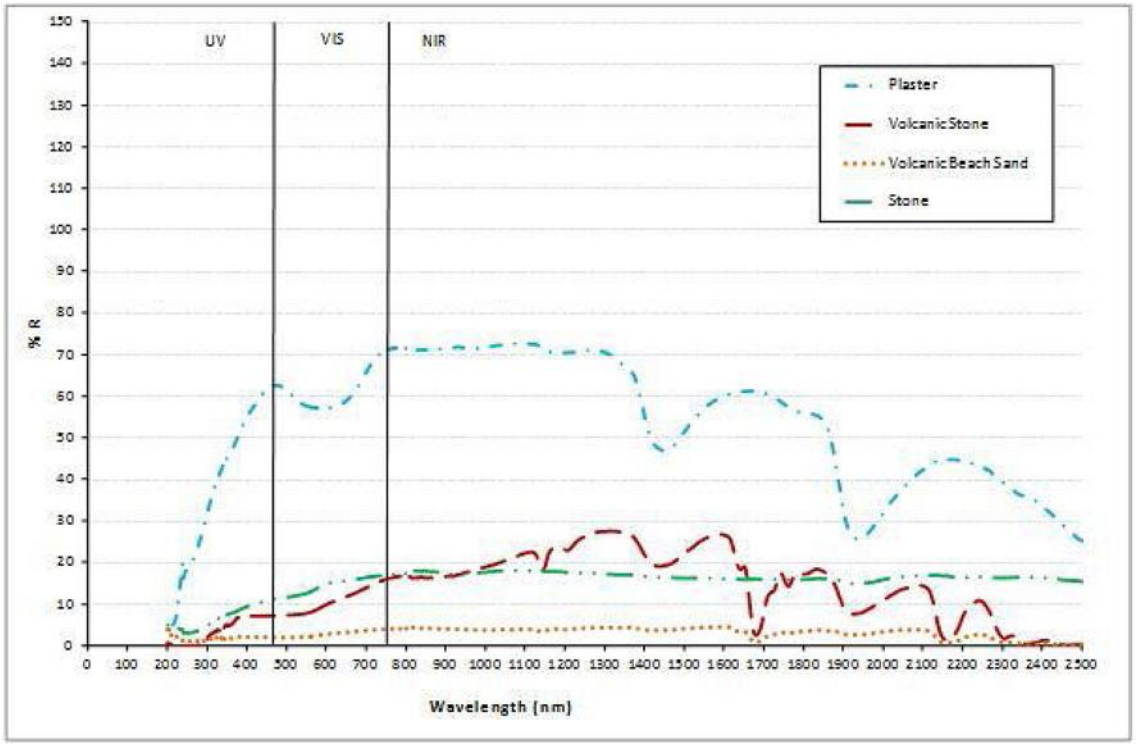

Fig. 12 – Reflectance graph of the above samples.

Results and Conclusions

What is cherished nowadays as “grand” architecture is in fact the constant struggle for survival in the previous century. The need to thrive through the sometimes cruel climatic conditions, the least means of constructing materials, the lack of advanced mechanisms, all lead to the magnificent and impeccable architecture of the underground dwellings. Both the comfort and need in that given time, merged and the perfect example of vernacular environmental sustainability was created by the local people.

An environmentally conscious study-approach of the cave houses was interesting due to the low-tech techniques that are usually used. These techniques are energy saving systems. Sustainable historic cave house examples may have more than one lessons to teach us in the field of energy saving and sustainable planning.

Although underground spaces do indeed have a high potential as energy conserving living spaces, because of their natural heating and cooling, due to the earth mass, this potential is not universal and depends on a number of different parameters such as:

- Local climatic conditions that affect the indoor underground conditions.
- Ambient extremes that affect underground temperatures, even if this effect becomes marginal with increasing depth.
- Relative humidity is a detrimental factor in achieving comfort conditions in indoor underground spaces (most of the times the humidity levels are very high). In the case of ambient air with high relative humidity levels, indoor-underground conditions may prove to be uncomfortable.
- Ventilation. As it seems to be negligible under natural conditions, it is obvious that mechanical ventilation is necessary, unless natural ventilation is possible through the introduction of openings in varying distances and heights.
- Lighting is a problem inherent to the underground spaces, especially for the inner space of the cave.

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Historical Maps in GIS

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Abstract: The contribution deals with the usage of old maps in GIS for urban redevelopment. St. Peter-Paul’s cathedral and Špilberk castle were selected as a model area the historical centre of Brno city (Czech Republic). The main temporal points of urban development were established on the basis of historical maps, plans and documents. The goal of this project was an attempt to establish urban redevelopment in these temporal periods. The project analysis was made together with the cooperation of the experts of the branch of middle age archaeology. The final output is a GIS project in ARC/INFO created with the geo-database, which contains all temporary levels of map sheets, significant geographical objects with the attribute data and historical and current time photos of the interested objects. Also 3D model of Špilberk castle have been created in the ARC/INFO system.

Keywords: old maps, city plans, GIS, historical data warehouse, 3D model.

Introduction

Historic buildings or conservation area has undergone many changes during its history. They changed not only the appearance of the objects but also their style, layout or functionality. The aim of this project was to determine the method of reconstruction of historic buildings on the basis of contemporary materials (documents, reports, maps, photographs, etc.) and to determine their location or appearance at some stage of their development using GIS (PROCHÁZKA 2007; 2009 and ŠTĚPÁNKOVÁ 2009).
Historical centre of Brno and Špilberk castle were selected in the region of interest. Brno is the second largest city in the Czech Republic with more than 400 000 inhabitants. It is the administrative centre of South Moravia, and its historic district is a separate part called Brno - the city. The entire project was run in several major phases (Fig. 1):

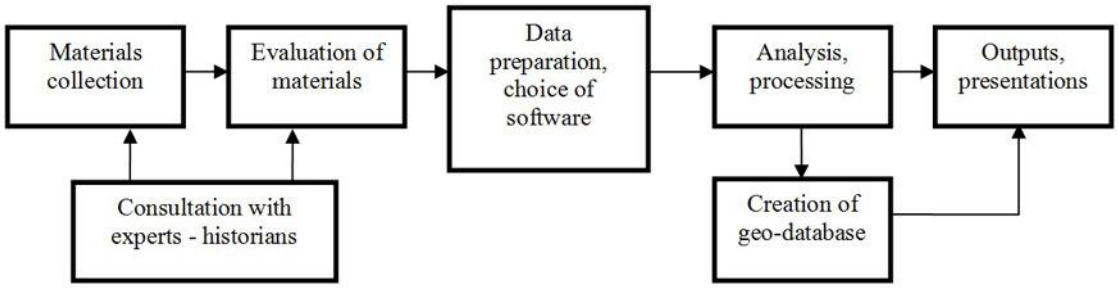

Fig. 1 – Development of the project.

1. Collection of historical materials relating to the area of interest,
2. Assessment of the materials and consultation with experts in the field of history,
3. Preparing and selecting the appropriate program; processing,

4. Data processing and analysis of appropriate software, identifying the main stages in which were significant changes in the region, creation of geo-database,
5. Outputs creation and presentation.

Each phase of solutions is described in subsequent chapters.

Historical Data Collection and Evaluation

This phase was the most difficult of all (HITCHCOCK 1996). Although the center of Brno has a rich history, historical material has been preserved relatively little. The paradox is that most of the preserved historical documents were located outside the city of Brno, even outside the Czech Republic. In fact, some of the visited organizations as Museum of Brno city, Archive of Brno, Moravian provincial archive, National office for preservation of historical monuments in Brno, bishopric of Brno have some materials but the quality of its was insufficient in many cases. The most valuable items were found in the Military Archives in Vienna. It concerns the collection of 21 plans since 1658–1819, 5 profile sheets and 3 sheets of construction plans. All above mentioned materials were purchased by Institute of Geodesy, Faculty of Civil Engineering, Brno University of Technology for the needs of this project. Current map materials that are necessary for the reconstruction were provided by Facility management of Brno city and Czech Office for Surveying and Cadastre (CHARVÁT et al. 2007).

De Rochepien's plan of Brno city of 1749 and the plan of 1754 belong to the oldest and the most valuable exemplary (Fig. 2). Overview of all collected historical materials is given in Table No 1. Collected data were evaluated with the help of experts from the field history and adapted for further processing.

Data source (company)	**Date**	**Number of sheets**	**Content**	**Format**
Military Archive Vienna, Austria	1658–1783	29	Plans of Špilberk castle and Brno city	A0–A1, raster, TIFF, 200 dpi
Archive of Brno city, Czech Republic	1720–1944	10	Plans, sketch of Brno city	A3, raster, JPEG
Museum of Brno city, Czech Republic	1749–1984	4	Plans in scale 1:1000	A3, raster, JPEG, TIFF, B/W
Archaia ltd., Czech Republic	1997–2004	3	Plans of Špilberk fortification	DGN, DWG
ELGEO ltd., CZ.	2006	2	Digital cadastral map	DGN
Facility management of Brno city, Czech Republic	2006	1	Building structure investigation of Špilberk fortification	Raster, JPEG
Czech Office for Surveying and Cadastre	2002	4	Fundamental Base of Geographic Data (3D)	Raster CIT, vector SHP
Geodis Ltd., Brno	2003	2	Ortho-photo 20 cm/pixel	Geo-TIFF, JPEG

Tab. 1 – Overview of all collected historical materials.

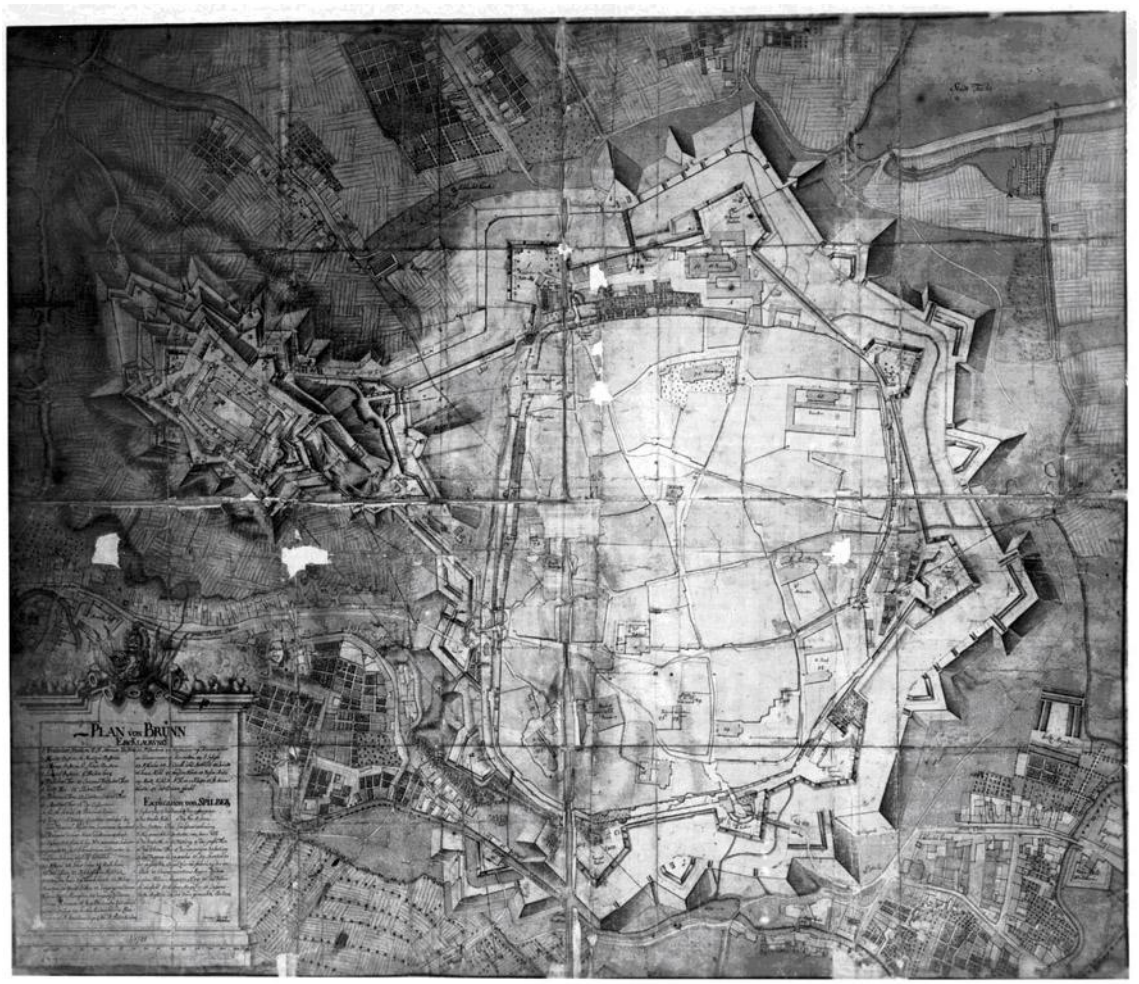

Fig. 2 – Plan of Brno city from of 1754 year.

The collected materials occurred to be insufficient for processing. Above all it was necessary to look up and determine appropriate identical points for geo-referencing of old maps. Further, it was necessary to verify current map material and compare it with a reality. The collected data were completed with direct geodetic measurement in field for these reasons (PUNDT 2002 and VIVONIP 2004). The actual selection of suitable materials for reconstruction was consulted with experts at Middle age archaeology from Brno Museum. A basic document for a choice of appropriate elements and identical points for reconstruction was present on cadastral map of a given locality. This map contains objects which can be divided into 2 categories:

1. Preserved parts of an object of late 18th century.
2. Objects with small construction works which cannot influence identification with old maps and plans (facades adaptations, building reconstruction on an original object etc.).

Above mentioned objects contained localities for placement of reference points for geo-referencing of old map documents. Other necessary identical points were obtained by geodetic surveying of south-west bastion of the castle Špilberk which was newly reconstructed in the frame of archaeological research in the year of 2002. These points are the most accurate from the point of view of the geo-referencing process. On the contrary, the historical maps and plans have the lowest quality which is influenced by these factors:

- The ravages of time, causes fading of drawing which results in losing a part of a map.
- Precision of scanning in case that the map consists of several (in many cases damaged) parts.
- The exact dimension of map frame and field are unknown.
- Method of geodetic measurement and its accuracy are unknown.
- Disunited attribute style of drawing of maps and plans (various line styles and weights).

Geo-referencing of historical maps was based on affine transformation according this equation:

$$X = xq_x \cos(\alpha + \delta_\alpha) + yq_y \sin(\alpha + \delta_\alpha) + t_x$$
$$Y = xq_x \sin(\alpha + \delta_\alpha) - yq_y \cos(\alpha + \delta_\alpha) + t_y \quad (1)$$

where,

- t_x, t_y is shift in the x, y axis,
- q_x, q_y is scale factor in the x, y axis,
- α is angle of rotation,
- δ_α is coefficient of non-orthogonality of both axis

Data Preparation and Processing

ArcGIS software by ESRI was selected for the project. Some files had to be adjusted before entering into ArcGIS. Raster data was preprocessed with Adobe Photoshop (cropping, downsizing, conversion, etc.), vector data has been adjusted in MicroStation V8. Some layers had to be geo-referenced using identical points upon entering into the system ArcGIS. In many cases, especially in historical maps, it was very difficult, because many elements of the past disappeared. S-JTSK system (Datum of Uniform Trigonometric Cadastral Network in the Czech Republic) was used for the whole project. All altitude dimensions were calculated into altimetry system called Bpv (Baltic Vertical Datum after Adjustment). There were they successively inserted into the system or 172 layers created newly, which were grouped into 23 categories. These layers have taken from institutions or private entities:

- Historical maps,
- Ortho-photo maps,
- Geological map,
- ZABAGED (Fundamental Base of Geographic Data in the Czech Republic) – contour lines and topography,
- State map of Brno city in the scale 1:5000,
- Utilities map of Brno city
- Zoning plan of Brno city
- Current cadastral maps of Brno municipality

Four periods were determined on the basis of analysis of existing layers in which were the most important urban changes, namely:

- 1750–1815
- 1816–1880
- 1881–1945
- 1946–2010

These new layers have created further categories or layers:

- ► Municipality fortification,
- ► Situation in 1890,
- ► Housing development in four above mentioned periods,
- ► Historical sightseeing tour in 1750 and 1890 – (Fig. 4), (ŠTĚPÁNKOVÁ 2009),
- ► Digital terrain model with layers: TIN, aspect, slope, hillshade view, TIN-grid (Fig. 8)

Further followed special layers were created:

- ► Layer for WMS (Web Map Services)
- ► Layers of significant historical objects: st. Peter's and Paul's cathedral, st. James church and German house,
- ► Graph of selected profiles of Špilberk hill,
- ► Group layers of reconstruction of Špilberk castle.

Geo-database has been designed for all newly created layers (Fig. 3), (BARTONĚK et al. 2009).

The topography and altimetry reconstruction of the castle Špilberk was created as a special part of the project. 3D model of Špilberk castle during the Baroque period based on historical and current maps was created – see Figure 9 (PROCHÁZKA 2009).

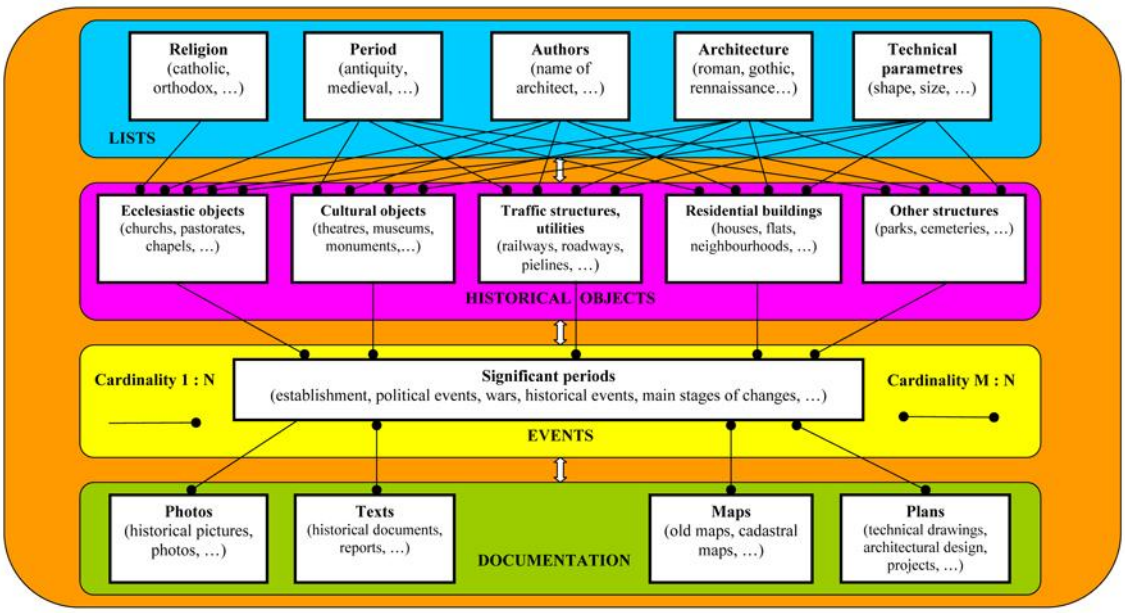

Fig. 3 – Geo-database of the historical objects.

Data Preparation and Processing

The main results of the project are:

- ► Collection of historical and contemporary material (map, documents, photographs and reports) of the selected location,
- ► Classification of the material, determining of the main stages of construction work (Fig. 6)
- ► Creation of new layers that show major changes in selected buildings,
- ► Creation of a common geo-database of historic buildings,

- ► Connection to the WMS services, where each user can work on-line with the selected map data,
- ► A special coating on the important historical places of Brno (St. Peter and Paul's cathedral, St. James church and German house),
- ► Creation of GIS analysis in the locality – 3D model, profiles,
- ► Complex process of reconstruction of the Špilberk castle in both 2D and 3D models.

All major results are presented in Figure 4 to 9. Figure 4 shows the main phase of structural changes in the centre of Brno. There is marked historical guided tour in 1750 with outstanding stops. In Figure 5, you can see important milestones in the development of the St. Peter's and Paul's cathedral, based on old maps. Figure 6 shows the historical centre of Brno in 1750 and Figure 7 the same site in 1890. It is clear in both these figures what significant changes have taken place during the 140 years. The church buildings and squares are relatively stable, big changes can be observed in transport infrastructure (rail, tram). Another figure presents a 3D model of representative sites created in the 3D Analyst module in ArcGIS (Fig. 8). Elevations of the legend are given in altimetry system called Bpv (Baltic Vertical Datum after Adjustment).

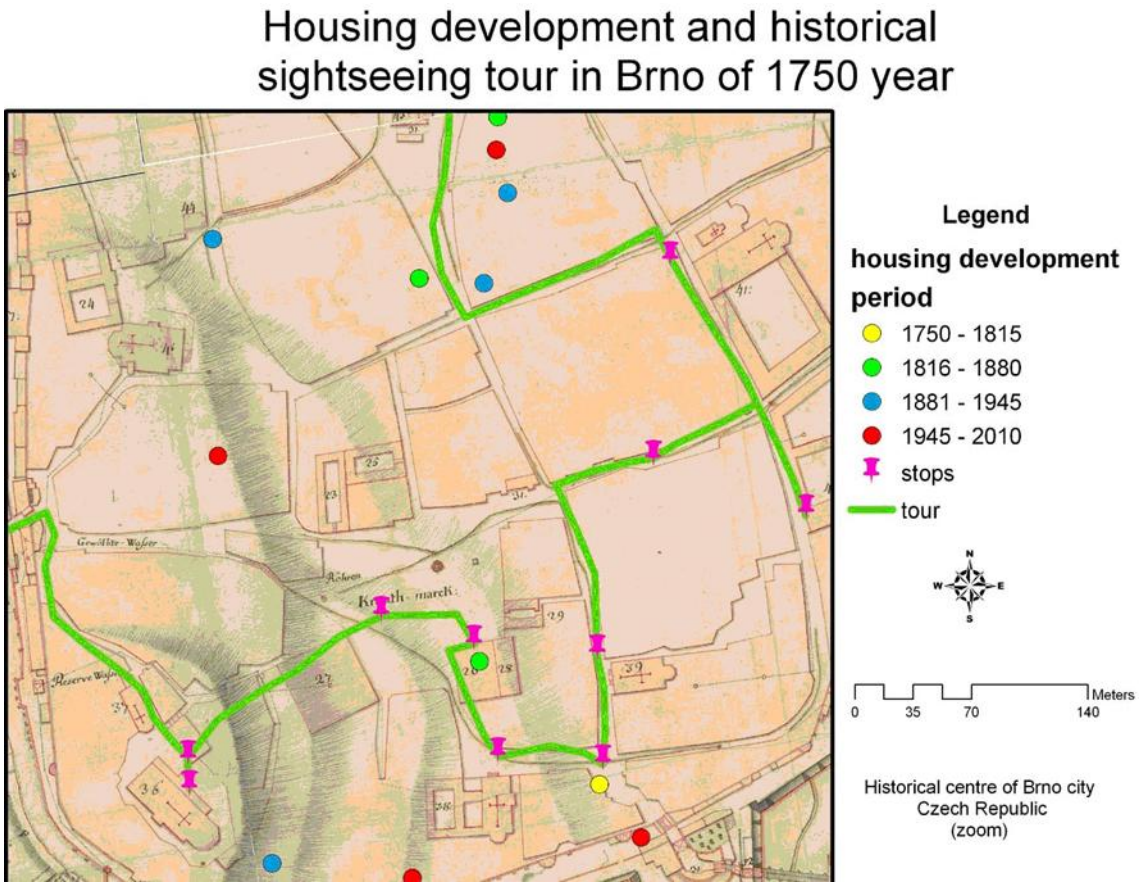

Fig. 4 – Housing development and historical sightseeing tour in Brno.

The last figure represents the result of reconstruction of the Špilberk castle. This reconstruction is in 3D and has 2 phases (PUNDT et al. 2000):

1. The creation of Digital Terrain Model (DTM) of Špilberk hill – see previous Figure 8.
2. 3D model of historical reconstruction of Špilberk castle and its fortification – see Figure 9.

These materials have been used for making of DMT:

- A plan of Špilberk castle of 1984 borrowed from Brno Museum in the scale 1:1000. The plan contained contour lines with the interval 1–0,5 m which have been digitalized.
- Altimetry of Špilberk in ZABAGED system (Fundamental Base of Geographic Data) – see table 1.

These materials have been used for 3D model of historical reconstruction of Špilberk castle and its fortification:

- Plan of 1749 by Pierre Philippe do Beichade de Rochepine containing 15 dimensioned sections.
- Plan of 1759 with 2 sections missing in the previous plan.
- Plan of 1809 showing the fortress damaged in the period of Napoleonic wars.
- 4 map sheets of 1917 containing detailed drawing of building adaptation in the years 1840–1880 including altimetry spots dimensioned heights of terrain and fortification.
- Contour lines of ZABAGED (Fundamental Base of Geographic Data) in the locality.
- Geo-database of topography map created in a previous phase of the project.
- Current digital cadastral map of Brno centre.

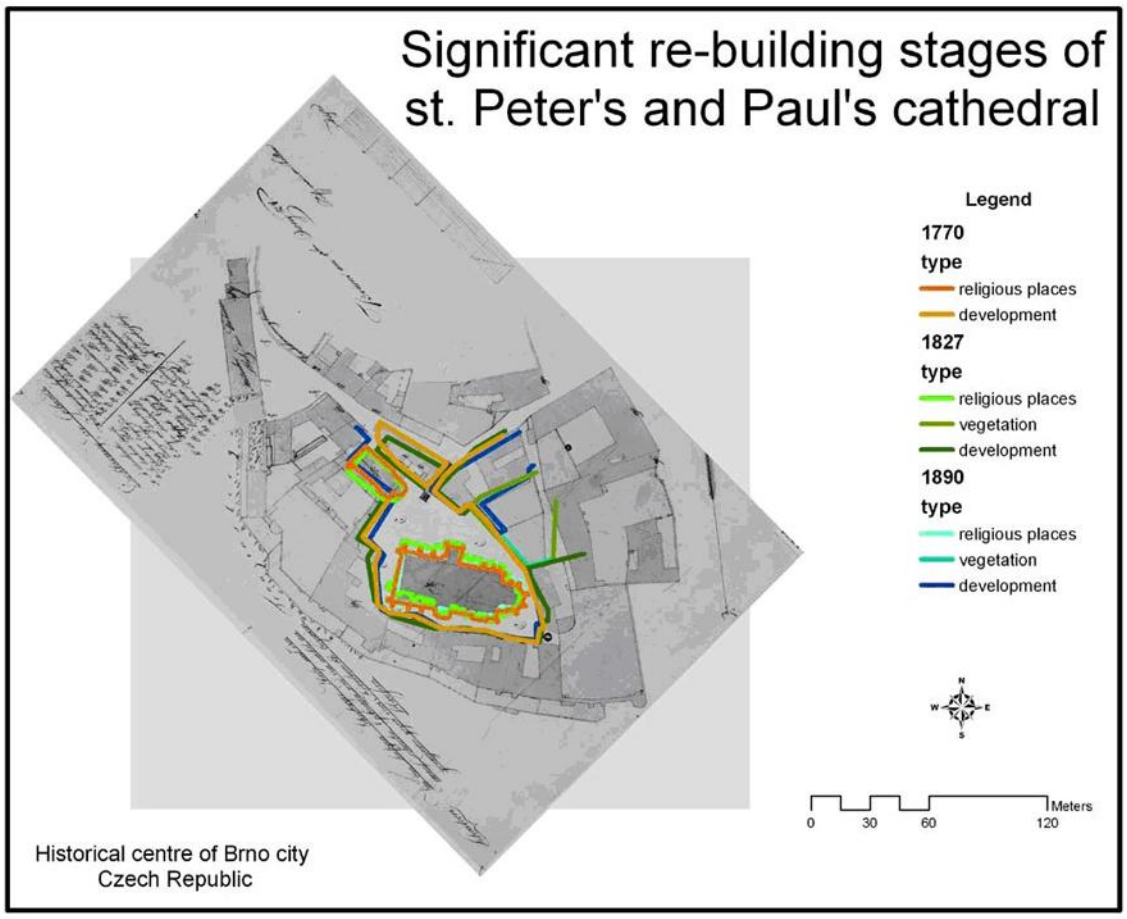

Fig. 5 – Significant re-building stages of St. Peter-Paul’s cathedral.

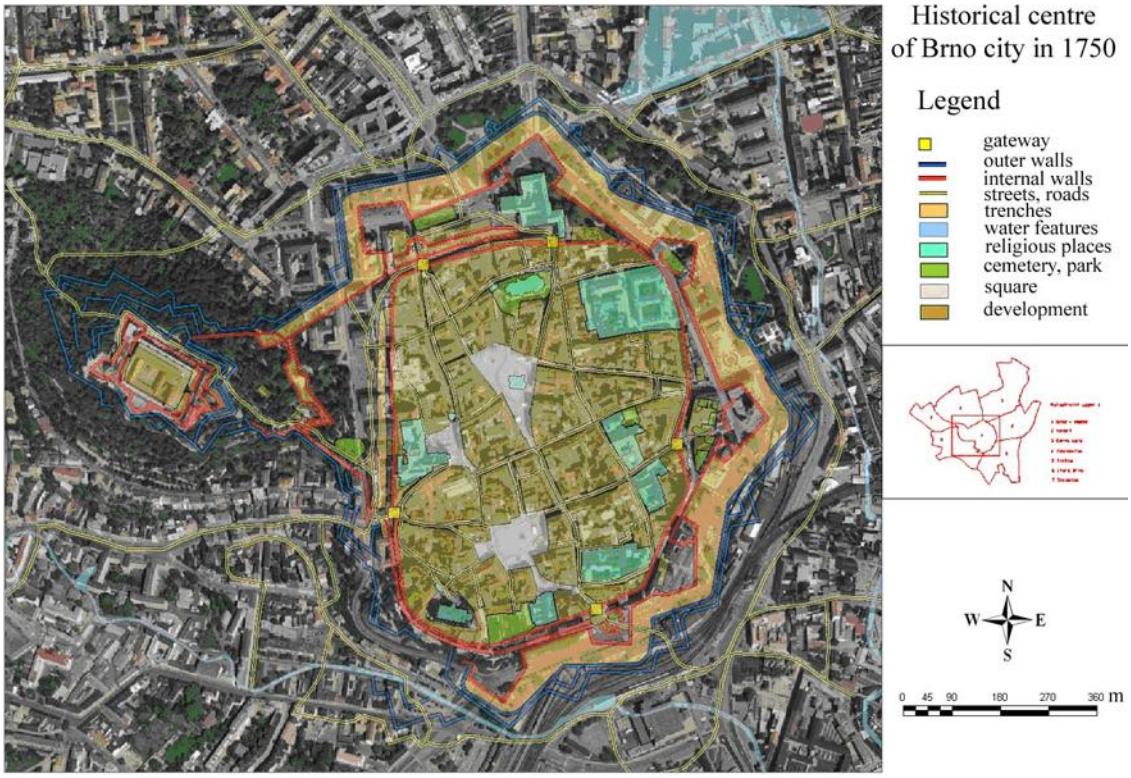

Fig. 6 – Historical centre of Brno city in 1750.

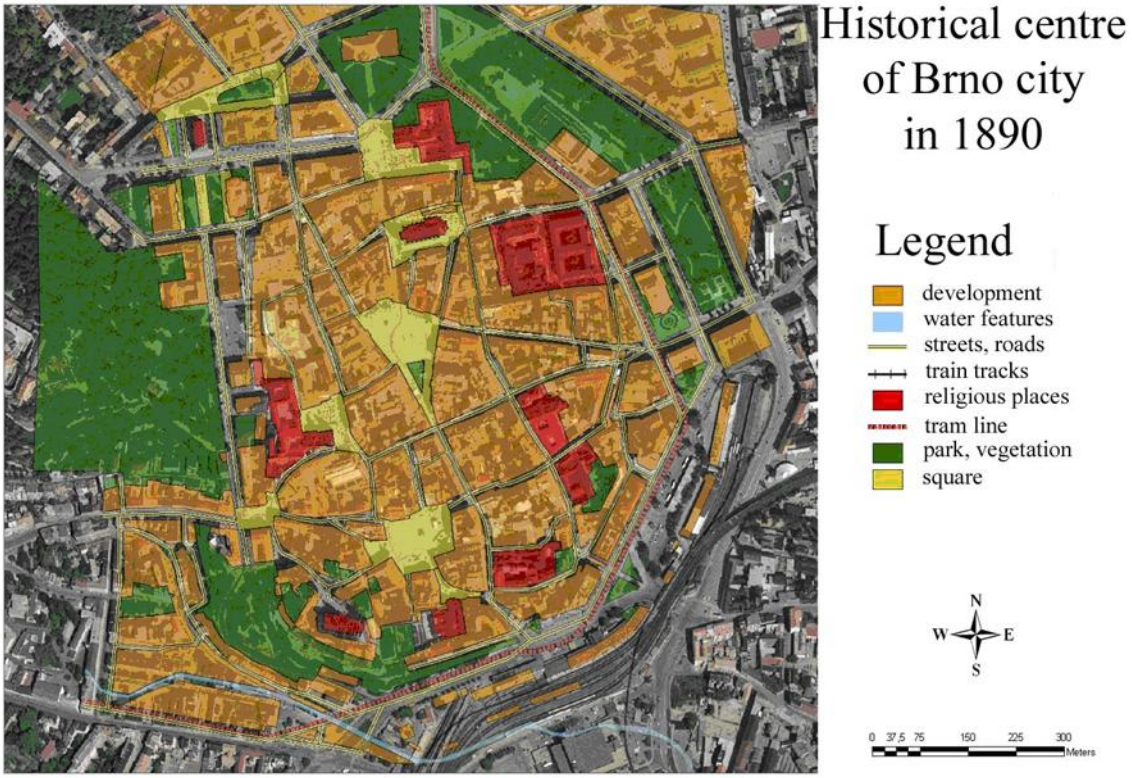

Fig. 7 – Historical centre of Brno city in 1890.

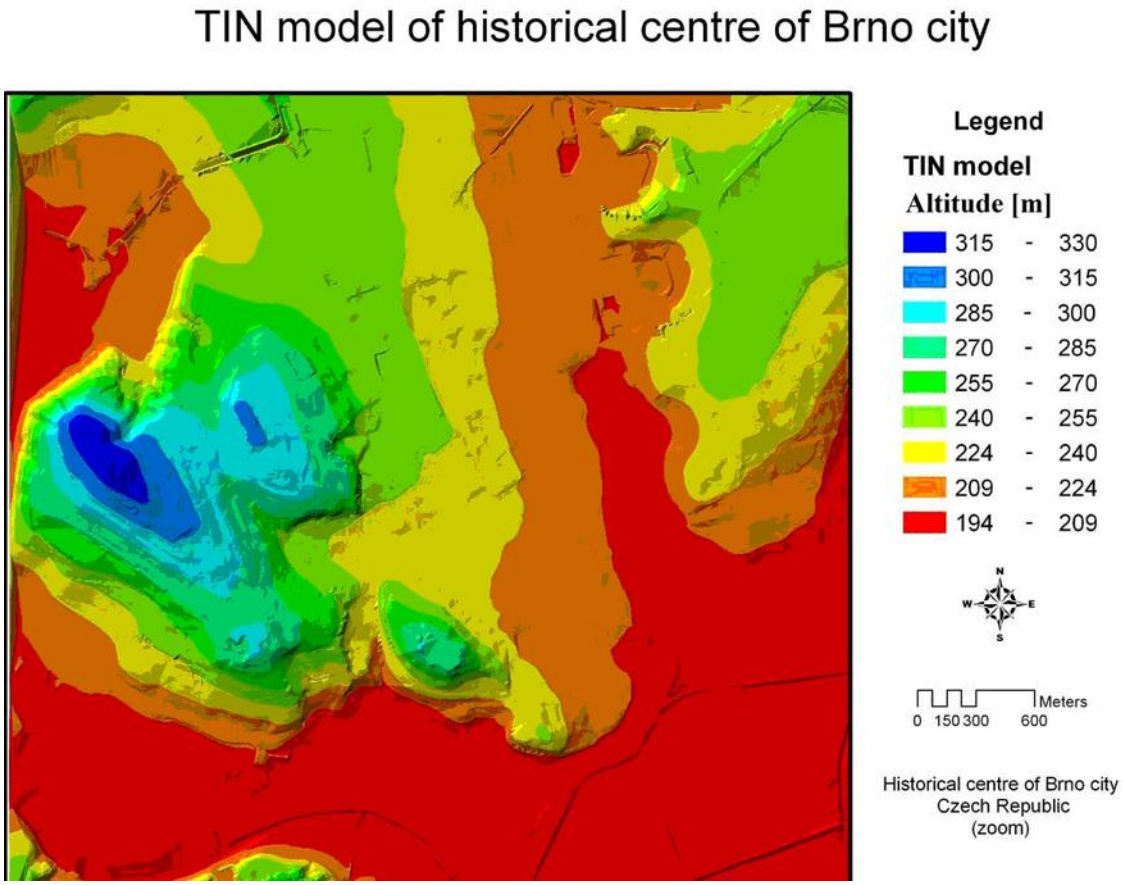

Fig. 8 – TIN model of historical centre of Brno city.

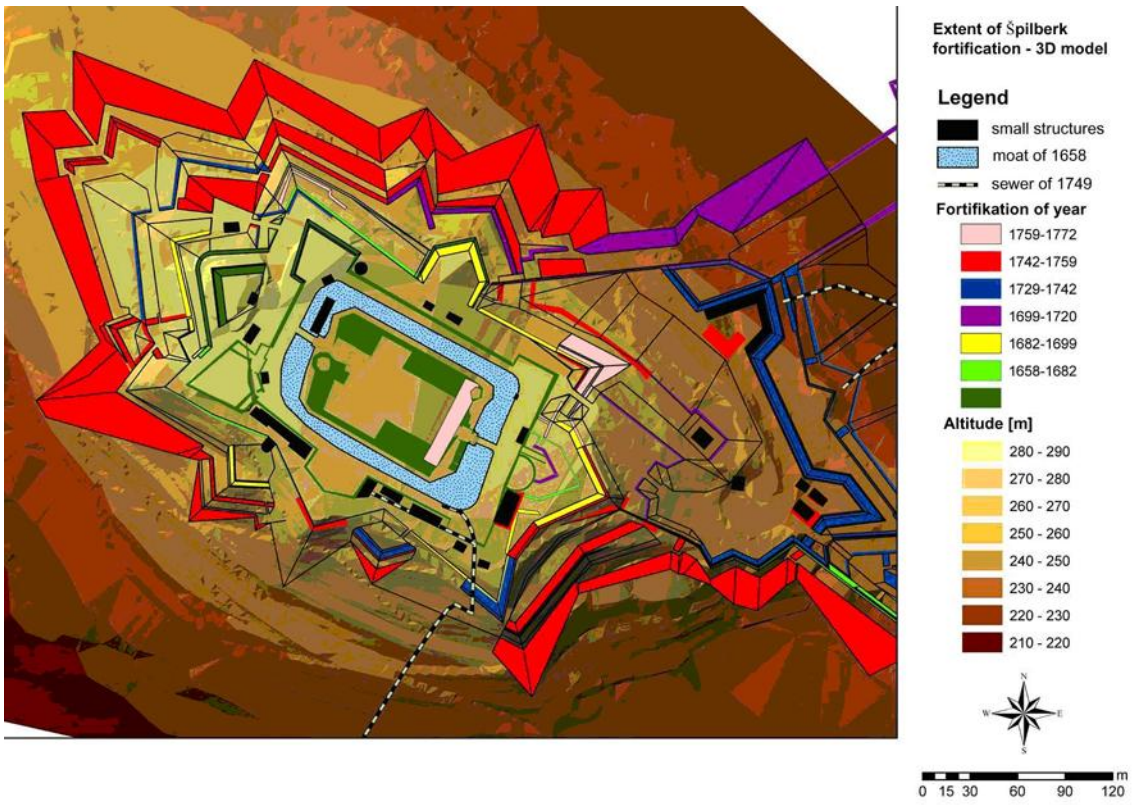

Fig. 9 – Extent of Špilberk fortification (3D model).

Conclusions

The goal of the project was a documenting of the historical development and changes in core of the housing city, a creating of a functioning system of historical database, a serving a special interest group of users. This process was done on the basis of maps imported into the ArcGIS program. Furthermore, it was also working with information obtained from literature. Some materials (especially historical maps) did not meet the required accuracy, therefore, had to be supplemented by direct measurement in field. Created project allows a comparison the development of urban historical core of Brno in various stages of the Middle Ages to the present. Layers contain the most important of all elements classified according to purpose, style and time. Next, the fly over the terrain was created by module ArcScene. The entire project was exported into a format PMF (Publish Map Format), which can be viewed by ArcReader. This application enables users work with all layers without license (free ware). The project was completed by WMS capabilities, which allows the sharing of geographic information in the form of raster maps on the Internet. It allows a connecting of geographical data (maps, satellite images, ortho-photo, etc.) to the workflow software (GIS, CAD). These data are stored on other servers, in different formats (*.jpg, *.tif, *.png). This data is already related to a given coordinate system, which allows us their correct interpretation.

Another contribution of this project is a creation of 3D model today non-existing baroque fortification of the Špilberk castle. It will be historically the first 3D digital model of the citadel taking original shape the one the second half of 18th century. We believe the results of historical reconstruction of Špilberk castle and its surroundings will become a valuable contribution for institutes and people working in the field of medieval archaeology, but it will also draw attention of general public. The project is not closed completely, maps are prepared and its future depends only on the ideas of more effective treatment and completion, because each area and building has a own special history.

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Evaluation research of the educational role of Information and Communication Technology (ICT) for the presentation of the Past (Case Study: Hellenic Cosmos, Foundation of the Hellenic World, Athens)

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Abstract: This paper describes the research we carried out at Hellenic Cosmos (HC is the exhibition centre of the Foundation of the Hellenic World, Athens Greece). We investigated the usefulness of interaction and virtual reality technology for learning the past in Cultural Heritage settings. More specifically, the intention of the survey was to examine the learning outcomes in museum educational programs comprised by virtual reality and interactive exhibit elements. We present the results of the survey that can be used as a foundation for discussing the role that new media play as mediators in the construction of knowledge. Finally, the conclusions can be a basis on which to discuss about the suitability of ICT (Information and Communication Technology) displays for gaining knowledge of the past, the increase of the engagement, the different kinds of learning that new media allow etc.

Keywords: virtual reality, interaction, museum education, presentation of the Past.

Introduction

Nowadays, new media has been part of museums and intends to reinforce the communication with the audience. New technologies, like multimedia components and virtual reality, occur in museums, and that is the reason why there is a considerable interest in visitors' learning through them. Moreover, the organised educational actions for school teams count many years in the museum realm of Greece. On the contrary, the educational programs that use advanced technologies constitute a recent reality while the institutions that support them are very few. The case of the HC is one of the most representative examples where its educational programs are almost completely based on high-tech exhibits, like virtual reality and interactive displays.

The aim of this survey had to do with the way the students experience these exhibits and their suitability for learning through the educational programs that are held. More specifically, we wanted to investigate if the learning goals of the two displays are achieved in the frame of the educational programs that the HC presents.

The displays we used as the basis of the survey were two: The Tholos, which is the Virtual Reality theatre with a semi-spherical screen, and the "Meeting at the Ancient Agora", an exhibition that constitutes of different exhibits, either high-tech (multimedia and VR applications) and more traditional ones (text, images, hands-on etc.). To meet the goals of the survey we used face-to-face questionnaire with members of school groups, then we made qualitative and quantitative analysis of the gathered data as well as the interpretation of the outcomes.

The Hellenic Cosmos

The Foundation of the Hellenic World (FHW) is a Greek privately funded non-profit Cultural Heritage institution based in Athens, Greece (GAITATZES et al. 2000). FHW's mission is the preservation and dissemination of Hellenic history and tradition, the creation of an awareness of the universal dimension of Hellenism and the promotion of its contribution to cultural evolution. Its aim is the understanding of the past as a point of reference for the formation of the present and future so that contemporary thought may be inspired by the Hellenic spirit, always with the contribution of the advanced technologies (ROUSSOU 1999). The Hellenic Cosmos (HC) is the cultural centre of the Foundation, founded in 1998, and uses state-of-the-art ICT (Information Cultural Technologies) and museological trends to offer educational programmes, virtual reconstructions, documentaries and exhibitions (PUJOL 2008).

Virtual reality at Hellenic Cosmos

At the time the survey took place in 2008, the HC had three main exhibits involving virtual reality on display: The "Kivotos" (a CAVE-like system composed by 4 back-projection screens that shows archaeological sites' reconstructions with the help of stereoscopic glasses), the "Tholos" and the exhibition "Meeting at the Ancient Agora". More specifically:

The Tholos and its Educational Program

The Tholos is an innovative display (inaugurated in December 2006), and due to its state-of-the-art technology, the HC is one of the very few cultural institutions in Europe that offers VR presentations of archaeology and past. It consists of a semi-spherical screen inclined 23º that surrounds a room with 132 seats, each one equipped with a joystick and four buttons, that allow interaction with the application. The navigation in the Tholos is not recorded, but real time. The museum educator leads the spatial navigation with the help of a wand, and a second one [museum educator] makes the narrative and gives information of archaeological content (description of the buildings, functions). One of the main goals of the Tholos is to give the audience the opportunity to participate in the display and decide for the progress of the program through the interaction with the application.

The interactive tour at the Ancient Agora comprises and presents three different periods, the Classic, the Hellenistic and the Roman period. These three reconstructions give the opportunity to the visitor to perceive the main features, the development, the evolution and the changes in the site's function through time, as it is recorded in its architectural and city-planning differentiations. The real time navigation begins with the amphora (the ancient vase), which is the means for the time journey. The used technology creates a real 3D effect and a sensation of flying, while the students feel that they move within the virtual world and transfer in different places. The destination of the first travel by the amphora is the Agora of the Classic times. The museum educator explains the sociopolitical conditions and the most important aspects of public life in these times. Furthermore, he/she gives the opportunity to the students to decide the direction they prefer (to go left or right), by the use of the buttons in their seats. Then, they go on with the transfer from Classic to Hellenistic period by the amphora and they end up at the building of the Stoa of Attalus. At this section, the audience could decide which floor of the Stoa will be visited. The last period of the time-journey is the Roman era,

where we see the construction of temples, auditoriums, libraries etc. The final unit of the educational program is the voting for the ostracism of 416 BC. by the participants with the help of the buttons on their chairs.

Meeting at the Ancient Agora and its Educational Program

The “Meeting at the Ancient Agora” is the most recent exhibition of the HC. It complements the Tholos educationally and conceptually and aims to bring to life the social, political and intellectual reality of the Ancient Agora of the city of Athens in the period in which the Agora was constructed. It deals with the values that were born in the Ancient Agora and shaped contemporary political thought, such as justice, isonomy, freedom of speech, participation to common affairs etc.

Its main feature is the combination of many different types of exhibits, both natural and interactive applications of advanced technology (text, images, scale models, videos, recorded narrations, hands-on and technological applications), which allow different kinds of exploration and degrees of collaborative interaction (PUJOL 2007). This environment provides a multitude of experiences that allows opportunities for critical thinking and aims to encourage the audience to approach the ideals that were born in the classical years in Athens and realize the importance to contemporary societies.

The educational program begins with the museum educator asking the students what they know about the Ancient Agora of Athens, in order to discuss and to extract from them the existing knowledge or experience. The next section deals with the archaeological excavations that bring to the light the findings of the Ancient Agora and the most important archaelogists that got involved in the excavating activities. Then, the school team goes to a touch screen display that presents the ten tribes of Athens and the relative regions of the city. The next unit is about the “Philosophy and the Rhetoric” where the museum educator starts a discussion about the philosophers and their role in the society. Then, a few students are asked to take the floor and argue about a class issue (for example recycling) with their schoolmates. The aim of this part of the educational program is to be comprehensible that the dialogue is one of the ideals that was born in the Ancient Agora and to consider its importance to our societies. The next exhibit is another interactive touch screen that examines whether or not somebody is able to become a deputy according to the criteria they had in the 5th century BC. The students learn the procedure and the criteria that the Athenians of the Classic years used to use for the candidates of the representatives for the Athenian Parliament. The last exhibit is a traditional hands-on display and aims to show the procedure of the judge selection. The museum educator has the opportunity to get back to the tribal topic and ask the students if they remember the name of their tribe according to the first display of this educational program. At a first glance of the educational program, it is obvious that interaction succeeds to keep the interest of the students, but this will be analyzed later by the results of the survey.

Goals and methodology

The sample of the survey was constituted by students that made an educational visit in the HC, from the 3rd grade of the elementary school to the 9th of high school. The choice of this specific target group had to do with the fact that these students had already a first contact with the cognitive object that deals with the

particular exhibits, the Ancient Agora. According to the school program, as it is determined by the Ministry of Education, the students of the 3rd grade of the elementary school are taught Greek ancient history for the first time. So, our sample has already a cognitive background, provided that, according to the theory of constructivism, the process of learning is built on existing knowledge and it depends on the experiences that the individual have before the museum visit (HEIN 1998). After the pilot testing of the questionnaire in December 2007, the interviews were conducted from January to March 2008. The total amount of the collected questionnaires was 127, from 38 Greek schools. After the data gathering, a quantitative (categorization of answers, uni-variant and bi-variant techniques) and qualitative (interpretation and comparison) analysis followed, with the help of the software SPSS. To meet the goals of the survey we used mainly the interview with a face-to-face questionnaire. The structured interview (combination of open-ended and categorized questions) guarantees the most accurate completion of it because the interviewer can help the interviewee to understand exactly the questions, avoiding misunderstandings (BORUN and KORN 1999: 18).

Research results

In the first question, we ask the children to describe the experience they had at the HC with just a sentence. The largest percentage of the answers (12,6%) refers to "time traveling", following the "tour in the ancient Agora" and "the feeling that you were there" (11% each), an "educational experience" (9,4%) and finally "virtual reality" (8,7%).

Answer	students	persentage
educative	12	9,4%
enjoyable	4	3,1%
new technologies	2	1,6%
impressive	7	5,5%
interesting experience	2	1,6%
immersion	14	11,0%
reconstruction/image of buildings of Ancient Agora	4	3,1%
interactive	4	3,1%
combination of entertainment and learning	7	5,5%
virtual reality	11	8,7%
life like, good quality graphics	1	0,8%
tour at the Ancient Agora	14	11,0%
useful experience	4	3,1%
time travel	16	12,6%
for younger kids	1	0,8%
combination of immersion and time travel	1	0,8%
new technologies tour	3	2,4%
combination of entertainment, learning and new technologies	8	6,3%
interactivity and virtual reality	4	3,1%
interactive tour	8	6,3%
total	127	100,0%

Table 1 – How do you describe the experience you had at the HC?

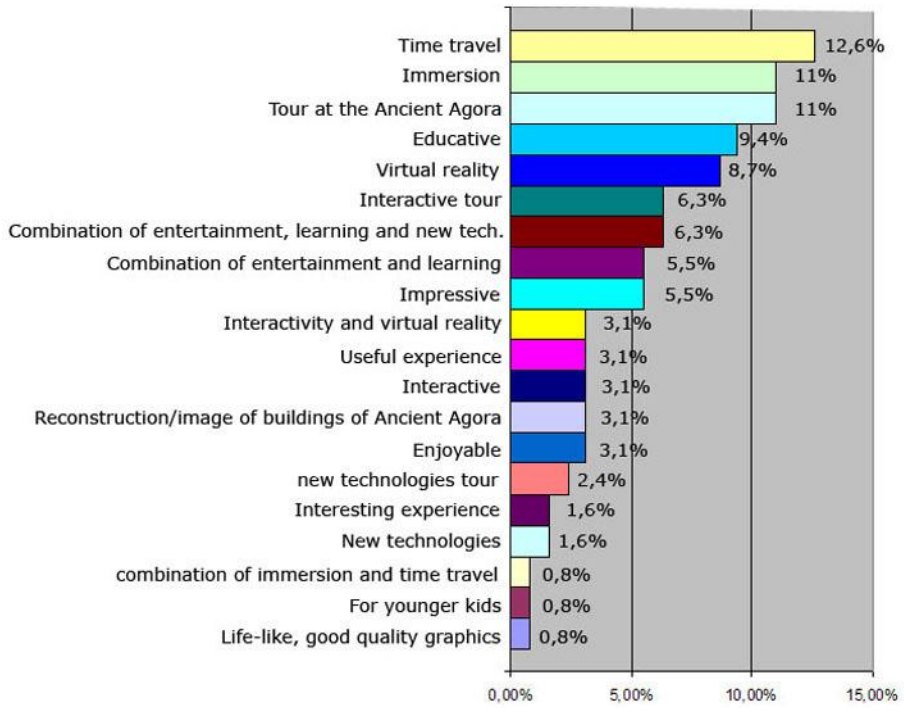
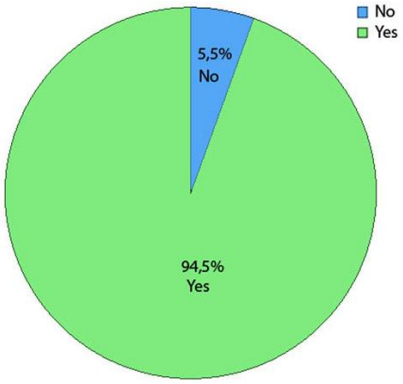


Diagram 1 – How do you describe the experience you had at the HC?

It is obvious that the majority of the students experienced these two visits as a space-time journey, a transportation to other places and periods. If we attempt to make one more step, we will perceive that the feature that “transported” the visitors is the immersion of the Tholos. This is a logical result because first of all the Tholos is a really impressive display and secondly is probably a new experience for such young children. We should not forget that many researches claim that the innovation and the originality have positive influence in the process of children learning (FALK and DIERKING 1992: 57). The use of words such as traveling and time touring are expressions that are used from the HC in its advertisements for example, and probably have influenced the way that the students “see” and finally describe the Tholos. Finally, it is remarkable that a considerable percentage characterized the experience educative (9,4%) or a combination of learning and entertainment (6,3%), that shows that the students feel that this is not only about amusement but it is a tool to learn as well. Therefore, this may show some socially acceptable perceptions that have influenced the students about the role of the museums and the aims of their programs. At this moment however, we are not able to evaluate this tension, we will come back later when we may have a clearer picture.

The second question was trying to find out if the museum educator helped the children and the visit generally. 94,5% of the participants believe that the museum educator enhances the interpretation of the experience and helps them to understand while having a good time during the programs. This result underlines the significant role that the human guide plays for the construction of the experience.

answers	students	percentages
no	7	5,5%
yes	120	94,5%
total	127	100,0%



Table/Diagram 2 – Did the museum educator help you?

Then we asked them the reason why they believe that the museum educator helped. 55,9% declared that the educators offered explanations and resolve doubts, 15% that they facilitated the process of learning and 7,1% answered that they either explained or gave necessary guidelines for the visit in the displays. We found here that despite the fact that the new technologies provide important possibilities, they may not be sufficient communication mediators and may not achieve their full potential in Cultural Heritage displays. The necessity of the human presence derives not only for the guidelines or the explanations, but it becomes clear that the virtual/ interactive experiences need a mediator between the displays and the audience for the construction of meanings and knowledge. Moreover, we should not forget that the audience is not accustomed to these technologically high environments (ROUSSOU 2002: 3), even for ages that are considered to be already familiarized with the new technologies. Though, the most important of these results is the fact that even 5% that gave negative answer, acknowledges the importance of the educator as the mediator between visitors and displays. They pointed out that they would like to have the option and the time to explore the displays on their own as well, without canceling the significance of the museum educators.

answer	students	percentages
need time to explore the displays on their own	7	5,5%
offered explanations	71	55,9%
guide the visit	4	3,1%
useful information	3	2,4%
keeps in discipline the group	1	0,8%
better than books	1	0,8%
facilitate the process of learning	20	15,7%
solve doubts	2	1,6%
not very good explanations	1	0,8%
offered explanations and guidelines	9	7,1%
offered guidelines and keeps the group in dicipline	1	0,8%
not strict like a teacher	4	3,1%
useful assistance and conversation	3	2,4%
total	127	100,0%

Table 3 – Why [the museum educator helped/not helped you]?

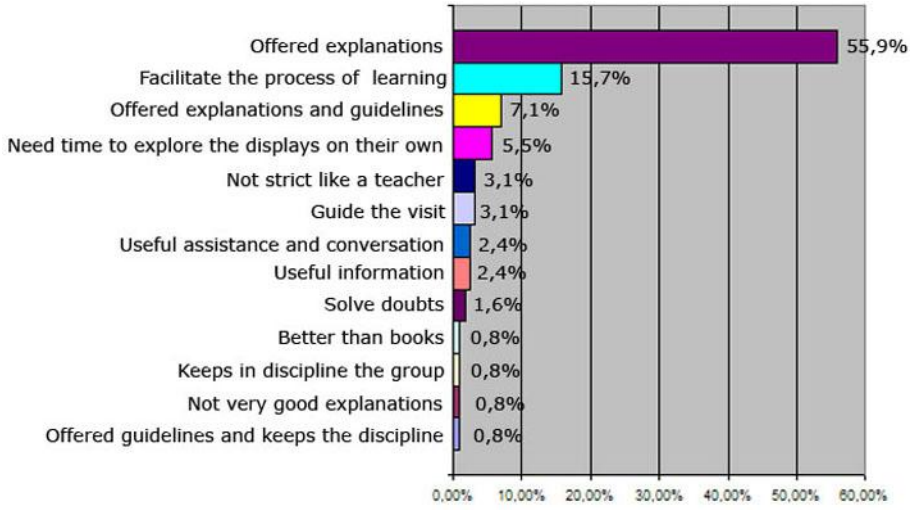
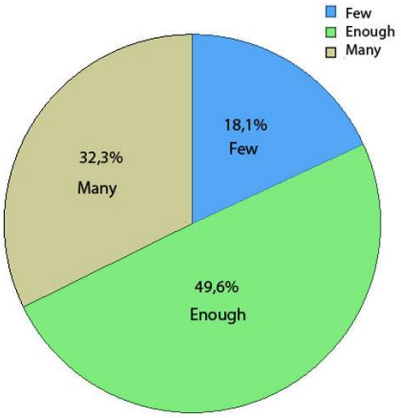


Diagram 3 – Why [the museum educator helped/ not helped you]?

The 4th question asked about the learning dimension of the visit. The response was positive: 32,3% “learned many things”, 49,6% answered that they “learned enough” and 18,1% “learned a little”. On the contrary, we didn’t have negative replies (“I learned nothing”). So, according to the students, new technologies are useful and effective for learning.

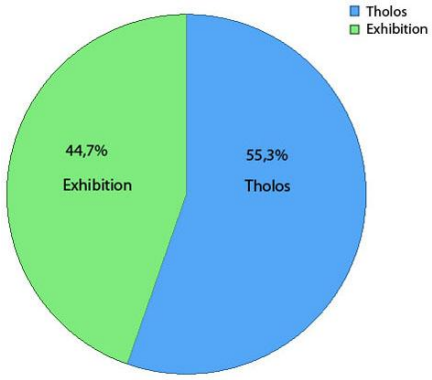
answers	students	percentages
few	23	18,1%
enough	63	49,6%
many	41	32,3%
total	127	100,0%



Table/Diagram 4 – Did you learn anything today?

Question number 5 supplemented the previous one, asking the students to compare the effectiveness of the two educational programs for learning, in the Tholos and in the exhibition Meeting at the Ancient Agora and give the reason for their answers. The sample here is smaller because this question is addressed to the students that visited both displays (103 students). So, 55,3% consider the Tholos more effective for learning while 44,7% believe the same for the exhibition.

answers	students	percentages
Tholos	57	55,3%
Exhibition	46	44,7%
total	103	100,0%



Table/Diagram 5 – Where did you learn more?

In the second part of the question we asked the children to give the reason for the previous answer. Here are the results:

From those who selected the Tholos, 24% justified their choice because of the visual components, 7,9% found beneficial the combination of the visual components and the explanations of the museum educator, 8,1% found the Tholos enjoyable and the last 8,1% characterized it impressive, which helps the learning process. Regarding the Meeting at the Ancient Agora, 8,9% considered the exhibition as more suitable for obtaining knowledge because of its richness of information that is given. Finally, the other 7,9% referred to the opportunity to ask and discuss that was not possible in the Tholos.

The above answers describe two different types of learning: In the case of the Tholos, it provides a reconstruction of the place in the past and its characteristics offer a real feeling of transportation. Moreover, it is a new and impressive means with a dynamic audiovisual presence that attracts the interest of the student, which is related to the increase of the engagement and the reinforcement of the learning process (FALK and DIERKING 2000). Furthermore, it seems that for those who characterize the exhibition more suitable for learning, the most decisive factors are the interaction with the digital exhibits, the human presence and their conversation, the active participation and the navigation in space and time.

answers	students	percentages
Tholos: image and good quality graphics	26	24%
Tholos: combination of image and discussion	9	7,9%
Tholos: specific and focused thematic	2	1,9%
Tholos: more enjoyable	7	8,1%
Tholos: impressive experience	9	8,1%
Tholos: option to choose	1	1,0%
Tholos: immersion	1	1,0%
Tholos: spatial information	2	1,9%
Tholos: superficial information	1	2,0%
Tholos: visual information, not reading	1	2,0%
Tholos: opportunity to decide & immersion	2	2,9%
Exhibition: more information	10	7,9%
Exhibition: detailed information	11	10,7%
Exhibition: human presence, not only buildings	6	6,8%

Exhibition: opportunity to discuss	11	8,9%
Exhibition: proximity to the exhibits	3	2,9%
Exhibition: interactive displays	1	1,0%
Total	103	100,0%

Table 6 – For what reason [did you learn more at Tholos or at the exhibition]?

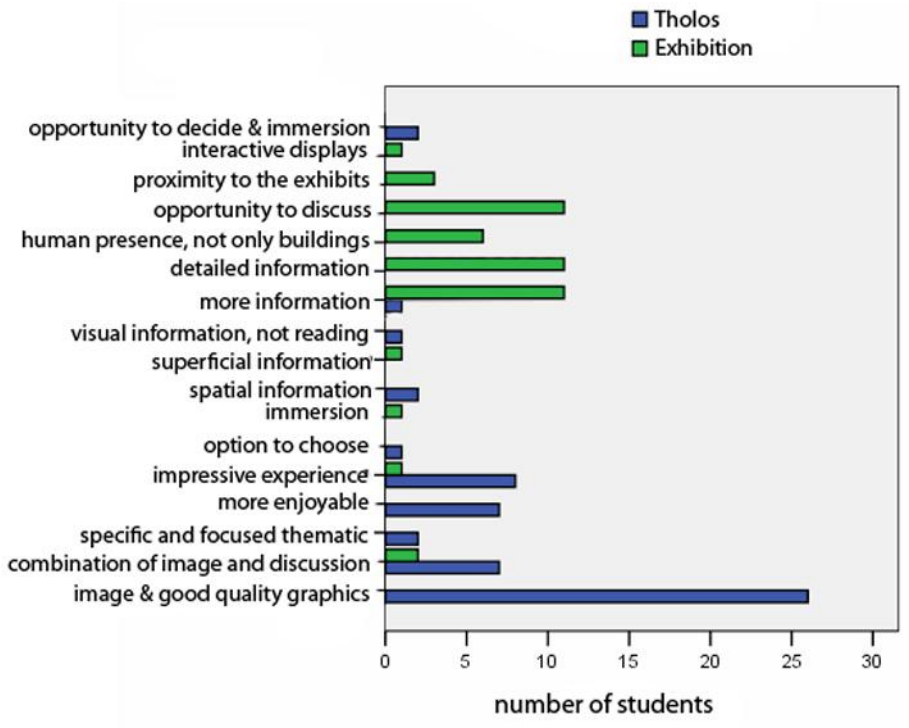


Diagram 6 – For what reason [did you learn more at Tholos or at the exhibition]?

Then, we asked the students to recall something that they learned from these two visits. 20,5% mentioned the “election of the judges”, 15,7% the “architecture of the Market”, 11% the “criteria of deputies”, another 11% the “sports” that were carried out, 10,2% a name of the philosophers, and another 10,2% “10 tribes”. It is worth pointing out that all the above answers concern the content of the exhibition, except the architecture. Here we notice something paradoxical: Despite the fact that in question 5 the majority of the students declared that the Tholos is a more suitable environment for the learning process, the answers in question 7 show that all that they mention as acquired knowledge emanated from the exhibition for the Agora. The reason for this antithesis is that Tholos provides visual information and general idea about the place, the architecture and the buildings. At the exhibition, on the contrary, the given information is much more structured and consists of easily identifiable units. That means that the structure of the exhibition facilitates the process of acquainting knowledge. Moreover, we noticed that all the replies to the above question derive from the direct interaction between the student and the exhibit. It is more than clear that the judges, the deputies and the Athenian tribes are information from the exhibits that require the personal interaction of the students. This underlines the significance of the interaction and participation for the acquisition of knowledge and its capacity to stimulate the interest. George HEIN (1998: 34) says that in

constructivistic environments, learners use both their hands and minds, to interact with the world and they finally reach conclusions and increase their understanding about the phenomena of the world.
Finally, the Tholos, due to the visual character of Virtual Reality technology offers more abstract, spatial and superficial knowledge, while the exhibition contained more factual and well documented information. It appears that each exhibit supports a different type of learning, the first one based on the virtual reconstruction and on its audiovisual tri-dimensionality. The second one supports the direct interaction and the active participation. By using different communication means, the evaluated educational programs can attract the interest of more students. According to FALK and DIERKING (1992), the type of learning constitutes a fundamental aspect of the construction of the museum experience. Many theories are related to different learning styles (based on interests, characteristics, abilities etc.) such as Gardner’s multiple intelligence according to which the learners' intelligence profiles consist of various combinations of different types of learning, like the kinesthetic, the musical, the interpersonal, the linguistic etc. (GARDNER 2005).

answer	students	percentages
judges selection	26	20,5%
criteria for deputies	14	11,0%
philosophers names	13	10,2%
ostracism	10	7,9%
athletic events	14	11,0%
architecture of the Agora	20	15,7%
information for the 10 tribes	13	10,2%
place for conversations	3	2,4%
temple column orders (Doric, Ionic etc.)	2	1,6%
location of Agora	7	5,5%
market place	4	3,1%
existence of a Banker	1	0,8%
Total	127	100,0%

Table 7 – Tell me something that you learned during the visit.

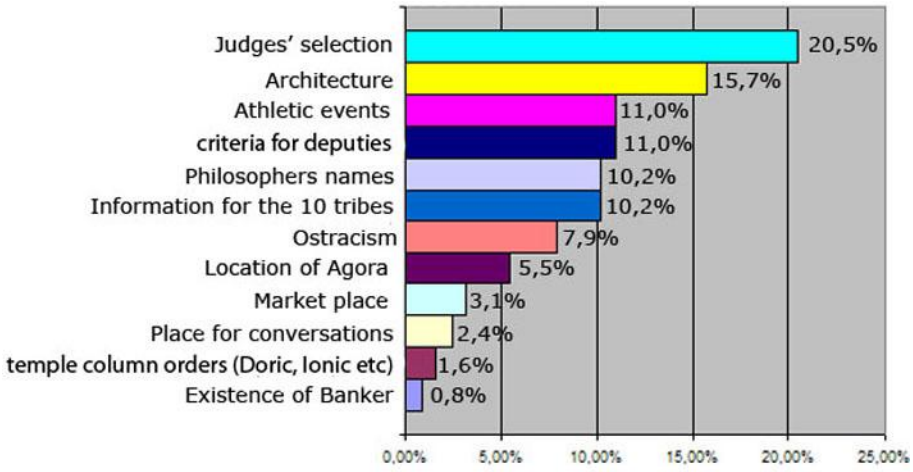


Diagram 7 – Tell me something that you learned during the visit.

The next question focused on the most impressive element of the visit according to the students. The four most frequent answers are: 19,7% referred to its immersivity, followed 15,7% with the construction of the buildings, 14,2% answered the interaction and 10,2% the time travelling via the amphora. It is obvious that these four answers referred to the two main characteristics of the virtual reality technology of Tholos: The immersivity and the interactivity. These results reinforce the usefulness of the technological exhibits, the strong impression they made on the visitors and the effectiveness of multiple sensory displays.

answer	students	percentages
travel through the amphora	16	12,6%
building constuction	20	15,7%
graphics and virtual reality	13	10,2%
interactivity	18	14,2%
immersivity	25	19,7%
choice of deputies	5	3,9%
technology and virtual reality	5	3,9%
exhibition entrance	1	0,8%
navigation in the Tholos	8	6,3%
touch screens	3	2,4%
trees and nature	1	0,8%
big and impressive screen of Tholos	3	2,4%
scale models at the exhibition	3	2,4%
exhibition photos	1	0,8%
immersivity and navigation	2	1,6%
immersivity and interactivity	3	2,4%
Total	127	100,0%

Table 8 – What impressed you the most?

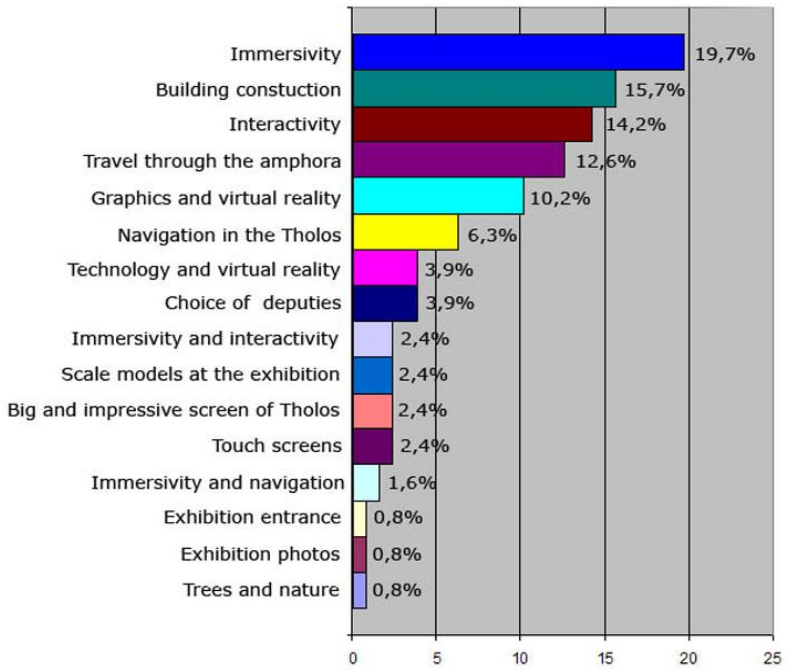
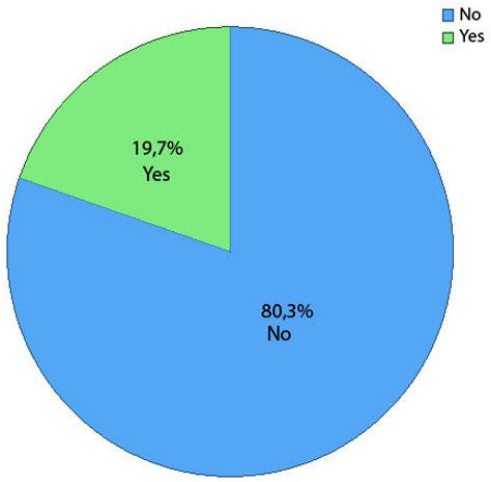


Diagram 8 – What impressed you the most?

Question 9 examines if there were any type of preparation in the school class before the visit. 80,3% didn't have any preparation while only 19,7% gave a positive answer. These percentages show that the school system doesn't consider the pre visit preparation an important process, despite the fact that according to the constructivist learning paradigm the previous knowledge is an important paramount for learning because it determines the relevance of the new information and creates links with the past experiences (HEIN 1998; FALK and DIERKING 2000: 28).

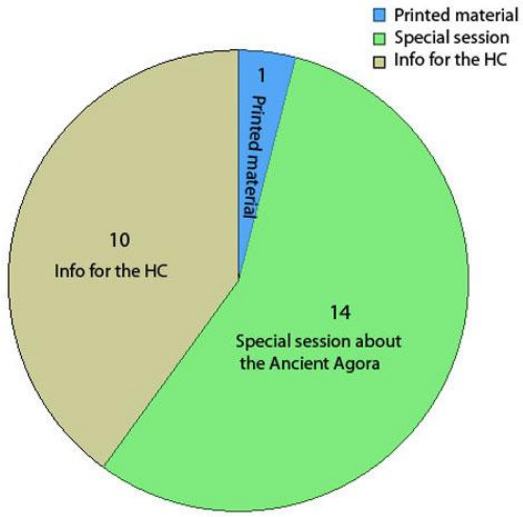
answer	students	percentages
No	102	80,3%
Yes	25	19,7%
Total	127	100,0%



Table/Diagram 9 – Did you have any type of preparation in your class before the visit?

Then, we asked from the 25 children that gave a positive answer to define the type of preparation they had before the visit. 14 children had a special session about the Ancient Agora, the other 10 were given information for the Foundation of the Hellenic Cosmos and only one student replied that they were given printed material (related data, games etc.). These results reflect the relation between museum – school and it seems that the museum visit is not considered a process of learning that depends on the existing knowledge and requires repetitiveness.

answer	students	percentages
printed material	1	4,0%
special session about the Ancient Agora	14	56,0%
info for the H	10	40,0%
Total	25	100,0%



Table/Diagram 10 – What kind of preparation?

Conclusions

The main conclusions of this research are shown below:

- Most of the features that the students mentioned as acquired knowledge comes either from the interaction with the displays or with their classmates (touch screens, voting at the Tholos etc.). Thus, we notice that the importance of the active participation and the personal involvement is enhanced, which are the two main components of the constructivistic theory (HEIN 1998: 34).
- It is worth pointing out that the interviewees characterized the interaction and the immersion, the most significant features of the virtual reality, impressive and helpful for the learning process. This conclusion enhances the important and influential role that new technology can play in the formation of the museum learning experience (BRICKEN 1991; DEDE 1998).
- The experience of these displays was characterised by the participants as interesting and entertaining. This signifies the improvement of engagement and respectively, according to constructivism, reinforces the procedure of learning (HEIN 1998). However, it appears that despite the technological supremacy of these displays they don't manage to "communicate" with the audience, especially without the human mediator. The presence of the museum educator remains one of the most critical factors for the construction of meaning and finally for the completion of the virtual experience (ROUSSOU 2002; ECONOMOU and PUJOL 2006).
- It is interesting to note that despite the fact that the majority of the students answered that the Tholos is more effective for learning, when they were asked to mention one thing that they have learned in HC their answers derived from the exhibition for the Ancient Agora. However, this result might be reasonable if we think that the Tholos provided a general image/idea about the reconstruction of the Ancient Agora (architecture, venue etc.), while the exhibition deals with more specific subjects, like the the required criteria for the election of deputies or the process for the choice of the judges. Eventually, it didn't become clear which display reinforces the educational role of the museum. What, however, is apparent is the fact that the two programs concerned different intelligences, as they are determined by H. GARDNER (2005). As a result, the programs become more attractive and efficient for a larger quantity of visitors, provided that we know that the increase of the interest is a significant condition for the construction of the knowledge (HEIN 1998).
- It didn't become clear which display is more suitable for learning the past. However, the results confirmed that ICT allow different learning styles, as they are defined by Howard Gardner's theory of multiple intelligences.
- We noticed that the great majority of pupils hadn't been prepared before the visit, which is a fact that underlines the lack of preparation in schools. In particular, it seems that it is not taken into account that the process of learning depends on existing knowledge and the educational programmes could seek connections between the already known and new information (FALK and DIERKING 1992: 25; 152)
- Finally, the link between the children and the new technologies is a parameter that influences positively their attitude toward the displays, provided that is very likely that they have already navigated themselves in three-dimensional environments. As a result, they are more adaptable with the displays of the HC and familiar with the navigation in the virtual world (PROVENZO 1991; BRICKEN and BYRNE 1993).

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Carved stone and web geography

A full digital approach to localization and information handling for rupestrian monuments

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Abstract: The rupestrian settlements have always been a highly suggestive and interesting subjects for archaeologists and artistry scholars. In many rupestrian sites, one of the main problem has always been the clear reading of the shape of the cave and the creation of relationship between a certain variety of information and graphical and textual elements coming from the state of knowledge about that structure. Often the place where the monument is situated can be quite difficult to find and to access, even in the case of some well-known sites it can be hard to find their exact position when moving in their surroundings. A possible answer to this complex problem, can come from a multimedia digital solution, combining the web geographic resources and the use of virtual panoramic images capable to create links to a wide range of data. In the proposed case study, the complex settlements in the Massafra area, near Taranto in Puglia – Italy, has been taken as a test to build a system based on Google Earth paths and waypoint tracing combined with panoramic images built using standard photographic cameras and a dedicated tripod head. The overall result is linked to a system of connections capable to establish a complete network between the location of the monument and all the available information about architecture, art and history related to it. In specific, the Church of San Simine and Sant'Angelo are the core of the research, while a partially rupestrian architecture was studied in the town center of Massafra. As shown, this work has born from the wish to deal the studied projects in a manner capable to develop a method to establish a different technical methodology which can be applied also in other architectonic cases and can be expanded using the latest multimedia technologies.

Keywords: Rupestrian, Panoramic, Google Earth, Web Geography, Digital Imaging.

Step one: the sites

The territory of Puglia, Italy, involves 13 municipalities (Gravina in Puglia, Altamura, Santeramo in Colle, Laterza, Ginosa, Castellaneta, Palagianello, Mottola, Massafra, Crispiano, Statte, Montemesola, Grottaglie) where in each one it is possible to find host signs of "Rupestrian" civilization.

In the proposed case study, the surroundings of Massafra, near to Taranto in Puglia, Italy, is an area where many rupestrian sites are placed. Almost all these settlements took place between the tenth and thirteenth century and they are located in wide canyons called "gravine".

Therefore, this area is the cradle of civilization that knew how to use rocky gorges as homes, work environments and worship. These canyons were offering an easy way of digging into the rock, because of

their geomorphological construction composed from crumbly sandstone, as well an easily defendable position against all eventual external threats.

Fig. 1 – Example of gps tracking.

Without having an appropriate knowledge of the territory, it is very complicated to find these sites and to reach them, because of their strategic position and centuries of neglect. These two reasons can mean a discouraging fact even for people interested in rupestrian settlements and also can be considered as a negative influence upon the tourism. It expresses a lost chance to visit and to study some rupestrian jewel – like of the Byzantine age like the churches of Sant’Angelo in Mottola or San Simine in Pancrazio.

The church of Sant'Angelo (Mottola, Taranto, Italy)

The church of Sant'Angelo has a rare structure, it is composed of two underground spaces overlaid with a similar planimetric plan: the upper floor as well as the lower floor is divided into three aisles ending in apses with that one difference that the lower floor was used as a burial area (similar examples were found in Asia Minor).

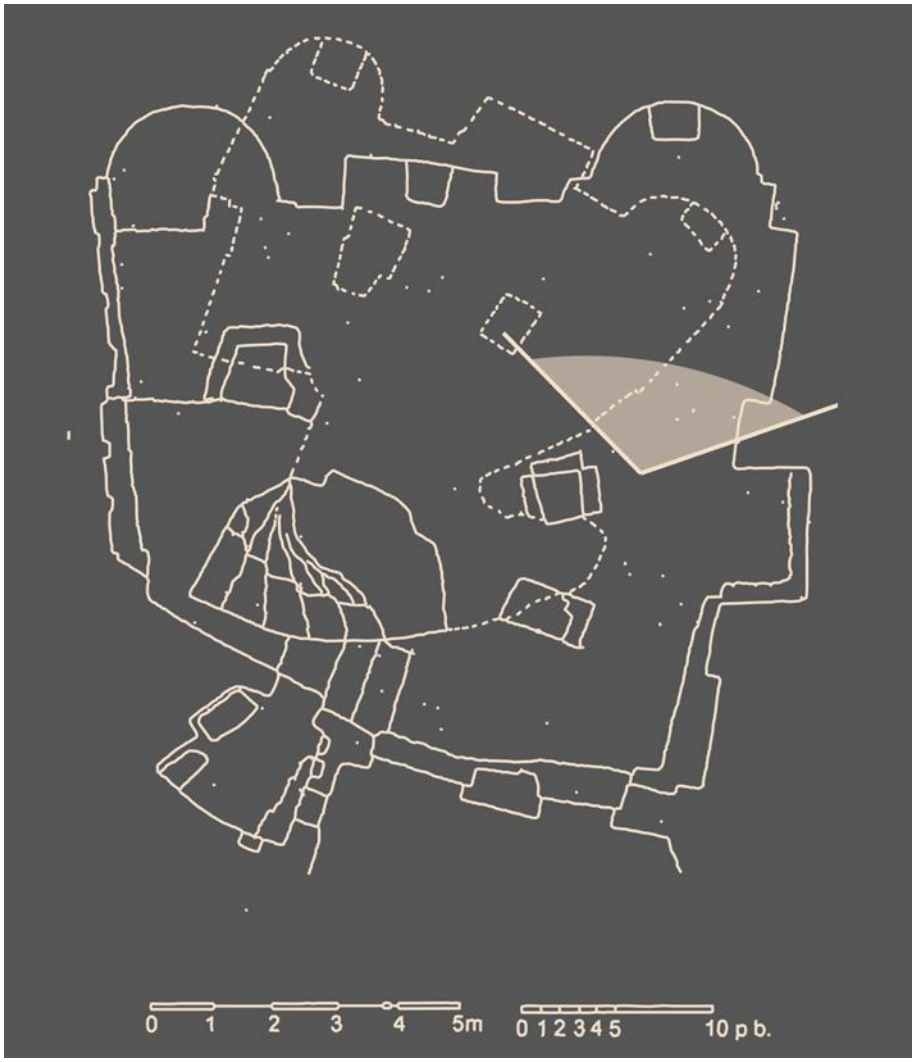

Fig. 2 – Church of Sant'Angelo: plan view.

Initially, the structure was used as a church for buries like we can see it from the repetition of the iconographic theme of Deesis.

Probably the original structure was formed by two naves and left aisle, which is situated close to the north wall and it seems it was dug later on. As shown by the architectural style that part of the church is different from all the rest. In the thirteenth century the stairway leading to the Crypt was excavated and was used for burial rites.

The church is liturgically oriented with apses directed to the East and with aisles divided by three monoliths pillars. There are barely visible traces of the original iconostasis on the floor which was probably destroyed during the construction of the Crypt.

Outside, the church has a large pronaos that was covered with roofing tiles found during the excavations in 1972.

The upper floor

The upper floor is the most ancient. It was built in the twelfth century. All the frescoes of this church are seriously damaged: their bad condition is specially caused by the air pollution, water infiltration and some acts of vandalism. All the frescoes are from the thirteenth-fourteenth century. It is possible to suppose that there had existed many other older frescoes but unfortunately during the years they have become lost.
On the right of the upper floor there is a painting of saint Bishop. The painting is palimpsest and includes the ruins of Madonna with Jesus sitting on the throne with an overlapping layer of a saint. On the external archivolt's side are painted two flying angels with red clothes. Close to these angels there is a fresco of St. Sylvester Pope with Mithra and pastoral.
In the second niche there is painted the scene of the Martyrdom of St. Stephen, partially destroyed during the construction works of the aisle. The following scene is the scene of Jesus Baptism which was painted in the thirteenth century. Another fresco is the palimpsest of Saints Vito and Paul. In the third arch it is barely visible St. Augustine who blesses with his right hand and in his left hand holds the pastoral.
Two Deesis are still present in the apses of the upper floor. The first Deesis is situated in the first apse and shows St. James appearing with the “*pecten iacobaeus”* on his mantle and with pilgrim's bag instead of St. John the Baptist.
In the third apse on the left side there had been the fresco of Madonna with Jesus on the throne, but in the present we can see only damaged remains of it. Close to the fresco of Madonna with Jesus on the throne there are the archangels Michael and Gabriel. Dott. Diehl made an incorrect evaluation of this fresco and swapped the figure of Madonna with the figure of Christ Pantocrator between the archangels Michael and Gabriel. On the arches of the apse there is the lion of St. Mark and the eagle of St. John which are the symbols of evangelists.
Along the left wall there are other traces of frescoes that identify: St. Margaret, St. John the Evangelist and an Angel. On the left wall near to the second entrance the figure of St. Vito is painted. On the ceiling just in front of the main entrance it is possible to see a black eagle with a book in his paws, as the symbol of John Evangelist. On the left column opposite to the main entrance there are some remains of the fresco of St George on the horse from the late thirteenth century.

The Crypt

The down floor with a burial area is from the thirteenth century. The only two intact graves which were excavated in 1972 by Dr. Roberto Caprara, contained a skeleton of a young woman and a skeleton of a young child. On the woman's skeleton knees were placed two coins from Brindisi dating back approximately to 1265. On the child's skeleton were found two silver circles placed on his/her skull.
On the right part of rounded ceiling there is the Jesus Pantocratore fresco who is sitting on the throne and near to him there are San Basilio and San Andrea. This fresco is from fourteenth century. The area under the arch which divides the right aisle from the main one, it is possible to see the fresco of San Pietro that is holding the keys and a paper roll. Another two frescoes, again in very bad conditions, represent San Paolo and San Bartolomeo.

The church of San Simine (Massafra, Taranto, Italy)

The church of San Simine is located upon a hill, approximately 2 km far from the town and it is impossible to see this settlement because the pine trees cut off the view. To access the church is possible through two doors of which the left one is crowned by a bezel.

The structural arrangement is for many elements archaic and therefore we can assume that the hall had been excavated earlier than the apse during the first stage of excavation between the tenth and eleventh centuries.

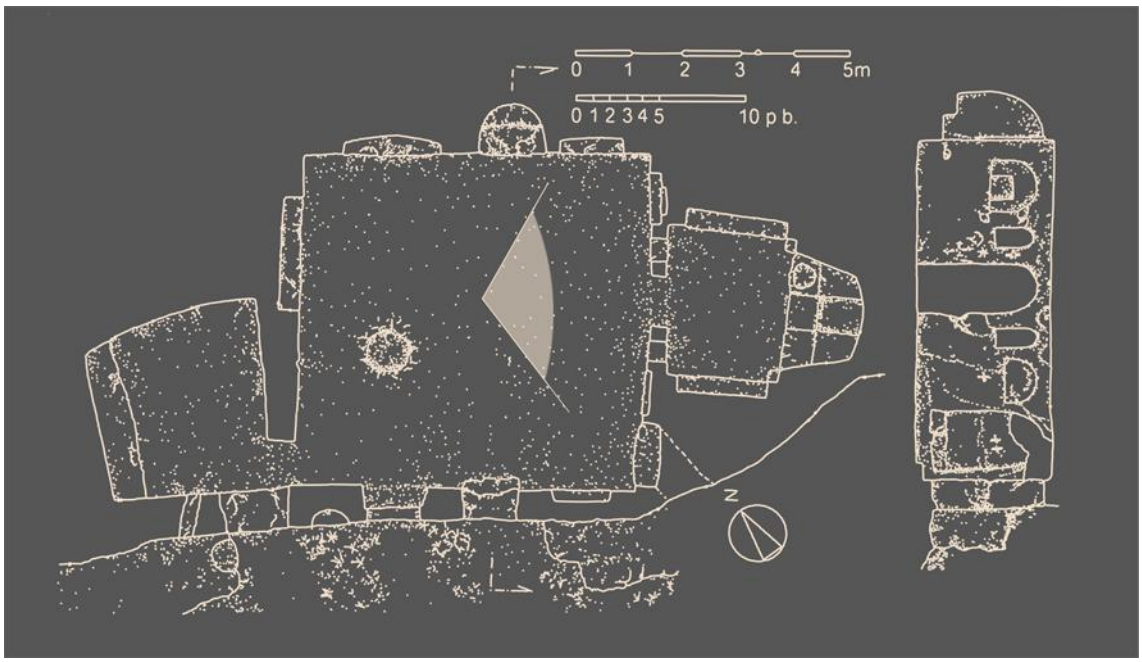

Fig. 3 – Church of San Simine: plan view.

The presbytery of the church is structured according the forms and elements typical for a specific period (as the barrel vault), so its construction can be dated to the twelfth century. The structure consists of a hall with a rectangular niches and arches on the walls and presbytery ending in a semicircular apse.

The church has a square form with a main single hall of dimensions 6.30 m x 5, 80m with an entrance on south. Like the church of Sant' Angelo, also this church has its liturgical orientation to the east. There is another entrance at the back of the church and its existence is probably caused by an enlargement of a window.

The small raised platform holding the altar is separated from the main hall by an iconostasis which led the authors to consider this church as a church with an Oriental Rite. While in 2008 Dott. Caprara and Dott. Dell'Aquila were conducting a research on churches with iconostasis, they reached an answer that the Church of San Simine could not be a church with an Oriental Rite. Their explanation was based on the fact that many of these churches as San Simine were officiated by Latin Rite. In according with this fact and by comparisons with the church of Saints Andrew and Procopius in Monopoli (dated in 1070–1075), they were also able to set the foundation period of Church of San Simine between the late eleventh and at least early twelfth century (not before 1090 and not after 1110).

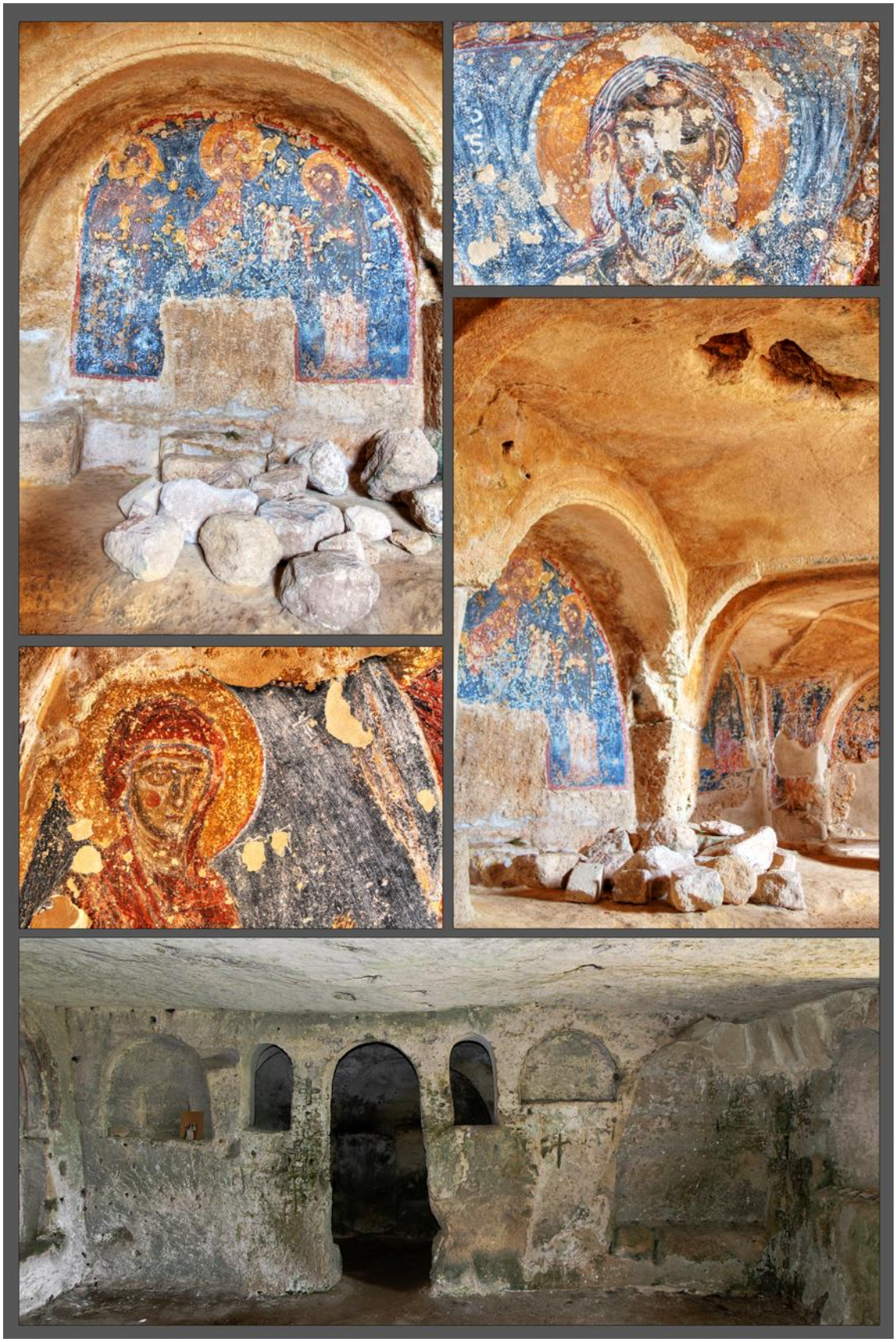

Fig. 4 – From the top left: central apse of Sant'Angelo; part of the frescos on the column of the central aisle; part of the frescos on the main apse; two of three apse on the upper floor; iconostasis in San Simine.

The peculiarity of the church of San Simine is the hall much wider than the trapezoidal small presbytery. As a consequence the iconostasis is a larger wall than the walls commonly built in other churches. It means that in addition to the door and two windows, there were also created two niches with flat bottom and rounded arch where there were icons or paintings.
On the north wall there are three niches: inside the right one, Madonna with Jesus sitting on a throne is painted, in the left one it is possible to read the remains of a fresco which shows a saint and it seems that he represents St. Jude Thaddeus.
On the west side of the church in connection with its main hall, there is a small irregular almost quadrilateral room with niches, with a small couch, with ruins of a seat. These equipments are usually interpreted as the place of a hermit's accommodation. In the context of church of San Simine, hermit's role was to guard the church. Like the church of San Simine, during the excavations executed in 1972 in the church of Sant'Angelo on its north side, were found a small pot and a dish belonging to the hermit.

Step two: the approach

The purpose of this project has always been to focus on the creation of an information network regarding the rupestrian locations of Massafra area that would be extendible also for all the rest of archeological locations with about-mentioned problem of access and research.
To reach this purpose we have mainly relied on two types of technological tools:

The GPS system

The GPS system has been a fundamental element for our project. Basically, the GPS or the Global Positioning System tracking is really a powerful and innovative tool because it determines the exact location of a certain person, asset, vehicle and location.
The information is easily transmitted through certain devices such as mobile phones, GPS trackers, and computers with Internet. Any information can usually be viewed in real time on a map to help anyone to locate his/her subject easily and quickly.
An advantage of GPS tracking system is that it can work in many various ways. The most common one is when GPS devices record the position of vehicles as they make their journeys. “Some systems will store the data within the GPS tracking system itself (known as passive tracking) and some send the information to a centralized database or system via a modem within the GPS system unit on a regular basis (known as active tracking) or 2-Way GPS.
A passive GPS tracking system will monitor location and will store its data on journeys based on certain types of events. So, for example, this kind of GPS system may log data such as where the device has traveled in the past 12 hours or more.
The data stored on this kind of GPS tracking system is usually stored in internal memory or on a memory card, which can then be downloaded to a computer at a later date for analysis. In some cases the data can be sent automatically for wireless download at predetermined points/times or can be requested at specific points during the journey” (www.eetimes.com).

As we already mentioned, we took advantage of this instrument which allowed us to mark the paths with a high level of detail and precision to reach the rupestrian settlements.

The 360° panoramic view

Modern and innovative ways of 3D space presentation are the spherical 3d panoramas and virtual tours, by using the 360°x180° panoramic photo projection.

There are many kind of 3D panoramic view:

- 360° panoramic view,
- virtual panoramic view,
- spherical panoramic view,
- QTVR panoramic view,
- cubic panoramic view.

This is a new way of representation, which covers all the space around one definite point for the angle of 360° horizontally and for the angle of 180° vertically.

The 360° panoramic view of rupestrian monuments was done through the use of a “pan and tilt head” which placed on the stand, has allowed:

- The correct positioning of the camera axis for rotation in accordance with the optical zoom.
- The exact progression angle for the acquisition of frames in increments of 45° on the vertical axis and 30° horizontally.
- The realization of multi-shots (for a minimum of three for each angular increment) with a variable exposure, to create an image with high dynamic range (HDR).

Fig. 5 – Church of Sant'Angelo panoramic view.

The panorama created with all the pictures (about 200 pictures for each environment; and many poses have required more than three different exposure value) was then blended: for the first, we have identified the photos of the same group related to each pose to be blended into a single frame with HDR and, subsequently, through the use of Pano2Vr software to be defined as a single spherical image and video.

By simple use of mouse or keyboard you can view all the space around, below and above you, and plus draw nearer the things and objects or distance them. That means you can carefully examine the details or study the general concept.

The way to use the 3D panorama it's very easy. With the help of the left button you can rotate the image in the required direction and to draw the objects nearer or to distance them (zoom) it’s enough to give a twiddle to the wheel on your mouse.

Fig. 6 – Church of San Simine panoramic view.

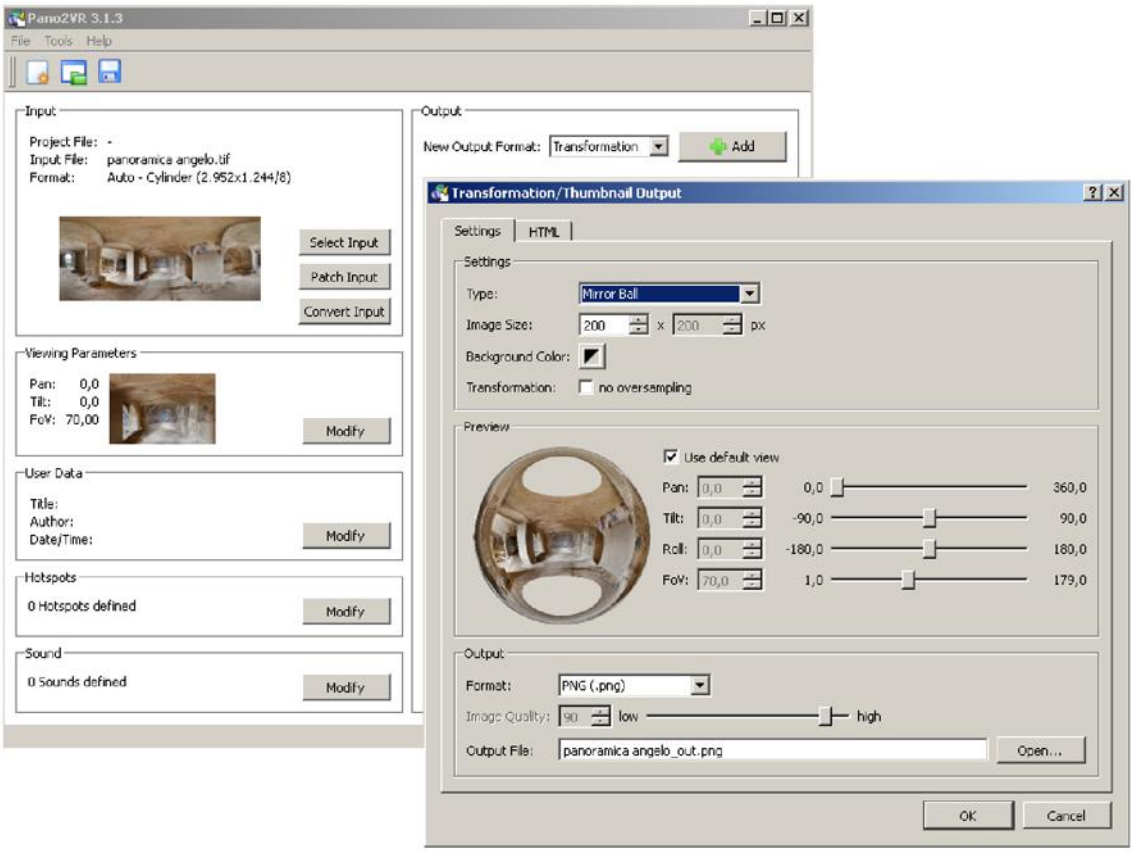

Fig. 7 – Pano2VR software's screenshot.

This type of representation not only involves a great photo of the interior but allows the navigation in such a way to facilitate the perception of the relationship between the decorative and architectural environment.
All the incorporated elements of paintings shown on 360° panoramic view can be activated again via "hot spots" directly into the video by clicking on the target.
As shown, several spherical 3D panoramas can be banded together, and that’s exactly the way to make a virtual tour (also known as VR tour or 360 tour). By making one single click on the pointer in the 360° panorama you’re making a real journey, while moving from one panorama into another within some areas called “hot spots” that allow passage from one area to another allowing a complete virtual tour of all the interiors.
The integration between the video and a web page can be used to add new information such as references or other metric mappings and in order to give the visitors of the virtual tour a better orientation, the panorama can be supplemented with the interactive map with the “radar”, which shows the view direction and the viewing angle.
In contradistinction from the video, you’re not reliant on the camera movements, because the movement in space is completely under your control.

Step three: the World Wide Web

The project had the intent to realize an information network with multiple levels of analysis and data using GPS tracking and high-resolution 360° panoramic photo.
The World Wide Web is the suitable place where to create an easy access point and at the same time to promote these archeological locations.

Fig. 8 – Screenshot of the testing web site www.theamesroom.com/360.html.

It is possible to get all the information about the access routes through standard tools offered by Google Earth, Google map, etc. and also, via web-links to a html page, to reach a 360° panoramic tour of the single rupestrian monuments.
This kind of representation not only involves high quality photos but allows to the users to understand the morphological and iconographic straight lines of these sites via virtual tour.
The viewing of the spherical 360° panoramas and virtual tours doesn't require the high speed data transfer, which makes it possible to place and extensively advertise them on the Internet.
It's not necessary to install any additional programs to have an ability to view the virtual panoramas and tours. It requires only to have a web-browser, like Internet Explorer, Google Chrome or Mozilla Firefox with at least one installed plug-in as Adobe Flash, Quick Time, Java, DevalVR, Shockwawe etc.
Another important issue of the panoramic 3D presentations via World Wide Web is the twenty-four-hour availability and the possibility for the visitor to explore the object whenever he/she would like and from any place on the world.
As shown, this research was born as a wish to deal the studied projects in a manner capable to develop a method to establish a different technical approach, which can be applied also in other architectonic cases and can be expanded using the multimedia technologies.

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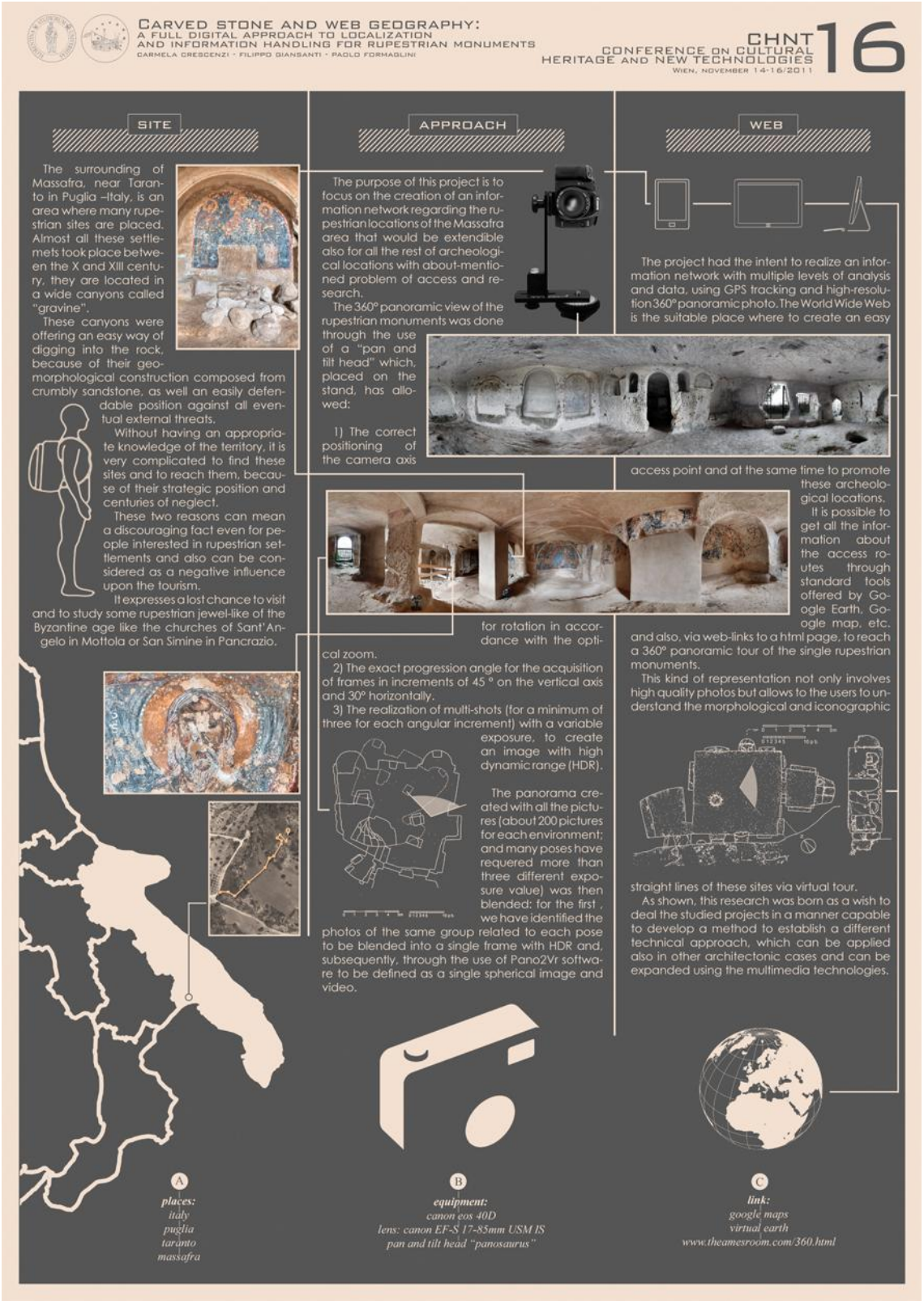

Fig. 9 – Poster presented at the 16 International Conference on Cultural Heritage and New Technologies – Wien 2011.

Digital processing of IR Thermography and ultrasonic signals in the diagnostics of carbonate building materials

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Abstract: Non destructive diagnostic techniques have been undertaken using infrared Thermography (IRT) and ultrasonic methods (UM) in order to assess the state of the decay of carbonate building materials of the important monument of the Tower of San Pancrazio in the historical town centre of Cagliari (Italy). In this experimental application the analysis of the IR thermography and ultrasonic signals acquired in a sector of the masonry wall of the Tower of San Pancrazio was enhanced by the digital processing of the data while also analysing them in the frequency domain.

Keywords: Non-destructive diagnostic techniques, IR thermography, ultrasonic techniques, building materials, digital processing.

Introduction

Non-destructive testing (NDT) methods are being developed for the maintenance, monitoring and conservation studies of masonry structures. Among these, infrared thermography (IRT) and ultrasonic methods (UM) appear to be particularly promising and useful in assessing the conservation state of building materials and the adequacy of restoration actions (DIANA and FAIS 2011). From our study it appears that due to the peculiarities of the two above mentioned methods, their integrated application can be very useful.
IRT is one of the most widely applied technologies in the diagnostics of monumental building materials. Thanks to this method, especially if carried out with instruments characterised by a high resolution and thermal sensitivity, it is possible to visualise and analyze, based on a calibration curve, the thermal profile of a structure starting from measured surface temperatures closely linked to the emissivity of the structure itself, which depends on its composition and its state of preservation. It's worth highlighting that for the optimal application of the technique must operate under conditions such that the temperature difference between the altered areas and healthy areas is the maximum possible.
Therefore a thermographic investigation can provide a large amount of fundamental data for a precise and detailed diagnosis of the shallow parts of the investigated structures.
UM based on the analysis of the propagation of elastic waves through a material are widely used to detect the elastic characteristics of carbonate building materials and thus their mechanical behaviour (CASULA et al. 2009; CHRISTARAS 1997; FAIS et al. 2008). UM are non-destructive and effective both for site and laboratory tests, though it should be pointed out that many features of the material (moisture, heterogeneity, porosity and other physical properties) can affect the propagation of the elastic waves (BINDA et al. 2000;

CASULA et al. 2009; CHRISTARAS 1997; CUCCURU et al. 2011; FAIS et al. 2002; FAIS and CASULA 2010; GALAN et al. 1991). Starting from the longitudinal velocity values relative to the propagation of elastic waves the elasto-mechanical conditions of the stone materials can be deduced. In this respect it should be emphasized that the measured velocity values must be considered relative and not absolute. However, a variation of velocity in a certain area indicates a variation in the characteristics of building materials.

Materials and methods

Materials

The stones normally used in the building of the monumental structures of Cagliari come from a prevalently carbonate sequence, outcropping only in the town hills and known as "Calcari of Cagliari *auct*". This sedimentary sequence of Tortonian-Messinian age consists of three different types of carbonate rocks named from top to bottom *Pietra Forte*, *Tramezzario* and *Pietra Cantone* (GANDOLFI and PORCU 1967).

Compositional and petrophysical characteristics of the three carbonate lithotypes (Pietra Cantone, Tramezzario and Pietra Forte auct.), belonging to the Calcari di Cagliari Formation,used in the historical buildings.

Samples	Pietra Cantone	Tramezzario	Pietra Forte
Lithology	Marly-sandy limestone (auct.)	Weakly marly limestone (auct.)	Shelf limestone (auct.)
Ca-(Mg) CO_3 Content %	86-90 %	97-100 %	96-100 %
Textural Characteristics	Matrix-supported	Clast-supported	Over 2/3 spar cement (Folk, 1980) Original components bounded together during deposition (Dunham, 1962)
Grain roundness	Sub-rounded	Sub-rounded, sub-angular	Sub-rounded, sub-angular
Folk's classification (1980)	Biomicrite	Biosparite	Biosparite, biolithite
Dunham's classification (1962)	Mudstone, wakestone	Grainstone	Boundstone
Mesoporosity (average % accounted on thin section)	4-10 %	5-10 %	1-2 %
Porosity types according to Choquette e Pray (1970)	Vug type	Intraparticle, moldic and fracture types	Intraparticle, moldic and fracture types

Tab. 1 – Compositional and petrophysical characteristics of the investigated carbonate rocks.

A systematic sampling was carried out in the main outcrops of the above mentioned lithotypes and in the ancient quarries of the town and numerous rock samples have been analyzed with the purpose of determining their compositional and textural characters. The analysis were performed on powders of the

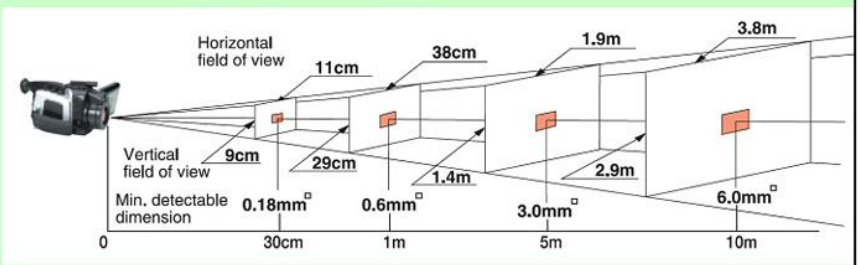
samples with the Dietrich-Fruhling calcimeter and X ray diffractometer to determine the carbonate and terrigenous components, and on thin sections under the petrographic microscope for limestone textures (grain size, grain-matrix and grain cement ratios, grain roundness, sorting, contact types).
Table 1 shows the main results obtained. It can be seen that the only mineralogic component of these rocks is calcite of the microcrystalline type (micrite, FOLK 1980) in the *Pietra Cantone* samples and of the macrocrystalline type (sparite, FOLK 1980) in the *Tramezzario* and *Pietra Forte* samples. The amount of calcite is less in the *Pietra Cantone* limestone because small quantities of a terrigenous insoluble component, formed by quartz, feldspars, iron oxides and illites, are also present.
The results (Tab. 1) also show the various fabrics – matrix supported, clast supported and boundstone – that characterise the three carbonate types and the different roundness of the bioclasts. These compositional and textural characteristics can account for the different values of mesoporosity and pore types observed. The determination of the latter two elements is very important because porosity is one of the many rock features that control the propagation of elastic waves through a material.

Methods

IR thermography

In this study the IR thermography survey was performed by the Thermo Tracer TH9260 System (NEC Avio Infrared Technologies Co., Ltd), whose main characteristics are shown in Table 2.

Specification			
	Range 1	Range 2	Range 3
Measuring range	- 20 ~ 60 °C	- 40 ~ 120 °C	0 ~ 500 °C
Resolution	0.06 °C at 30°C (30Hz)	0.08°C at 30°C (30Hz)	0.12°C at 30°C (30Hz)
Measurement accuracy	± 2°C or ± 2% (reading)		
Spectral range	8 ~13 µm		
I.F.O.V.	0.6 mrad		
Focus range	30 cm to ∞		
Field of view	21.7°(Horizontal) x 16.4°(Vertical)		
Frame time	30 frames/sec		
Thermal image pixels	640 (H) x 480 (V)		
Emissivity correction	Provided (0.10 to 1.00)		
Temperature setup level	- 20 ~ 60 °C	- 40 ~ 120 °C	0 ~ 500 °C
Sensitivity setup	0.1 ~ 20 °C/DIV	0.2 ~ 20 °C/DIV	0.3 ~ 70 °C/DIV
Operating temperature	- 15 ~ 50 °C (no condensation)		
Field of View Diagram (Thermal image)			



Courtesy from: NEC Avio Infrared Technologies Co., Ltd

Tab. 2 – Thermo Tracer TH9260 System imaging performances.

In particular, the IR thermography survey of the external face of the investigated wall structure was performed on different dates and at different times of the day. Thermal measurements were carried out at ambient temperature.

The fact that the thermal scanning data were heterogeneous reflected the substantial compositional variability of the building carbonate blocks (Tab. 1).

Thanks to the investigation it was possible to highlight the conservation state of the carbonate building materials of the investigated structure as a result of exposure to atmospheric agents. In fact, from the thermal contrasts detected in the thermograms it has been possible to establish a relationship between degraded areas and isotherms. In fact, besides affecting the mechanical condition of the material, exposure of the lithoid blocks to exterior weathering involves an alteration of the chemical-physical characteristics. These modifications are imprinted in the thermogram generated by the thermal response of the materials.

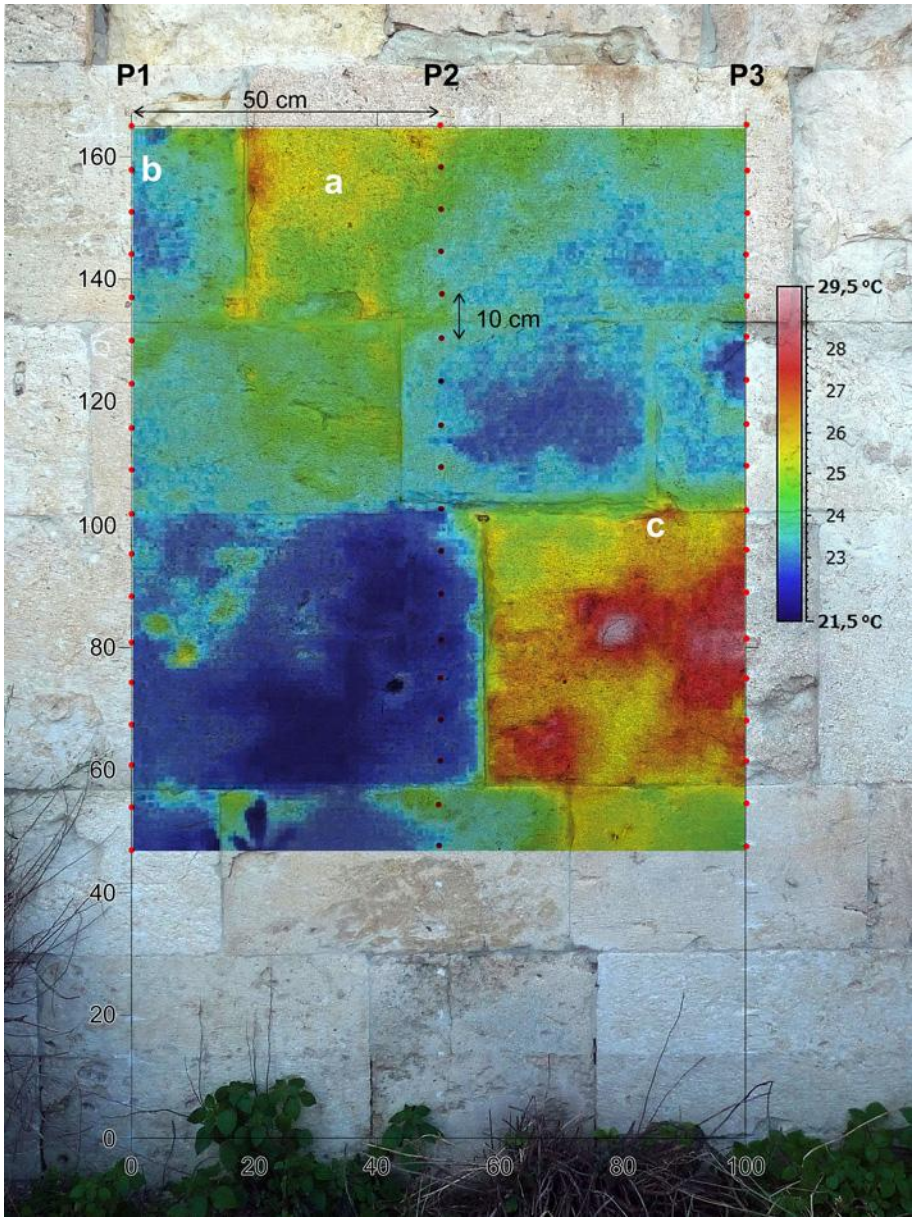


Fig. 1 – Thermal analysis.

The performed thermograms clearly identify geometric elements represented by blocks of different size and different carbonate rocks. Fig. 1 shows an example of a thermogram of the investigated sector of masonry. Superficial patinas, due to the formation of efflorescence related to the crystallization of soluble salts of external origin, particularly on the surface of the blocks of the "Tramezzario", cause a relatively colder thermal response. In the same lithotype, relatively high temperatures were detected in correspondence of "fresh" portions of the blocks, characterized by the typical granular texture rich in organogenic fragments (letter “a” in Fig. 1).
Alveolization processes are most evident in calcareous materials with lower $Ca(Mg)CO_3$ content ("Pietra Cantone"), which are more susceptible to weathering. This type of differential weathering occurs with the formation of cavities, which may be of variable shapes and sizes and are characterized by lower temperature levels in the thermograms (letter “b” in Fig. 1).
Degradation processes that occur with the detachment of surface portions of the block as a result of mechanical action or alteration, often at the edges, are characterized by higher temperatures in the thermograms. This condition is particularly evident in correspondence of the “Tramezzario” (letter “c” in Fig. 1).

Ultrasonic measurements

The ultrasonic measurements were performed in the surface mode (transmitter and receiver on the same surface of the investigated masonry) using the Portable Ultrasonic Non-Destructive Digital indicating Tester (PUNDIT) by C.N.S. Electronics LTD and 54 kHz piezoelectric transducers. For accurate measurements couplan silicon snag sheets were employed to provide a good contact between transducers and surface of the masonry structure. The measurements of the traveltime of the ultrasonic signal from transmitter to receiver were carried out along three parallel profiles in a vertical direction and particular care was given to take measurements at the same level in all the profiles. Starting from the measured traveltime of the ultrasonic signal and considering as space the distance between transmitter and receiver, the apparent propagation velocity at each observation point along the profiles was computed. The values of the longitudinal ultrasonic velocity were contoured to represent the distribution of the velocity on the investigated masonry sector with the aim of detecting damages and degradation zones by studying the velocity variations. In fact, ultrasonic signal characteristics change as the wave propagates through the carbonate materials with varying properties such as porosity, pore types, mineralogical and petrographical composition also as a result of degradation. Fig. 2 shows the longitudinal ultrasonic velocity map of the investigated sector of the masonry. It shows a wide range of ultrasonic velocity in the carbonate building materials, in which the longitudinal velocity (Vp) ranges from 1600 to 6400 m/s. The fact that it varies considerably is indicative of a relevant heterogeneity in the elastic characteristics of the building materials. The low velocity areas (yellow zones) in the map shown in Fig. 2 can be correlated to carbonate materials with poor elastic characteristics, while the high longitudinal velocity areas (blue zones) indicate materials with good elastic behaviour. To correlate the elastic with the mechanical behaviour of the materials, empirical and effective relations between longitudinal velocity and mechanical properties of the rocks can be used (ANSELMETTI and EBERLI 1999; EBERLI et al. 2003; WANG 2000; HOWARTH et al. 1989).

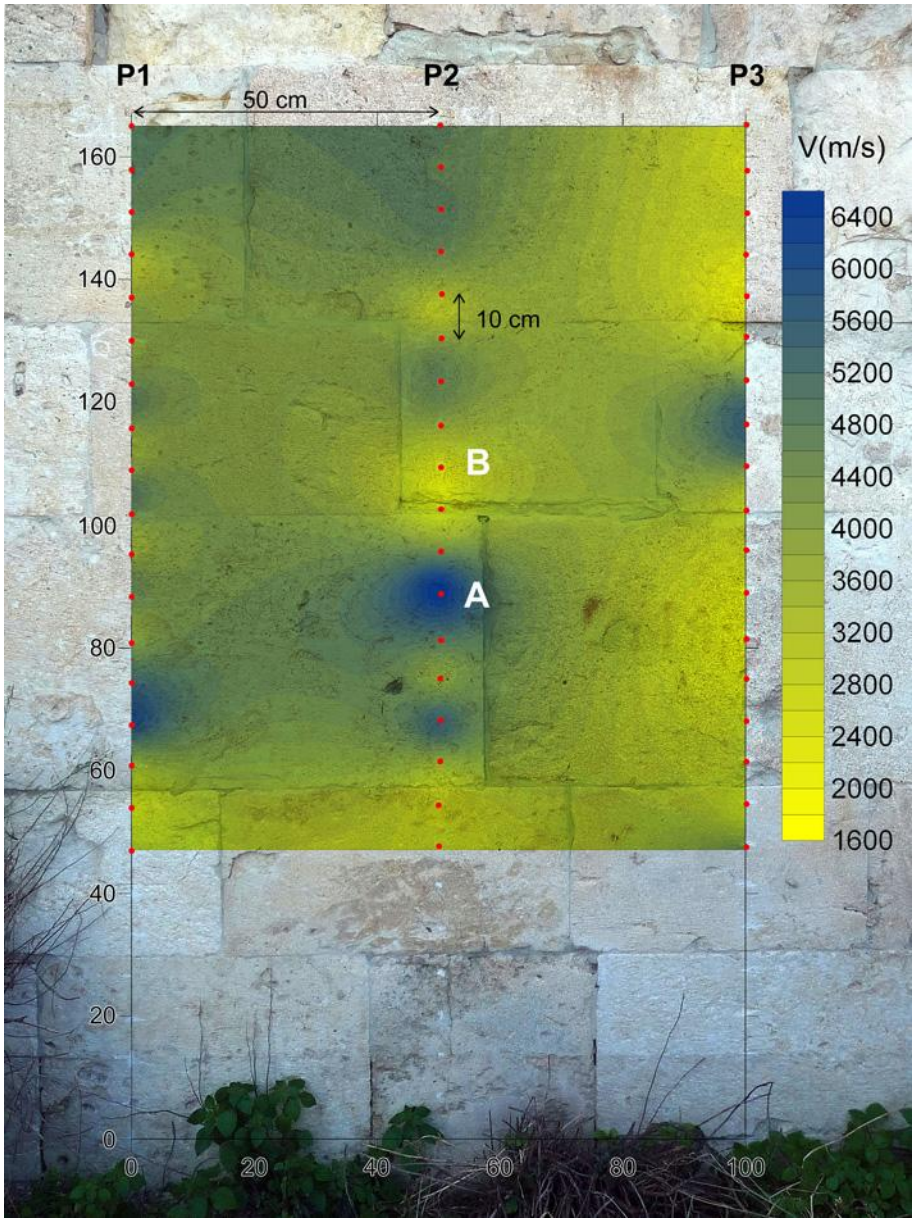


Fig. 2 – Ultrasonic longitudinal velocity (Vp) map by the surface technique at 54 kHz.

Digital processing of the signals

The physical processes under study can be analyzed either in the *time* or *space domain*, by the values of the study quantities, respectively as a function of time (ultrasonic waveforms) and space (thermal response), or else in the frequency or wave number domains. In these domains the processes are analyzed by giving their amplitude A (generally a complex number) as a function of frequency for temporal signals, and a function of wavenumber for spatial signals. From previous studies (CASULA et al. 2009) and from this analysis, it can be deduced that the frequency composition of the ultrasonic signals is strictly related to the mineralogical-petrographical characters of the rocks and elasto-mechanical state.

The analysis of the signals in the frequency domain, or in other words the spectral analysis, was carried out using the Fast Fourier Transform algorithm (FFT) (MARPLE 1987).

The synthesis of the results of the spectral analysis showed the importance of the signal frequency/wavenumber analysis in the diagnostics of building materials where the presence of defects, fissures and cracks in the rock affect the propagation of the ultrasonic signals and therefore their longitudinal velocity value, the thermal response of the IR thermography and consequently their spectral composition. As an example, Fig. 3 a and b shows two typical spectra obtained from the digital processing of the ultrasonic signals acquired in two sectors (A and B) characterised from different elastic conditions.

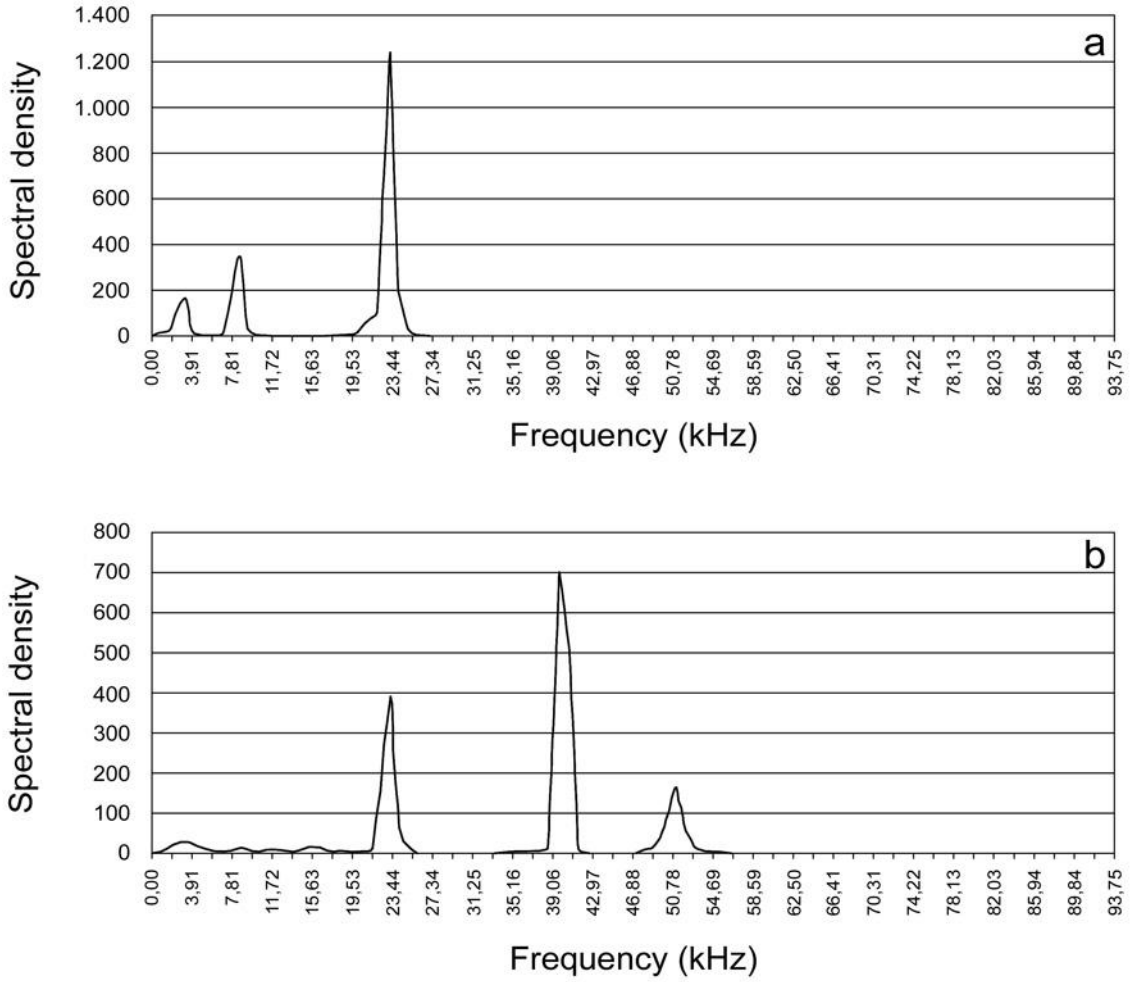


Fig. 3 – Examples of FFT spectra of the ultrasonic signals acquired in an altered (a) and unaltered (b) sectors of the investigated masonry structure.

Conclusion

The combined interpretation of IRT and UM methods provided a useful tool for the diagnostic process on the conservation state of building carbonate materials. The integrated application of IRT and UM methods enhances the accuracy and effectiveness of the analysis and can improve actions of maintenance, monitoring and conservation. Thanks to the thermal map of the exterior surface of the investigated masonry it was possible to distinguish anomalies in its thermal response in relation to processes of alteration of the chemical-physical characteristics of the carbonate rocks due to exposure to atmospheric agents that have produced different types of degradation (efflorescence, alveolization, surface disruptions).

It should be pointed out that, while the thermographic technique explores the shallow layer of the material, the ultrasonic techniques can inspect the entire masonry or a large thickness of it, depending on the acquisition data modalities. Compared to thermography, with the ultrasonic techniques the elastic mechanical characteristics of the building materials can be characterised more easily starting from the measurement of the ultrasonic longitudinal pulse velocity, even though it could become time consuming in the event of large surfaces. Comparing the thermal image with the longitudinal ultrasonic velocity map of the same sector of the investigated masonry, the different thermal responses can be related to the different elastic characteristics of the carbonate building materials.
Knowledge of the spectral composition of the signals improves the quality of the diagnostic process compared to what can be attained using measurements of velocity or thermal response alone.
The frequency spectra, interpreted also considering the petrophysical properties of the investigated rocks measured in the laboratory, have provided useful and objective information of a quantitative type on the quality of the carbonate building materials. In fact, in all examined spectra a good correspondence was found between the spectral composition of the time and space signals and the conservation state of the building carbonate rocks. Repeatable spectra would represent an effective material quality control check before and after restoration actions.

Acknowledgements

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Diagnostic Process of a Megalithic Monument by Ultrasonic Measurements

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Abstract: Ultrasonic measurements have been implemented in past years in the Cultural Heritage Field with the aim to improve the diagnostic process of a monument prior to any restoration. This paper presents the results of a study regarding the application of non-destructive ultrasonic techniques in evaluating the conservation state of the dolmen Sa Coveccada in northern Sardinia (Italy). In this context the use of the ultrasonic techniques integrated with minero-petrographycal and physical data as well archaeological information, was very effective both to define the elasto-mechanical properties of the building materials such as longitudinal ultrasonic velocity and fracture coefficient, and to detect the presence of discontinuities caused by alteration phenomena.
In addition, the ultrasonic techniques were used in laboratory on samples of the same volcanic building materials of the dolmen to investigate the repairing efficiency of chemical consolidating materials such as epoxidic resins and to test their compatibility with the investigated materials.

Keywords: megalithic monument, non-destructive ultrasonic techniques, elasto-mechanical properties, repairing efficiency.

Introduction

This study was carried out within the framework of a relevant project of restoration of megalithic monuments promoted by the *Soprintendenza per i Beni Archeologici di Sassari e Nuoro* (National Archaeological Authority of Sassari and Nuoro, Italy), *Opificio delle Pietre Dure di Firenze* (Italy), *Comunità Montana di Monte Acuto* (Mountain Community Administration of Monte Acuto, Italy) and *Comune di Mores* (Local Town Authority of Mores, Italy) with the endorsement of the *Direzione Regionale per i Beni Culturali e Paesaggistici della Sardegna* (Regional Directorate for Cultural Heritage and Landscape of Sardinia). The study dolmen (Fig. 1) is a megalithic structure of great historic and scientific importance and is the only example of its kind in Sardinian archaeology (Italy). This monument is unique for the singularity and height of the structure among the megalithic tombs of Sardinia and the comparison with the discovered in the necropolis of dolmen Ala Safat in Cis-Jordan (ATZENI 1966) and Grand Mont Rouge, and Coste-Hérault in France (CIPOLLONI SAMPÒ 1990) documents the circuits in which the dolmen was inserted in Sardinia and in this particular area of north-central Sardinia, during the Bronze age (third millennium B.C.).
Therefore in view of the historical significance, the problems of alteration of the monument and the consequent complexity of restoration the ultrasonic Non-Destructive (ND) techniques were applied because

they are very effective in evaluating the conservation state of building materials (CHRISTARAS 1997; CONCU and FAIS 2003; FAIS et al. 1999; FAIS et al. 2008; CASULA et al. 2009; FAIS and CASULA 2010; CUCCURU et al. 2010; GALAN et al. 1991; ZEZZA 1993).

Fig. 1 – Aerial view of dolmen (photo by *Carabinieri NTPC di Sassari*).

To improve the interpretative process the ultrasonic data were calibrated with physical and minero-petrographycal data using methodologies well tested in previous experimental studies (CUCCURU et al. 2010; FAIS et al. 2002; FAIS et al. 2005; FAIS et al. 2011).

The archaeological study

The dolmen is a rectangular complex extended along the direction NW–SE. It is 5 m long, 2,5 m wide and 2,7 m high (ATZENI 2007). It consists of a rectangular chamber (4.18 x 1.14 m) with a roofing slab, laterally delimited by two orthostates respectively on the North and South sides, and a facing East frontal slab with an entry door (0.50 x 0.50 m) with rounded corners (Fig. 2). Inside one of lateral orthostates, approximately 0.35 m above the floor there is a rectangular niche (1.22 x 0.88 x 0.50 m), perhaps the site of deposition. To the left of the frontal slab of the monument there is a small niche, hollowed in the thickness of the same ortostate.

Technical-scientific checks performed along the perimeter of the monument, specifically in the sectors which support the orthostates, by cleaning and stratigraphic tests have identified a processing technique of the

head of the ortostate functional to suppor a currently missing closure slab and channels for accommodating the lateral orthostates.

Fig. 2 – View of the monument (photo by G. Rassu).

The archaeological excavation in the area behind the monument has highlighted the building techniques of the dolmen, whose floor, obtained in the bedrock, had a perfect cut, about 20 cm deep, which represent a large step for housing of the above mentioned closure slab.
The cleaning operations have also allowed to identify the presence of lithic sections probably belonging to the monument while the ceramic finds allow an attribution of the monument to neo-Eneolithic age.
The archaeological surveys have also highlighted the diffused alteration processes (as esfoliation phenomena and erosion channels) of the building materials. Particularly, extensive growth of small roots in the microfractures facilitated the seepage of water and chemical solutions.
In this phase, the monument was also analysed by GPS and 3D Laser Scanner technology (Figs. 3, 4). The analysis of these representations allowed to detect serious expansions and micro-cracks in the vertical and transverse sense which produce a consequent static weakening of the structure. In particular, the covering slab has fractures that cross the entire thickness with a principle of collapsing towards the burial chamber.

Fig. 3 – 3D Laser Scanner reconstruction (A. Atzeni-P. Marcialis, Società Archeogeo-Nurri CA).

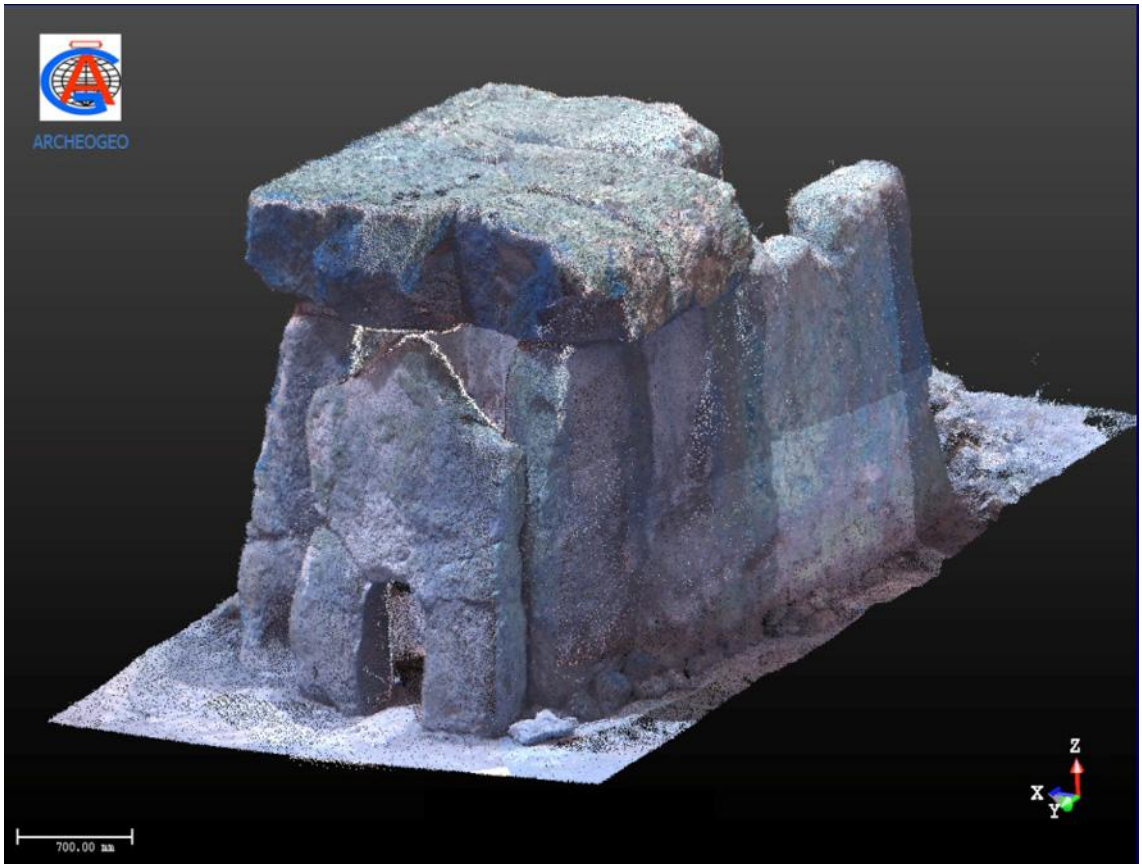

Fig. 4 – 3D Laser Scanner-points cloud of the monument (A. Atzeni-P. Marcialis, Società Archeogeo-Nurri CA).

Characterization of building materials

The dolmen was built using the volcanic rocks coming from the outcrops located near the plateau in which was erected. The macroscopic features of the building materials are those typical of the volcanic rocks, violet in colour, with clastc texture and lithic fragments coming from the pre-existing volcanic rocks and with the presence of diffused degassing vesicles of millimetric size.

The study of physical, minero-petrographycal and elasto-mechanical features of the building materials was carried out on inaltered samples of the same volcanic building materials, collected in the outcrops located near the monument. At the optical microscope (Figs. 5a, b, c), the volcanic rocks present a porphyric vitrophyric structure and an isotropic texture, with phenocrystals of plagioclase (often united in glomerocrystals), quartz, biotite, amphibole, clinopyroxene and sanidine, included in a vitreous fluidal mass with laminar flow, glass shards and spherulitic devitrification (Fig. 5c). From the petrographycal study the rock is classifiable as dacite.

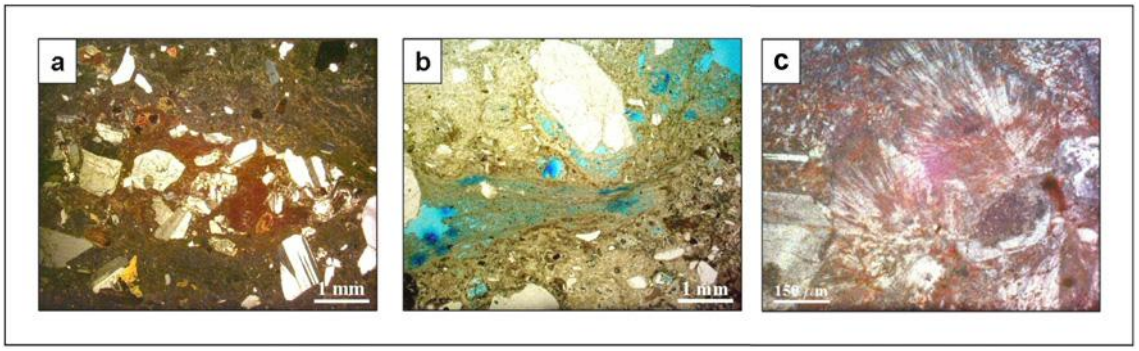

Fig. 5 – Analyses of materials at optical microscope: a) lithic element with plagioclase glomerocrystals; b) vitreous fluidal mass with laminar flow rich in micropores, sample treated with blue dye; c) spherulitic devitrification dues to the instability of volcanic glass which generates phyllosilicates which make the rocks more sensitive to the alteration processes.

To facilitate the recognition of the pores in thin section a blue resin was used (Fig. 5b). The mean porosity deduced by the study in thin section is of about 3% except from some part of the material in which the porosity reach 6%.

It is important to highlight that in the femic minerals, which are more unstable at environmental temperature and pressure, intense oxidation has caused an increase in microporosity and microcracks which at the macroscale have triggered some important forms of alteration such as exfoliation and fissuration that have drastically changed the stability and safety of the monument.

Moreover measurements of some physical properties of great interest for this study as bulk density, imbibition coefficient (water absorption) and effective porosity, whose mean values are respectively 1,64g/cm^3, 11,6% and 19%, were carried out. Water absorption and effective porosity are strictly connected with the number of vesicles in the volcanic rock.

Ultrasonic measurements

The ultrasonic measurements were performed in laboratory and *in situ* using the Portable Ultrasonic Non-Destructive Digital Indicating Tester (PUNDIT) by C.N.S. Electronics LTD. The acquisition parametres were

chosen considering the targets of the study and the features of the investigated materials. Preliminary ultrasonic laboratory measurements were performed. For these tests the direct or surface acquisition technique (transmitter and receiver on the opposite face of the investigated object) was applied using 82 kHz transducers. The mean value of the ultrasonic longitudinal velocity pulses (Vp of 2650 m/s), was subsequently used to calculate the elasto-mechanical parameters, as the dynamic Young modulus (17,32 GPa) and the dynamic Poisson ratio (0,17) which were finalized to the characterization of the volcanic building material.

In the subsequent phase of the study ultrasonic measurements were carried out *in situ* on the two lateral ortostates and in the frontal slab of the dolmen. An accurate visual inspection of the ortostates which allowed to carried out qualitative evaluations on the conservation state of the building materials, preceded the ultrasonic survey. On the basis of the results of the laboratory analyses and the visual inspection the ultrasonic survey was planned. For the acquisition of data the indirect surface technique (transmitter and receiver on the same face of the investigated object) was applied with 54 kHz transducers, using the “step by step” acquisition modality (Fig. 6).

Fig. 6 – Application of the “step by step” acquisition modality in the walls of the dolmen.

For the lateral ortostates and the frontal slab were obtained the longitudinal ultrasonic velocity maps. To facilitate the analysis and interpretation of the results, these velocity maps were overlapped to the photos of the investigated ortostates. As an example Figure 7 reports the velocity map of the south ortostate.

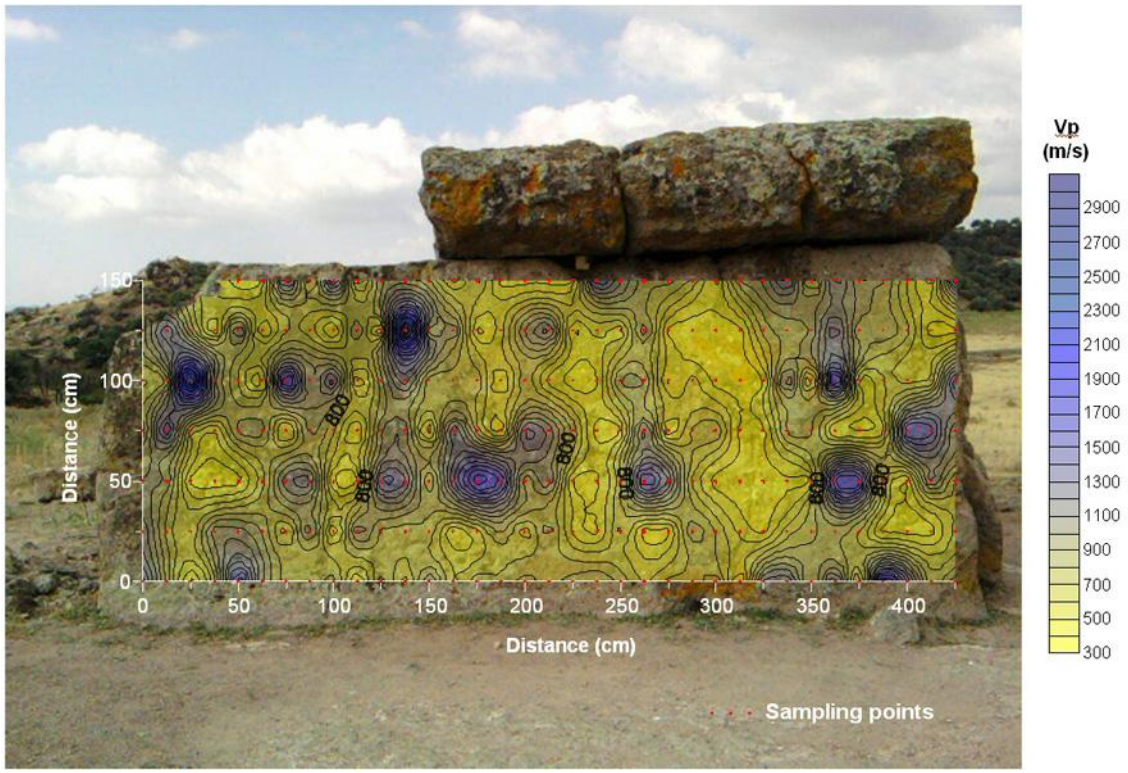

Fig. 7 – South ortostate of dolmen – longitudinal pulse velocity (Vp) map.

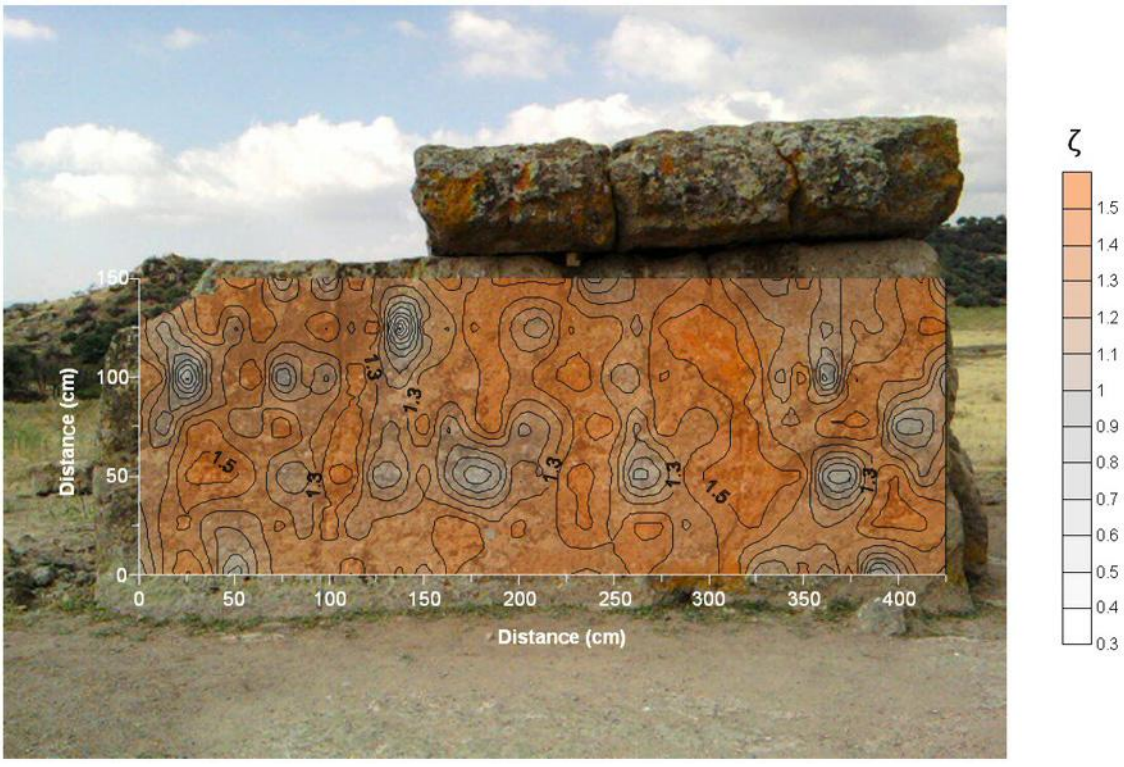

Fig. 8 – South ortostate of dolmen – map of fracture coefficient (ζ).

The analysis of the map has evidenced that the ultrasonic velocities measured in the installed building materials show a high decrease with respect to the velocities measured in laboratory on the inaltered rocks.

It is appropriate to point out that the ultrasonic velocity values must be interpreted as relative and not absolute values. In any case a variation in the velocity in a determinate sector of the monument is related to a change of the elastic features of materials then of their integrity state. Particularly the velocities markedly lower near the fractures and in those sectors whereas the alteration phenomena are into action. In these zones the ultrasonic velocity values, less than 900 m/s, indicate that the building material is strongly altered particularly near fractures and cracks. By the interpolation of the ultrasonic velocities, the maps of distribution of fracturation coefficient (ζ) were also obtained. Figure 8, shows as an example, the map of the south ortostate. In this map this parameter has the highest values near the principal fractures and the adjoining zones which are characterized by low ultrasonic velocity values (Fig. 7).

Early restoration works

The foundation of knowledge obtained from the ultrasonic analysis integrated with minero-petrographycal, physical and archaeological data, allowed to detect the more altered sectors of the monument and to define the priority actions for the restoration programm. Therefore in strong cooperation with the experts of the *Soprintendenza per i Beni Archeologici di Sassari e Nuoro* (National Archaeological Authority of Sassari, Italy) and *Opificio delle Pietre Dure di Firenze* (Italy) it was decided to carry out preliminary preservative actions (Fig. 9) in the more esfoliated and fractured zones of the ortostates by injections of epoxidic resin (EPO 150) which from the laboratory tests resulted the more compatible with the elastic features of the building materials. To check the efficiency of a possible restoration action carried out in a preliminary phase with this resin, laboratory tests were performed on two rock samples of the same volcanic building materials of the dolmen. The samples artificially broken, were restored by injections of resin and ultrasonic measurement were carried out to test the efficiency of the product.

Fig. 9 – Restoration actions: the teamwork.

The monitoring of the ultrasonic velocities for 42 consecutive days on the restored samples (Fig. 10) has pointed out a general and persistent improvement of the elastic features of the rock, as deducible from the analysis of the graph of Figure 10b.

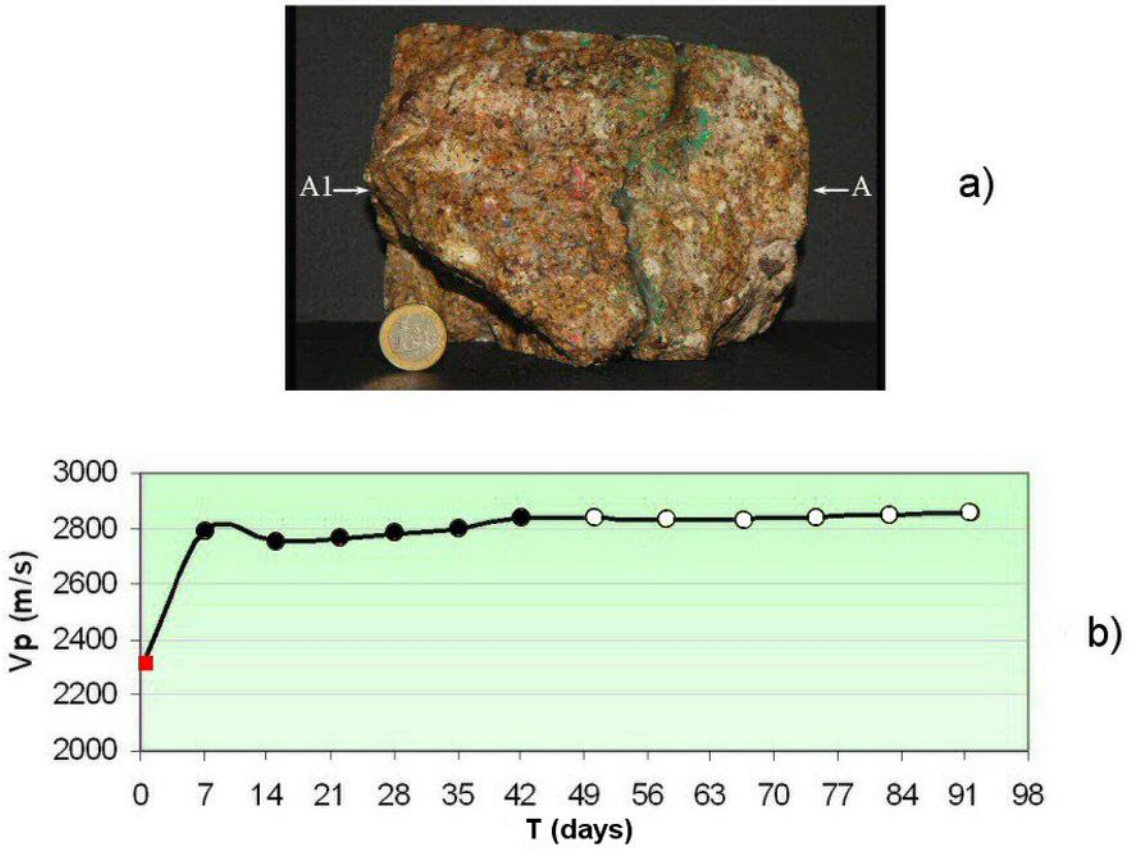

Fig. 10 – Laboratory test carried out on one of the two study rock samples a) A-A1 placement of the two transducers, transmitter-receiver); b) in time monitoring of the ultrasonic longitudinal velocity pulses (Vp). The red square represents the velocity value before the epoxidic resin treatment, with black dots, are represented the velocity values after the resin treatment, and the white dots, the velocity values measured in the resin treated sample, subjected to freeze-thaw cycles.

It is important to point out that the elastic conditions of the strengthened material have been unchanged after freeze-thaw cycles. In fact the ultrasonic velocities measured for 49 consecutive days on the restored samples (Fig. 10b), are not influenced by the temperature changes.
On the basis of the results of this integrated experimentation, the epoxidic resin was injected in a very altered test sector (Figs. 11a, b) of the external part of the south ortostate detected by the ultrasonic tests. As a consequence of the injections, a considerable increase of the ultrasonic velocities then of the elastic features of the materials was observed (Figs. 11c, d).

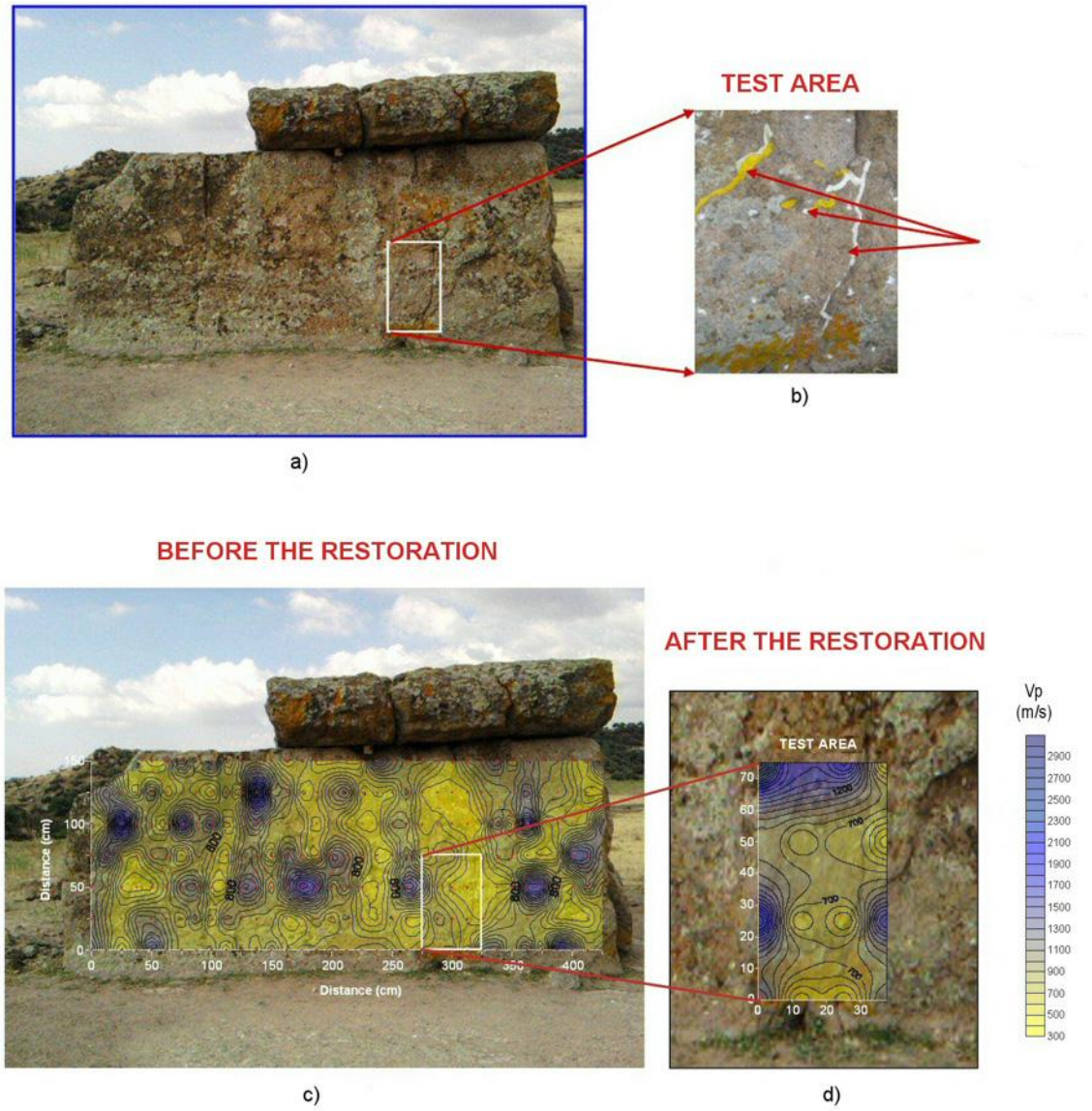

Fig. 11 – a) dolmen ortostate selected for the *in situ* restoration test; b) detail of the area treated with the resin; c) map of the ultrasonic velocity performed before the resin treatment; d) map of the ultrasonic velocity concerning the test area after the restoring.

Conclusions

The ND ultrasonic technique integrated with the physical and minero-petrographycal data and archaeological information allowed to improve significantly the diagnosis process of the study monument. In particular the archaeological study performed by surveys and using GPS and 3D Laser Scanner technology, highlighted serious problems due to several contributing factors as the meteoric leaching, the wind action, the flaking of the lithotype in lamellar detachments (esfoliation), in addition to degradation related to concentrations of different biological infestations. The minero-petrographycal study has pointed out the nature of the building rocks classified as dacite and the compositional and textural features which facilitate its alteration were highlighted. In fact the diffuse presence of mineralogical phases unstable under environmental conditions are the principal cause of the material alteration. It was also observed that compositional and textural features appreciably affect the propagation of the ultrasonic pulses which consequently have a high diagnostic

resolution power. The ultrasonic tests allow to define the elasto-mechanical conditions of the installed building materials and to highlight the presence of altered and fractured zones.
The integrated approach presented in this study revealed a very effective tool which allows to provide the fundamental basis of knowledge for planning the restoration actions, choosing the repair building materials and controlling their efficiency in time.

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Billions of Points for Archaeology

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Archaeological Heritage Office of Saxony

Abstract: High resolution DEM data is available now for almost the whole area of Saxony. To get presentations of that raw data, like hillshades and 3D-views, over 4.6 billion points within about 5200 tiles had to be processed. While the methods are clear in theory, there were some challenges in processing large amounts of 3D-data in practice, mainly regarding processing capacity and memory. Based on solutions with ArcGIS 10 Model Builder hillshades and ArcGIS Terrain Models were created with tolerable effort. They provide presentations without sheet divisions and support an easy generation of TIN and 3D-views. A first application of this preprocessed data in the field of archaeology was to prospect the Via Regia.
Ancient roads are important components of the cultural heritage, but documentation of them is often insufficient. While on-site prospection of terrain is expensive and time consuming, modern GIS technology and high resolution remote sensing data allow to prospect large regions at the desktop. About 400 km of ancient roads, assumed to be part of the Via Regia, where studied in this way. Many visibly preserved remains, just like hollow ways or crop-marks, where documented.
The focus of the project was rather an efficient handling of mass data then a scientific innovation. The methods support the practice of heritage protection not only for small project regions but state wide for the entire region of Saxony.

Keywords: archaeological base data, remote sensing, digital elevation model, archaeological prospection, heritage protection.

Preparing Billions of Points for Archaeological Use

The surveying department of Saxony issued high resolution DEM data. The airborne laser scans of about 18415 km² were finished in 2011 (Fig. 1). The standard DTM “ATKIS-DGM2”, a set of interpolated data with 2m-grid and an accuracy of +/- 0,2 m consists of over 4.6 billion (10^9) points within about 5200 tiles. In combination with raw data and primary classified data the DEMs consist of about 80 billion points. This treasure should be provided for daily archaeological use. But archaeologists don't use original DEM data; they expect a visualized presentation like hillshades or 3D-views. The raw data has to be prepared.
While the methods are clear in theory, there were some challenges in processing large amounts of 3D-data in practice. The GIS used was ArcGIS 10 (ArcEditor with 3D Extension) on an Intel Core2Duo (E4800, 3 GHz) machine with 8 GByte RAM and Windows XP. Previous projects (with ArcGIS 9) showed, that 3D processing needs considerable amounts of processing capacity and memory, some tasks needed several minutes for processing, other tasks ended with a crash. Hence the first tests were made to estimate processing time and reliability of the necessary tools.
As a result we found, that version 10 of ArcGIS is more stable in 3D processing then version 9. The creation of hillshades and other raster datasets worked with a standard DTM tile (2*2 km², 1 million points) and raw

data (up to 20 million points). Only the production and visualisation of large TIN models made problems, to preserve system operability about 300 000 points shouldn't be exceeded. The processing time of single processing tools, referred to one tile, ranged from some seconds to over 30 minutes. Considering the number of over 5000 tiles, it is recommended to carefully prepare an optimised processing sequence.
Two ways proved successful as visualisation in former projects. Hillshades are easy to handle, even without GIS, and they provide a good overview and many details of the terrain. To obtain more attractive presentations, 3D models like TINs should be used. They allow much interactive handling and sights from various viewing positions up to flight simulations. Depending on the available resources a preparation of all DEM data was not possible. So we decided to pre-process all ATKIS-DGM2 data into an ArcGIS Mosaic Dataset of hillshades and into a Terrain Dataset. Additional requirements, such as the use of higher resolution raw data or the creation of TIN at specified regions have to be met operative.

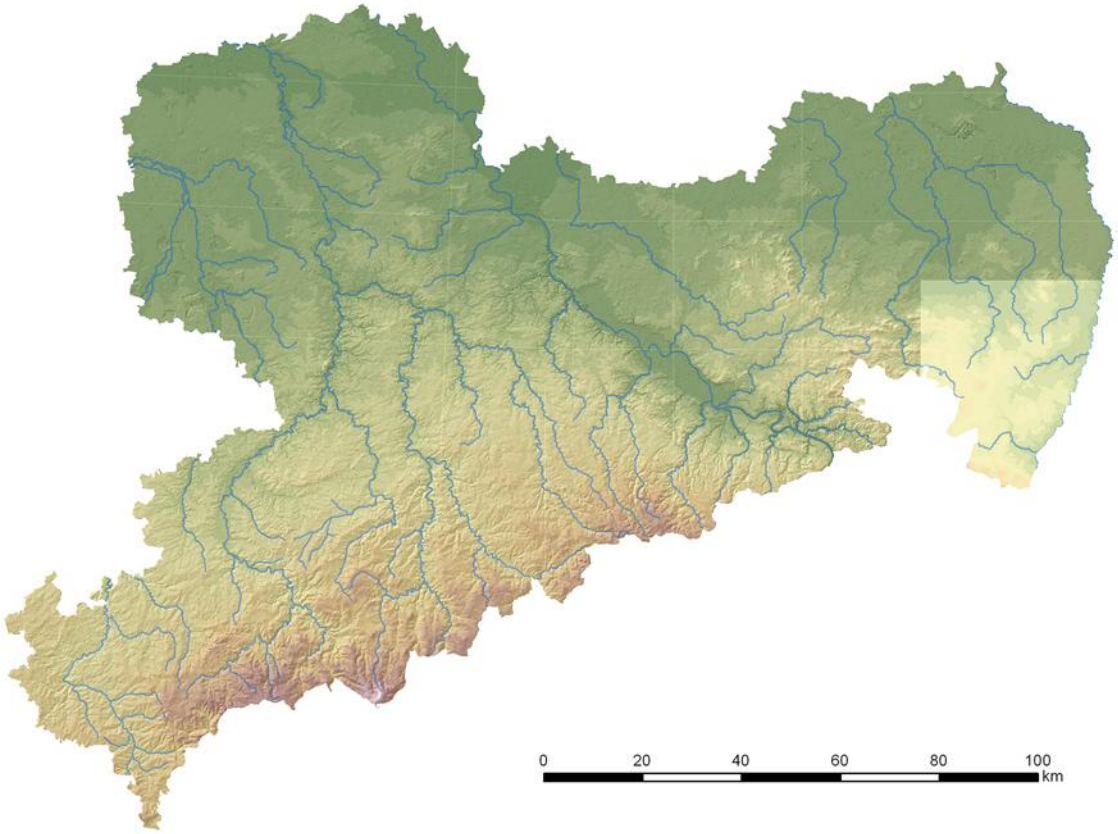

Fig. 1 – Overview of available high resolution DEM in Saxony (09/2011).

Subsequently several variations of processing queues were investigated. The tasks were designed and performed by ArcGIS Model Builder. At the end we decided in favour of 4 models:

Model 1 – Hillshades

The first model creates hillshades (as TIF) from the original ASCII DEM data. Intermediate products are ArcGIS Feature Classes with the 3D information; they are preserved for further operations.

► Input DGM2 → Iterate Files → Item.DGM2

This Item provides an iteration delivering all DGM2-files of a specified working directory combined with their names to the following steps.

- Item.DGM2 → ASCII 3D to Faeture Class → FeatureClass

  This step converts the ASCII formatted DGM2 raw data to a FeatureClass, a format which can be processed by ArcGIS.
- FeatureClass → Natural Neighbor → Raster (temp)

  Because hillshades are raster based data another conversion to ArcGIS Raster is needed.
- Raster → Hillshade → Raster (temp)

  This step generates hillshades in ArcGIS Raster format using Parameters like the direction of the light source.
- Raster → Mosaic to new Raster → Raster.TIFF

  At last a standard raster data format (TIFF) is created. This makes it possible to use the hillshades without having a GIS.

Whole Saxony was pre-processed with model 1, the duration was about 50 hours for all 5000 tiles.

Model 2 – Mosaic Dataset

This model organises the hillshades in an ArcGIS Mosaic Dataset. In this way all of the individual raster datasets can be accessed en bloc (like a mosaic).

► Input Raster → Iterate Files → Item.Raster

This Item provides an iteration delivering all hillshade Rasters of a specified working directory combined with their names to the following steps.

- Item.Raster → Add Rasters to Mosaic Dataset → MosaicDataset

  This step adds the hillshade Rasters to a predefined MosaicDataset, that can be accessed by ArcGIS without sheet divisions as an aggregate layer.

Whole Saxony was pre-processed with this model, the duration was about 1 or 2 hours for all 5000 tiles.

Model 3 – Terrain

Model 3 uses the Feature Classes from model 1 to create an ArcGIS Terrain Dataset. Terrain Datasets are able to save and organise large amounts of 3D data like the entire dataset of ATKIS DGM2 of Saxony.

► Input FeatureClass → Iterate Files → Item.FeatureClass

This Item provides an iteration delivering all DGM2 FeatureClasses of a specified working directory combined with their names to the following step.

- Item.FeatureClass → FeatureClass to FeatureClass → FeatureDataset

  This step adds all DGM2 FeatureClasses to a FeatureDataset as a precondition of combining them to a terrain model within the same FeatureDataset.

► Create Terrain → Terrain

An empty Terrain (dataset) is created within the FeatureDataset.

- ► Input FeatureClass → Iterate Files → Item.FeatureClass
  This Item provides an iteration delivering all DGM2 FeatureClasses of a specified working directory combined with their names to the following step.
  - Item.FeatureClass → Add FeatureClass to Terrain → Terrain (intermediate)
    This step adds all DGM2 FeatureClasses to the Terrain and creates internal data supporting the presentation at different scales.
- ► Terrain (intermediate) → Build terrain → Terrain
  This last step is required to complete the internal data of the Terrain as a whole. Now the Terrain can be accessed by ArcGIS without sheet divisions as an aggregate layer.

Some regions, mostly in the south of Saxony, were pre-processed. The processing time was very long and it increased more then linear with the amount of Data. The duration was about 2.5 min per tile (!) using 500 tiles and about 8.5 min per tile (!) using 1300 tiles. So we had a total processing time of over 200 hours (nine days). So we decided to use Model 3 only with small project regions in future, combined with Model 4.

Model 4 – TIN

A short model can be used to create TINs from Terrain Dataset using the current display extent. This model is not useful for large regions, so reasonable project regions (<1 km²) have to be used.

- ► Terrain → Terrain to TIN → TIN
  This easy tool creates a TIN from the terrain. It is suggested to use the extent given by the ArcMap window as geoprocessing extent for this tool (see geoprocessing options). Be sure that you don't use a geoprocessing extent that is too large for the presentation of the TIN.

This model was tested with several project regions, the duration is some minutes.

Results of Preprocessing

Final results are the Mosaic Dataset of hillshades and the Terrain Dataset, both are free of sheet divisions and easy to use within ArcGIS (Fig. 2, 3 and 4). The hillshades are also available as TIF images that can be accessed by a simple image viewer. Unfortunately the Mosaic Dataset cannot be presented as web map service without an extra license. The Terrain Dataset supports the easy generation of TIN and 3D-views of selected and limited regions (Fig. 5). The attempt to export a TIN into VRML and present it with independent software didn't succeed yet. The amount of data increased to about 3 TeraByte including the processed data without temporary files.

The focus of the project was rather an efficient handling of mass data than a scientific innovation. The methods support the practice of heritage protection not only for a small project region but state wide for the entire region of Saxony.

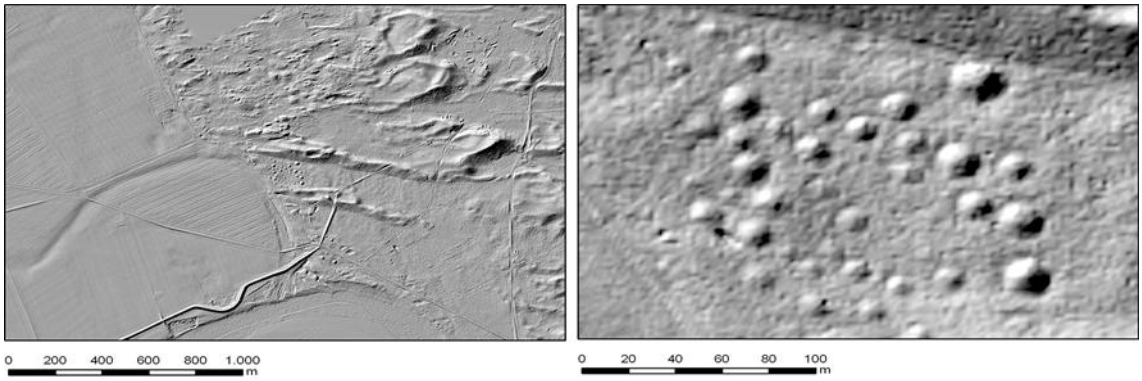

Fig. 2 – Hillshades of grave mounds at Rosenfeld (situation and details).

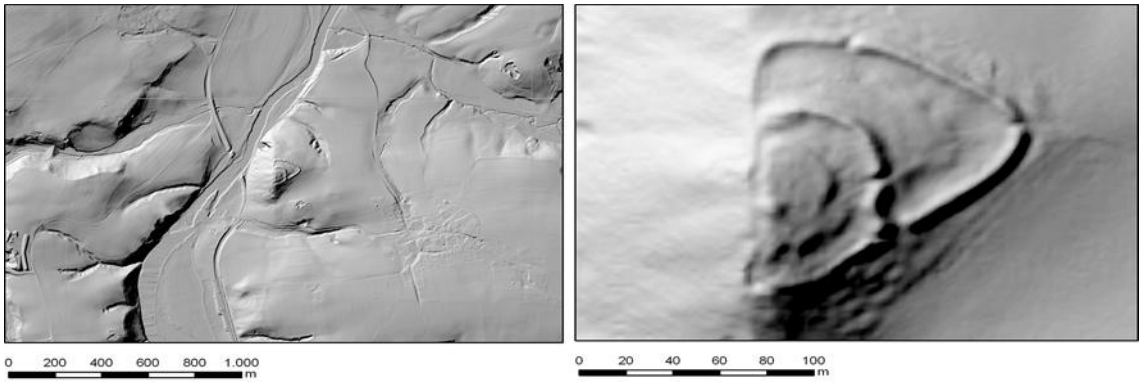

Fig. 3 – Hillshades of walls at Lastau (situation and details).

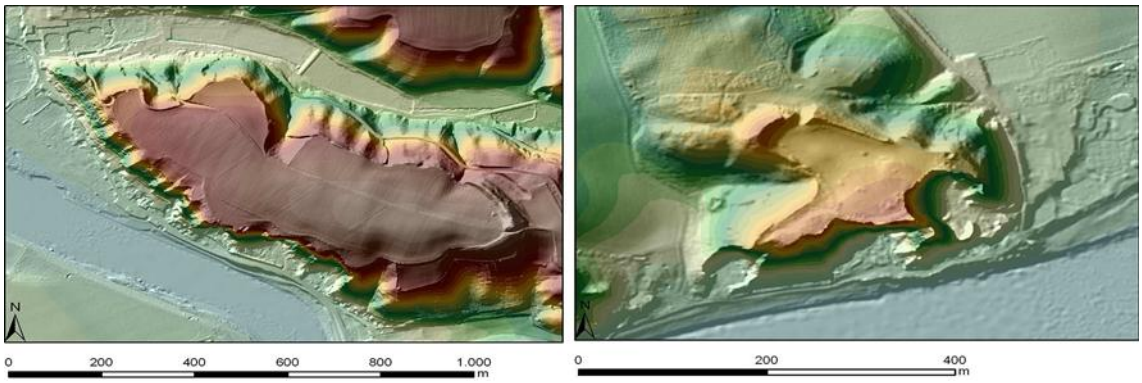

Fig. 4 – Coloured hillshades of ancient fortifications (Seußlitz, Göhrisch).

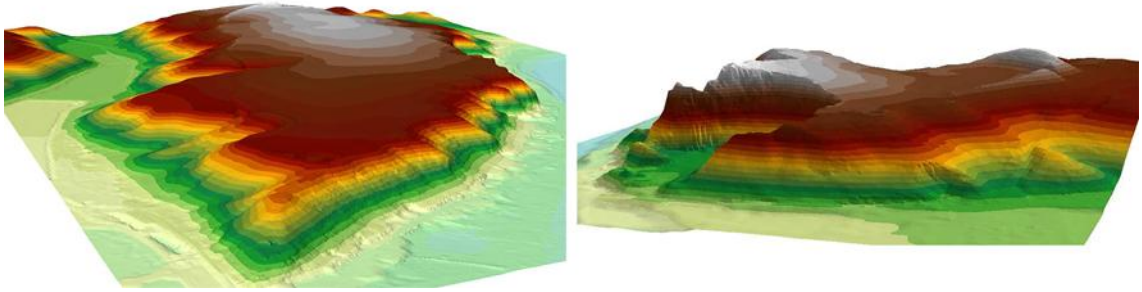

Fig. 5 – 3D-views from TIN (same regions as in Fig. 4).

It shall be mentioned that there are other proposals to handle mass data of laser scans with fast and efficient algorithms and solutions, such as "Streaming Computation of Delaunay Triangulation" (ISENBURG et al.) or the OPALS-Project of the Institute of Photogrammetry and Remote Sensing of the Vienna University of Technology (MANDELBURG et al.). But we took the easy way first. Because of existing experiences with the already implemented and working ESRI-System ArcGIS we decided to try this before venturing unknown territories.

On the Road – Using Remote Sensing Data to Prospect the Via Regia

Ancient roads are important components of the cultural heritage. Preserved remains have to be protected as monuments. But the documentation is often insufficient, because historical sources frequently deliver only topological features without specific route descriptions.

The evaluation of ancient maps without GIS is hard and tricky. On-site prospection of terrain is expensive and time consuming. But modern GIS technology and high resolution remote sensing data brought a change. Ancient maps can be georeferenced with reasonable effort and evaluation of remote sensing data (DTM, DOP, CIR) replaces on-site prospection. Prepared in this way it is possible to prospect even large regions from one's desk with reasonable effort. In this manner long distances of ancient roads were studied and identified as part of the Via Regia.

Using ArcGIS 10 we had easy access to the following layers:

- Meilenblätter von Sachsen (historic map from about 1800)
- Shaded relief (DTM, prepared as described above)
- Digital orthophoto (true colour)
- Digital orthophoto (CIR – colour infra red)
- Vegetation index (NDVI – normalised difference vegetation index)

The route of Via Regia is topological well known. The historic map Meilenblätter is the first very accurate map of Saxony and helped to identify potential specific routes on the map. Along these routes the other layers were examined carefully. As result all layers showed specific ancient remains of the route:

- Shaded reliefs indicate best in wooden areas, where relief structures are normally hidden by leaves. Outside the wood this structures are mostly well-known (Fig. 6).
- True colour orthophotos sometimes show crop or soil marks and structures that are preserved over time (Fig. 6).
- CIR orthophotos accentuate vegetation, among them some crop marks are better visible. But this doesn't work in wooden areas (Fig. 6 and 7).
- Vegetation index enhances differences in vegetation features, some structures become more clearly. As with CIR this doesn't work in wooden areas (Fig. 6 and 7).

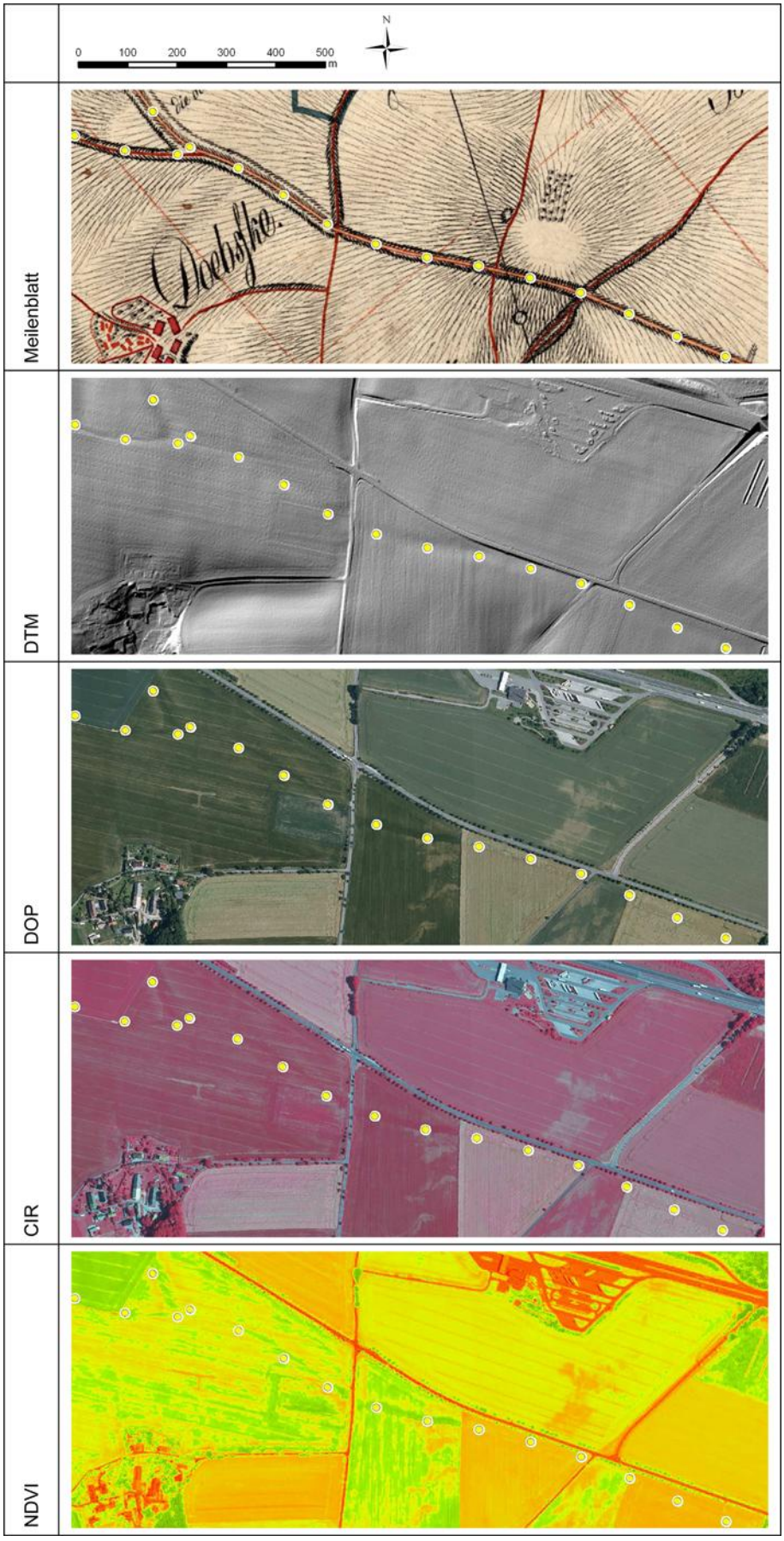

Fig. 6 – Post road Kamenz–Bautzen, north of Döbschke (Göda, Bautzen).

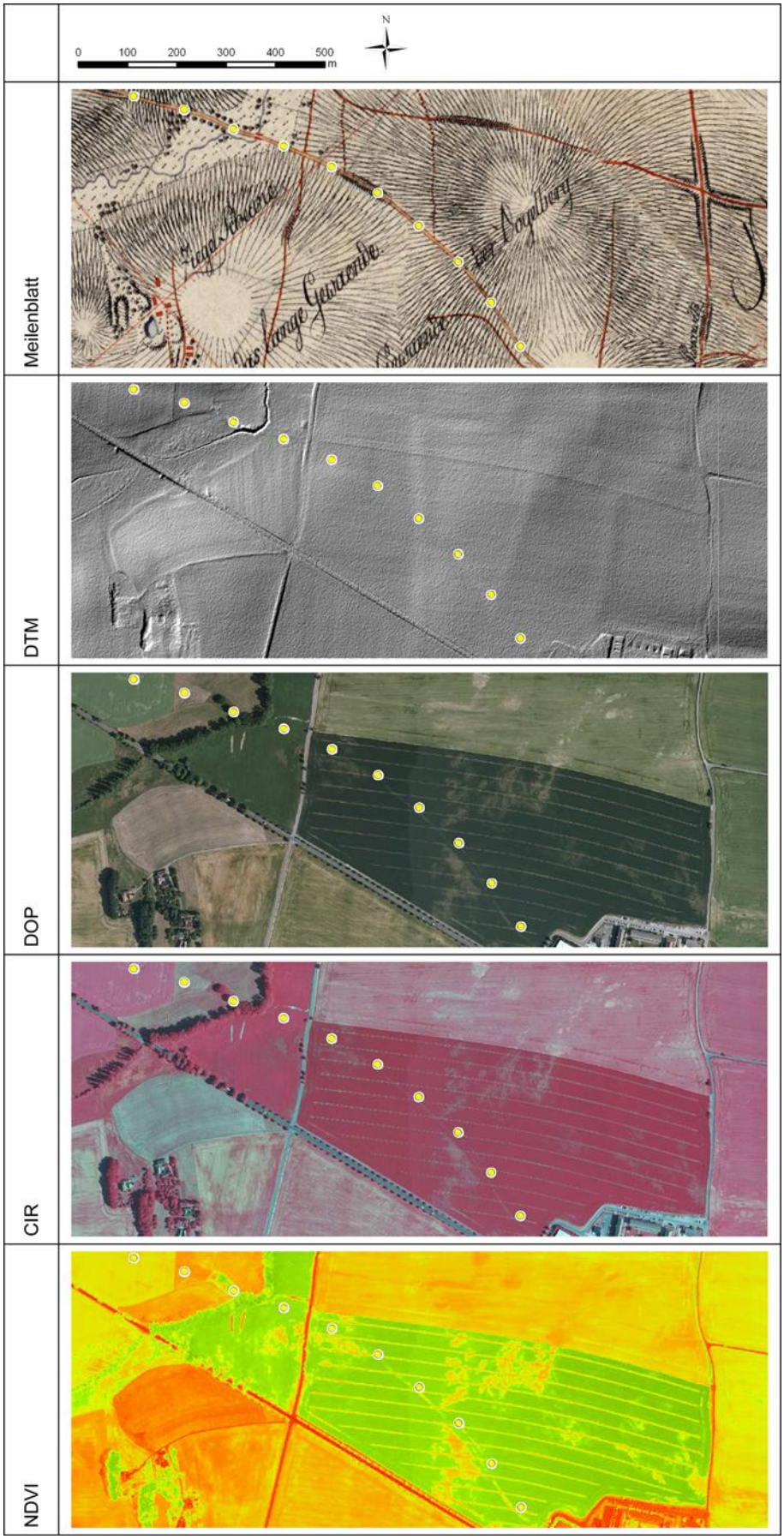

Fig. 7 – Post road Kamenz–Bautzen, north of Panschwitz (Panschwitz-Kuckau, Bautzen).

The result is a documentation of visibly preserved remains from ancient roads, just like hollow ways or crop-marks. About 660 km of traditional routes were prospected and 49 places with clearly visible traces of the route were detected and documented. Many tasks of on-site survey could be replaced by techniques of remote sensing using GIS. The duration of this project was less then two months, including introductory training.

Most details of the methods applied are well known, but falling prices allow the application even with rather low budgets. The method supports the practice of heritage protection not only for small project regions but state wide for the entire region of Saxony.

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ArchaeoLandscapes Europe

Increasing Public Appreciation, Understanding and Conservation of the Landscape and Archaeological Heritage of Europe

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Abstract: In many parts of the world over the past 60-plus years archaeological air photography has brought to light more previously unknown heritage sites than any other method of exploration. Air photography has now been joined by satellite imagery, airborne laser scanning and a variety of other airborne and ground-based survey techniques known jointly as ‚remote sensing', since they explore what is beneath the earth or ocean without disturbing its surface or damaging what lies below. To foster the cooperation between archaeological institutions in the field of modern surveying techniques the EU has started to support the large European networking project ArchaeoLandscapes Europe under the framework of the Culture 2007–2013 program. It is the aim of this project to support any kind of collaboration that enhances public awareness and dissemination of challenging skills in aerial and remote sensing techniques, at a very European scale. At the moment 50 partner institutions from 29 countries work together to create a self-supporting network of expertise and to disseminate the methods and techniques of modern archaeological surveying to institutions that are involved in archaeological research, cultural heritage management as to the general public.

Keywords: remote sensing, LiDAR, aerial archaeology, geophysics, European network.

Starting in September 2010, the *ArchaeoLandscapes Europe* Project (*ArcLand*) represents the culmination of a growing European cooperation from the mid-1990s onwards. Now federating 50 prestigious institutions in the field of archaeology and heritage protection (27 Coordinator/Co-organisers and 23 Associated Partners) from 29 separate countries, it will bring that process to a sustainable and self-supporting future as the long-term legacy of this and earlier EU-assisted initiatives. The project is granted by the EU within the framework of the Culture Programme 2007–2013 (CU7-MULT7 Agreement Number 2010-1486 / 001-001; http://www.archaeolandscape.eu).

The central theme of concerted action and cooperation will be stressed through annual meetings of the whole of the membership and the project's Management Board, to agree policy, review progress and plan new initiatives. Much of the project's work, however, will be undertaken through specialist 'focus-groups' and carefully structured 'work-packs' setting out operational programmes and timetables for each of the project's eight key objectives or 'Actions'.

Dialogue with target groups in the community will focus on multilingual and web-based presentation. Use will also be made of leaflets, booklets and more substantial publications to engage both with ordinary citizens and with specialists in various aspects of heritage exploration, management and presentation.

The project's long-term legacy will be better appreciation of the landscape and archaeological heritage of Europe, closer contact between heritage professionals and the general public, more effective conservation of the shared cultural heritage, the international sharing of skills and employment opportunities, better public and professional education, the wider use of archive resources and modern survey techniques, and higher professional standards in landscape exploration and conservation.

Aims of the Project

The ultimate aim of the *ArchaeoLandscapes Europe* Project is the use throughout Europe of aerial survey and 'remote sensing' to promote understanding, conservation and public enjoyment of the shared landscape and archaeological heritage of the countries of the European Union.

We want to increase public appreciation, understanding and conservation of the landscape and archaeological heritage of Europe through the application and international sharing of skills and experience in airborne and other forms of remote sensing.

The Project will achieve this through eight key Actions/Working Parties:

- By creating an ultimately self-supporting *ArchaeoLandscapes* Network, with a small central secretariat, to provide leadership, coordination and advice on the use for heritage purposes of aerial photography, remote sensing and landscape studies.
- By using traditional and innovative methods to publicize the value of aerial survey, remote sensing and landscape studies amongst the general public, students, teachers and all those who explore, enjoy or care for cultural landscapes and heritage sites across Europe.
- By promoting the pan-European exchange of people, skills and understanding through meetings, workshops, exchange visits, placements and opportunities for specialist training and employment.
- By enhancing the teaching of remote sensing and landscape studies through courses for students and teachers, and in the longer term through a European Masters degree in remote sensing and heritage management.
- By securing the better exploitation of existing air-photo archives across Europe by researching, assessing and publicizing their potential for heritage interpretation and landscape conservation.
- By providing support for aerial survey, remote sensing and landscape exploration in countries relatively new to their use, especially in northern, eastern and southern Europe.
- By further exploring the uses of laser, satellite and other forms of remote sensing and web-based geographical system in archaeological and landscape research, conservation and public education.
- By providing technical guidance and advice on best practice in aerial survey, remote sensing and landscape studies, with a particular emphasis on conservation and heritage management.

WP1 – Create a self-supporting ArchaeoLandscapes Network

The key element in attaining long-term sustainability will be the formation of a pan-European network of 'centres of expertise', to be known as the *ArchaeoLandscapes* Network. This cooperative partnership will secure funding from its members and from grant-giving bodies to support a small professional secretariat or 'nerve-centre'. This in turn will provide expertise, advice and support for organizations or institutions which

wish to pursue agreed objectives or to undertake partnership projects within the fields of landscape studies, heritage survey, conservation and public education.

The strength of *ArchaeoLandscapes* Network will lie in its heterogeneous nature and its total coverage of the countries of Europe, with a membership of 50 or more heritage bodies in the fields of education, research, conservation and public service. It will not rely on any individual institution for its continuing existence and its small secretariat may migrate around Europe over time as staffing opportunities or the availability of expertise dictate. The Network's members will agree key objectives and policies in the early stages of the present project. These will then be implemented, within and after the lifetime of the project, through a Management Board of 9 representatives, supported by the various Working Parties (Actions) and their leaders.

WP2 – Communicate the value of aerial survey, remote sensing and landscape studies

In many parts of Europe the last decade has seen a surge of interest in the traces of the past, not only in archaeological and historical sites and objects but also in the broader context of the landscapes within which these individual cultural features achieve their full meaning and impact.

A key action within the project is the use of traditional and new techniques to foster this interest and to show a broader audience how cultural landscapes and heritage sites can contribute to European as well as local identity and 'sense of place'. The power of aerial images, or the vision of our cities and rural landscapes on GoogleEarth and similar web sites, can bring this kind of appreciation to a wider audience than that reached by traditional hard-copy publications or carefully mounted exhibitions.

Traditional methods do nevertheless play a part in the project's communication strategy. An international exhibition first mounted at Prague as the end of a previous Culture 2000 project will continue to circulate to venues throughout Europe. Smaller exhibitions will also be designed and presented by project members as part of their own contribution.

At least three traditional publications are planned so as to publicize work carried out within the project – two reports of colloquia/conferences held in the middle and at the end of the project, and an account of a major study of the First World War Western Front and its aftermath in Belgium. Smaller 'popular' booklets and leaflets will also be produced and distributed, explaining the aims and achievements the project as a whole or of particular activities within it.

The main focus in the project's communication strategy, however, is the web-based output that can speak directly to a wider and in particular a younger audience. If the interest and commitment of these previously uninvolved members of the public can be captured and then nurtured, public appreciation of the shared cultural heritage of Europe will be enhanced, enjoyment increased and a sense of caring instilled in citizens who would not formerly have realized the significance of these living tokens of the past.

Without this public support attempts at wider and more sympathetic conservation will always face an uphill struggle. But it is also important to communicate with politicians who may be able to influence the legislative climate, and with professionals whose role it is to care for, conserve and 'present' the upstanding and hidden traces of the past. Meetings of various kinds with these two groups will therefore form an essential part of the project's work programme.

A particular contribution will be made by project partners who already have expertise in both traditional and innovative methods of catching the public and political imagination, such as the staff of the Discovery Programme in Ireland. Others will contribute particular expertise in the presentation of image- and map-based data of the kind needed by cultural resource managers and public service archaeologists in their efforts to protect sites and landscapes through the legal and planning systems.

WP3 – Promote the pan-European exchange of people, skills and experience

In a field with a relatively small number of professionals, spread thinly across Europe, it is essential to share understandings, skills, experience and research results. Together, the heritage community needs to learn from instances where countries, regions or institutions have managed to make a real contribution to landscape and archaeological conservation through the application of air-photographic and remote-sensing techniques.

The approach in this case has learned from earlier Culture 2000 projects in framing an effective and economical programme of meetings, conferences, workshops and colloquia on general or specific topics, in some cases carried through to traditional or web-based publication. The meetings will vary from larger conferences aimed at a broad exchange of experience across Europe to training schools and workshops for 10–25 participants, focusing on specific objectives.

A key feature of the project are regular meetings of the small 'focus-groups' which will be addressing a 'work-pack' for each of the project's eight objectives or Actions. These meetings set out work-programmes, monitor progress and coordinate their own activities with those of related focus-groups and of the project as a whole. Exchange visits between experts, and placements of 2 weeks to 3 months' duration, will also figure in the work-programme so as to give students or professionals the opportunity to gain experience and specialist training in European countries other than their own. There will be an emphasis on on-the-job learning and specialist instruction by staff or institutions, which have made particular advances in data-interpretation, methodology, instrumentation or communication techniques etc.

WP4 – Enhance teaching in aerial survey, remote sensing and landscape studies

The theory and practice of 'aerial archaeology' are taught in relatively few universities and polytechnics across Europe. Much the same applies to other forms of remote sensing (ground-based geophysics, airborne laser scanning etc). There is an urgent need to improve the range of opportunities open to intending students, as well as to professionals who wish to extend their range of skills. This challenge is addressed by creating contacts, facilitating exchanges and prompting discussion between teachers, professionals working in these fields and those who wish to apply these techniques in their research or conservation work. The improvement and broadening of course-content has a priority, with the shared and compared experience of existing teachers and professionals as key factors.

There is a particular concentration on establishing intensive short-courses in various institutions around Europe so as to increase the opportunity for students and professionals to learn new skills and to experience situations different from those in their own countries.

For those who cannot take part in full-time courses (of whatever duration) the project will create new opportunities through devising multilingual 'distance learning' material, which can be accessed over the Internet. A reasonable basis already exists in texts and illustrations used by project members in the past and this material will be brought together, refined and made widely available through the skill of partners who have specialist experience in web-based presentation.
A particular, but inevitably long-term, objective is the creation of a year-long European Masters degree (or equivalent) which will enable students to build up a special range of skills and experience by undertaking learning or research work at various locations around Europe. Selected partners in the network offer intensive courses of targeted teaching or research, of between 2 weeks and 3 months' duration. Students will undertake at least two extended placements outside their own country during their year of study, acquiring contacts and opening long-term possibilities for employment outside their native country.

WP5 – Exploit existing air-photo archives more effectively

Europe has a rich but seriously underexploited inheritance of aerial photographs from the last eighty years, documenting the dramatic landscape transformations of recent decades and containing a wealth of information about as yet unknown (and therefore unprotected) landscape features and archaeological sites from the more distant past.
The very existence of these archives, which are scattered throughout large and small institutions across Europe, is often hardly known in the broader heritage field and their potential for landscape and archaeological studies remains largely unassessed. The project compiles at least a preliminary guide to the existence and possible heritage value of these archives. It is recognized, however, that the full exploitation of these archives is a task, which will stretch far beyond the lifetime of the present project.
A particularly rich resource lies in the millions of air photographs for all parts of Europe, from World War II onwards, that have recently become accessible in Edinburgh through one of the key partners in the *ArchaeoLandscapes* project (TARA archive at the Royal Commission for Ancient and Historical Monuments in Scotland). A key objective, both for the curators of this archive and for other members of the project, is to help this archive to play a more effective role in heritage documentation and conservation across Europe as a whole.
Students and professional, predominantly from eastern and south-eastern Europe, will visit the Edinburgh and other archives to carry out initial identification, georeferencing and assessing the potential of uncatalogued parts of the collection and documenting previously unrecognized heritage sites and landscapes with a view to their better understanding and long-term conservation. The cataloguing work will also enable significant parts of the collection to be added to the archive's growing image database available on the Internet.

WP6 – Support aerial survey, remote sensing and landscape exploration

The concentration in this Action is on providing support, both financial and technical, for aerial and ground-based survey work in parts of Europe where the use of remote sensing techniques is still in its infancy. While Britain, Germany, France and (more recently) Italy have used aerial survey extensively in recent decades,

there are other parts of Europe where remote sensing and aerial survey have yet to become everyday tools in the armoury of archaeologists and landscape specialists, whether for research, conservation or public communication.
The project provides partners in Iceland, the Scandinavian and other countries with additional help in their attempts to bring these techniques into fuller use in their own countries. Help will also be given for an expansion of survey work in Poland and Romania, for a cross-border initiative in Hungary/Croatia, as well for air photo work of various kinds in Greece and Serbia. In all of these countries emphasis will be placed on the essential follow-up work of photo-interpretation, mapping and dissemination of the results to specialists and the general public alike.
A particular objective is to encourage this kind of work in Spain and Portugal, where aerial survey and other forms of remote sensing have so far been little used for exploration or conservation work. Intensive training schools will be mounted in Spain and Denmark, each of them introducing up to 25 students and professionals to the principles and practice of ‘aerial archaeology’, both in-flight and on the ground.
Smaller and less costly ground-based workshops will be held at least once a year to introduce students and professionals from these and other ‘fledgling’ countries to interpretation of aerial photographs, LiDAR scans and geophysical data, mapping and uses of the results in conservation work. In addition to these ‘practical’ uses, stress will also be laid on the role of aerial photographs in catching the public imagination and fostering concern for heritage landscapes and archaeological sites.

WP7 – Explore laser, satellite and other forms of remote sensing

The use of satellite imagery for cultural, conservation and communication purposes has long been a goal within archaeology and landscape studies. New possibilities have been raised in recent years through the development of high-resolution satellite systems and other forms of ‘aerial’ recording such as thermal imaging, airborne radar and laser scanning or LiDAR.
LiDAR in particular enables precise digital models of the earth’s surface and, given appropriate manipulation, can even ‘see through the trees’ to previously hidden cultural landscapes and archaeological sites beneath. The cost of commissioning LiDAR or satellite imagery, however, has limited its use within the heritage field. Meanwhile, regional authorities and utility bodies across Europe have been adopting LiDAR as their preferred method for mapping and landscape modelling.
As a result they now hold an extensive range of LiDAR data, of great potential for landscape and archaeological studies. Considerable technical expertise, however, is required to process the raw data for heritage purposes. The project therefore supports experimentation and skill-sharing amongst partners who can gain access to LiDAR and satellite imagery or who have already used it for cultural purposes. Concentrated efforts will be made to secure the release LiDAR and satellite data originally commissioned for non-heritage purposes.
Techniques such as LiDAR and satellite imaging will strike a chord with the younger generation, whose imagination can often be captured by seemingly ‘magical’ new technologies. The project’s communication strategy will draw on this potential for engaging with this readily approachable target group.

The project will explore the opportunity for presenting its results through Internet-based geographical systems such as GoogleEarth, enabling computerate sections of the community, for instance, to observe and even 'fly through' heritage landscapes throughout Europe, which would previously have been virtually inaccessible to them.

WP8 – Provide technical guidance and advice on best practice

An effective way of improving standards in any activity is the dissemination of information on best practice and reports on successful approaches to shared problems or possibilities. Within the relatively scattered heritage community this kind of information sharing is particularly important, maximizing the value of experience gained in one institution or country by bringing it to the notice of others elsewhere in Europe. Throughout its life the project will therefore compile and publish recommendations for best practice in such things as specialist teaching, communication with the general public and the use of planning procedures in heritage conservation. Technical guidance will also be issued on such subjects as LiDAR survey, aerial photography, geophysical investigations and the Internet presentation of heritage data.

For the most part these notes and recommendations will be presented in downloadable format on the Internet, to secure wide circulation and allow regular updating and the additions. Announcements will be made in the traditional technical and professional press, so as to inform potential readers of their Internet availability.

In this part of its work the project pays particular attention to best practice in conservation work and heritage management, including statutory provisions and practice in national legislation, and planning procedures throughout Europe. In this way lessons learned in one country will inform heritage professional elsewhere about provisions or procedures of potential relevance to their own particular situations.

Project Partner

It is one of the ideas or the *ArchaeoLandscapes* Project to include Europe as a whole to the *ArchaeoLandscapes* Network. The project membership therefore consists of partners from nearly every European country and will even be expanded during the next years. The cover the range of all kinds of archaeological and cultural heritage institutions like research institutes, museums, universities, state heritage offices and stakeholders of topics related to the *ArcLand* interests (fig. 1).

A list of all current partners is available at http://www.archaeolandscapes.eu/index.php/about/partners.html. These partners and the work are coordinated by the Roman-Germanic Commission (RGK; http://www.dainst.org/?ft=49) of the German Archaeological Institute, Germany (DE; http://www.dainst.org/) as the project leading institution which is supported by a team of 8 partner institutions which form the General Management Board of the project which is – amongst other things – also responsible for award of grants to support students and scholars to participate in the teaching and exchange events of the *ArcLand* project.

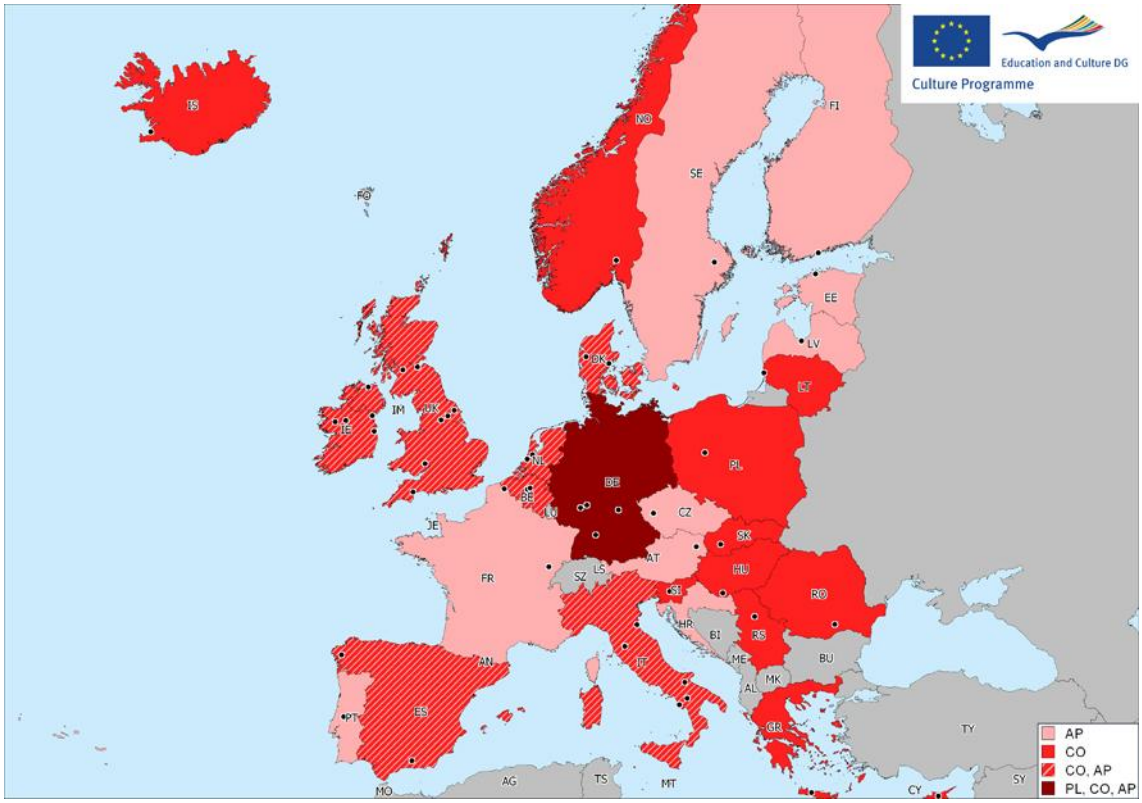

Fig. 1 – Map of the project partners of the *ArchaeoLandscape Europe* project as of December 2011. AP – associated partner; CO – co-organizing partner; PL – project leader.

Recent Project Activities

Various activities, amongst them the Dutch/Flemish/German workshop "New Developments in Archaeological Remote Sensing and Geophysics" in Münster (DE), the French/Slovenian workshop "Training and Research in the Archaeological Interpretation of LiDAR" in Glux-en-Glenne (FR) and the International workshop “Technological Advances in Landscape and Heritage Management and Recording" in Dublin (IR), have already been carried out. Two aerial archaeology training schools took place in Serbia (June 2011) and in Denmark (July 2011), future workshops and flying schools are in a planning stage as is the travelling exhibition which will be started 2013 in Dublin, various smaller and larger publications and the final international conference in August 2015 in Frankfurt, to be hosted by the Roman-Germanic Commission of the German Archaeological Institute. 16 students and young scholars have been supported by *ArcLand* grants to participate in one of the teaching activities or in an exchange visit.

The project's webpage will provide more information on future activities and on how to participate. Partners from the project will also publish case studies, best practice guides and other sorts of information during the lifetime of the project, which can be accessed at http://www.archaeolandscapes.eu.

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CHNT 16 Proceedings

The Lost Roman Sanctuary in Pula

Alka STARAC

Archaeological museum of Istria, Pula

Abstract: The rescue archaeological excavation that was conducted in St. Theodore's quarter at Pula from 2005 to 2009 encompassed an area measuring four thousand square meters, which was excavated up to a depth of eight meters. It was possible to single out seven basic architectural layers: Histrian, Roman, Late Roman, Medieval, Early Modern, Austrian, and the contemporary 20th century layer. The Roman building phase is surely the most important one, regarded from both an urbanistic and an architectonic standpoint. In addition to classical geodetic methods, the whole area was likewise scanned using a 3-D laser-scanner at various stages of the excavation. It was on this occasion, in 2005, that a 3-D scanning method was first used in an archaeological excavation in Croatia.

Keywords: 3D scanning, Hercules, sanctuary, temple.

State of research and methodology

The rescue archaeological excavation that was conducted in St. Theodore's quarter from 2005 to 2009 lasted 38 working months and encompassed an area measuring four thousand square meters (84 x 46 m). This area was created in 1873 as an inner courtyard of the infantry-artillery barracks. It was excavated up to a depth of eight meters. A total of 219 stratigraphical layers were documented in which 43,473 mobile archaeological finds were discovered, dating from the beginning of the 10th century BC to the 20th century. In accordance with historical periods it was possible to single out seven basic architectural layers: Histrian, Roman, Late Roman, Medieval, Early Modern, Austrian and the contemporary 20th century layer (STARAC 2009b). Archaeological stratigraphy and 14C laboratory analyses yielded the results that have been used in the process to determine the age of individual architectural layers. In addition to classical geodetic methods, the whole area was likewise scanned using a 3-D laser-scanner at various stages of the excavation.

The position in the urban core

Before the Romans, the location was occupied by a Histrian settlement around a freshwater spring, founded at the beginning of the Iron Age. The Roman building phase is surely the most important one, regarded both from an urbanistic as well as an architectonic standpoint. With the foundation of the Roman colony of Pola in 46–45 BC, an important sanctuary was erected at a freshwater spring inside its walls, which was situated to the north of the main road that connected the north-eastern gate with the forum (Fig. 1).

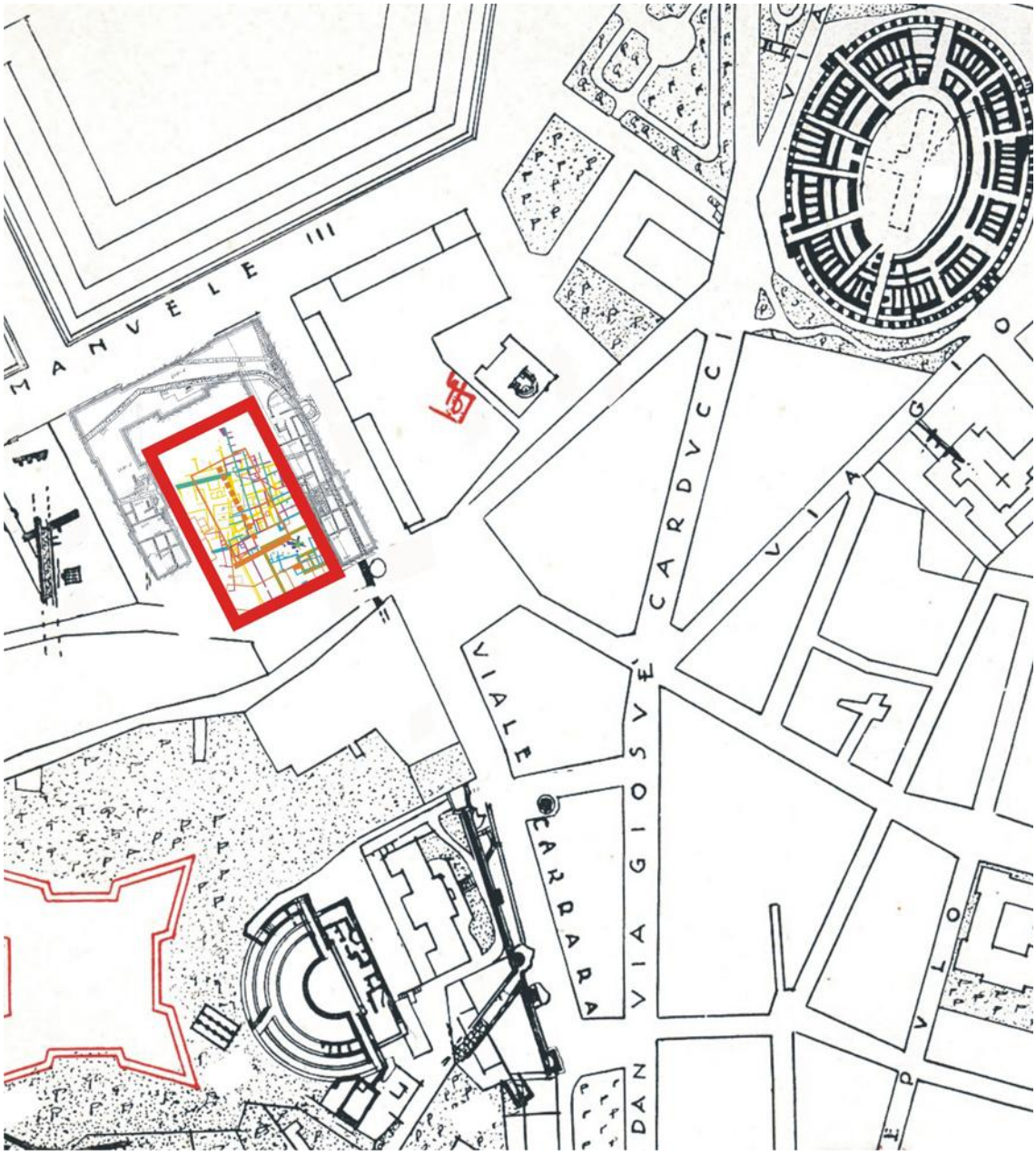

Fig. 1 – Area excavated 2005–2009 inside the walls of the Roman colony of Pola.

The gate was named after St. John in the medieval period, because of the nearby church of St. John. This sanctuary included a temple as well as an enclosed open area, and was most probably dedicated to Hercules if we are to go by an imposing cudgel in relief that was unearthed (STARAC 2009a) (Fig. 2).
A series of other structures were also erected on this location in the same period, which shared a common sewage-disposal and drainage system: the public baths, as well as a richly decorated urban residential house that featured a small domestic sanctuary dedicated to Salus, the goddess of health.

Fig. 2 – Hercules' cudgel in relief.

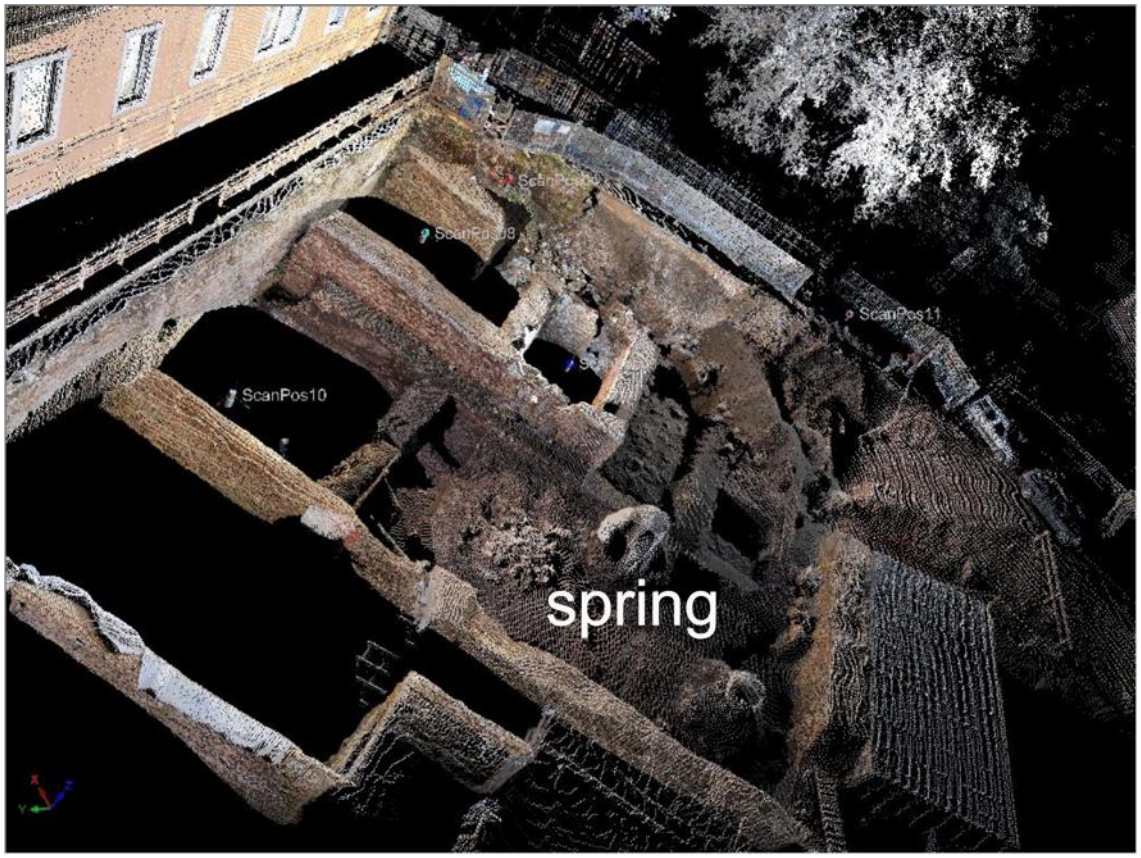

Fig. 3 – The Roman sanctuary with the well at the spring.

Description of the Roman Sanctuary

The remains of the Roman sanctuary include a rectangular, masoned podium that was identified as a temple podium, and a courtyard enclosed with massive walls, featuring a well erected over a natural spring (Fig. 3). The foundations of the temple rest on bedrock and have a rectangular ground plan that in its width varies from 8 to 9.5 meters, while its length measures 16 meters. There were almost no preserved architectonic remnants that could be unmistakably ascribed to the architecture of the temple, except for a fragment of an unfinished architrave that belonged to a structure measuring approximately ten meters in height, which was broken and discarded during construction works. The foundations of the temple were oriented in the west–east direction, its entrance being on the west. It was situated with its longer, lateral side parallel to the street, so that the entrance was visible from town, from the direction of the forum. The enclosure walls of the sacral complex courtyard were erected on the surface of a slope that descended mildly towards the north, towards the sea, and were devoid of any real foundations. The courtyard was filled-in with a trodden layer of lime and with layers of quarry stone and earth, on which a drainage deposit consisting of amphorae was subsequently placed (Fig. 4).

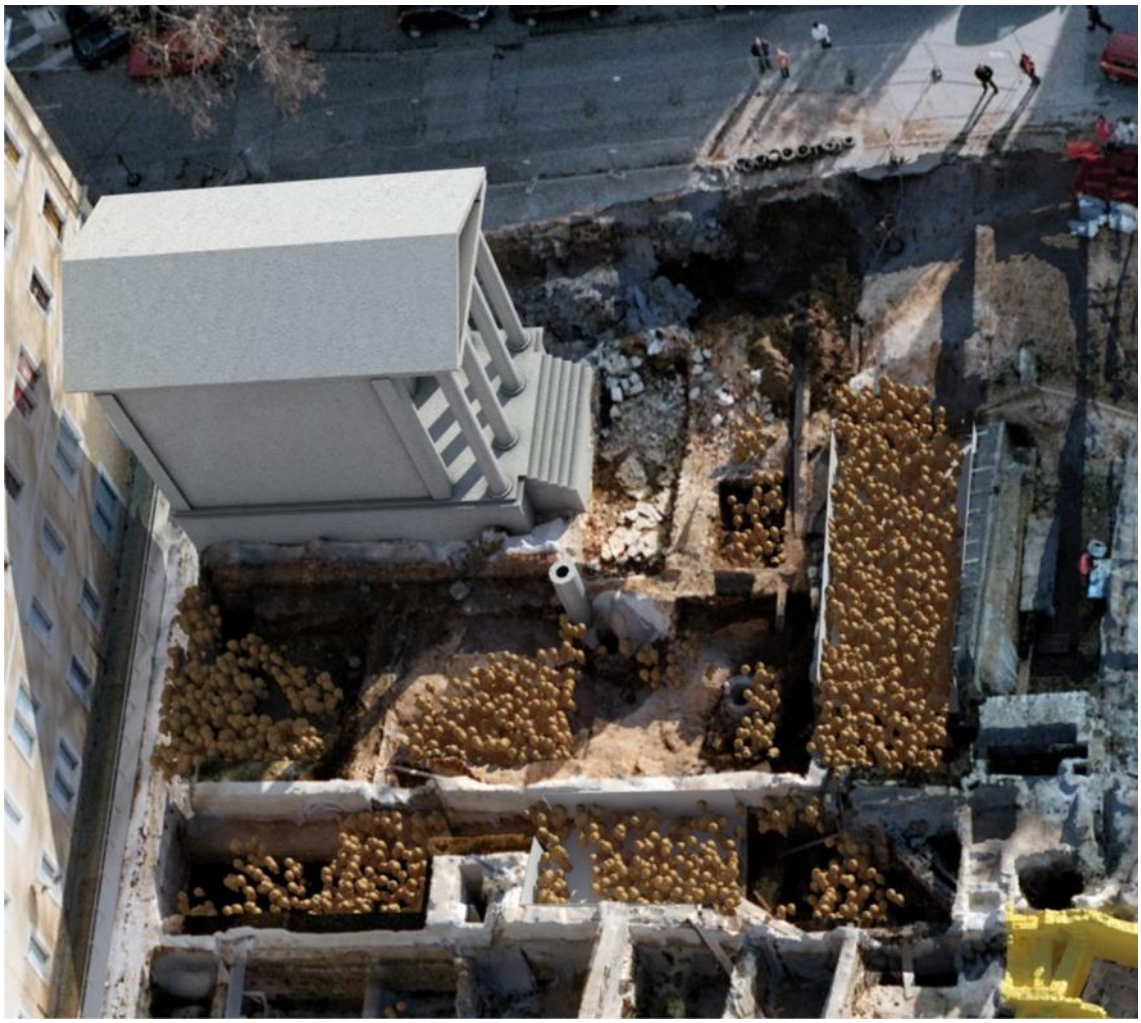

Fig. 4 – Reconstruction of temple with the deposit of amphorae, a 3-D model.

The Roman sanctuary was further expanded in the period between 45–30 BC. On the western and northern sides the courtyard was bordered by walls that fenced passages that were mutually perpendicular to one another, measuring 5.4 meters in width and approximately thirty meters in length. The dimensions of the entire complex, after the exterior passages had been built, measure 31 meters in width and 33 meters in length, which is approximately equal to the assumed full length of the complex. The assumed full width of the sacral complex is estimated at 45 meters. At the same time, the public baths and a luxurious house (domus) were built to the north of the sanctuary, both of which were connected by a single sewage disposal system.

Architectural decoration

Except for the block with a depiction of a cudgel, a fragment of an architrave, and a greater number of undecorated blocks of stone, there were almost no preserved architectonic remnants that could be unmistakably ascribed to the architecture of the sacral complex. The Roman architectonic elements that were discovered in the area of the sanctuary are few in number, and were mostly put to secondary use as common building material for the construction of the foundations of the convent structures: a Tuscan capital (or base) decorated in relief and a cornice in the same style, fragments of a frieze with acanthus tendrils, and a fragment of a temple door frame featuring a steplike profile. The architectural style of the temple remains unknown. The main building material was local limestone. Small, thin decorative wall tiles made of various multi-colored marbles speak about the luxurious lining of the temple interiors.

The deposit of amphorae

The deposit of amphorae was discovered during the rescue archeological excavation in the urban core of Pula, which lasted from 2005 to 2009, where in this five-year period a total of 2,119 amphorae were discovered (STARAC 2008). These amphorae were set in the drainage layer and served to level the terrain. By far the most represented amphora type is the Lamboglia 2, with a considerable number of amphorae representing the transitional forms between Lamboglia 2 and Dressel 6 A. There was a relatively modest number of amphorae with an ovoid body, and a single amphora featuring the early form Dressel 2-4. The amphorae were placed on several terraces and were positioned there vertically in several rows. The vast majority of them were placed upside down, their openings being closed intentionally, and they were perforated in the vicinity of the foot. The drainage layers featuring amphorae placed upside down onto a base consisting of rather large quarry stones played an important role in the drainage of rainwater towards the well, decreasing the pressure that water exerted on the walls of the terrace, thus preventing them from being gradually washed away and collapsing. In this manner the terrace of the Roman sacral complex was transformed into a water collecting reservoir with several layers of filters, directing rainwater towards the well that was built above the spring. Considering the data regarding the foundation of the colony of Pola, and the stratigraphical context of the intact drainage layer that was sealed on the surface by an original floor, it is possible to conclude that the amphorae were set immediately after the foundation of the Roman colony of Pola in 46–45 BC (FRASCHETTI 1983: 99), in a relatively short period of time between 45 and 30 BC. The secondary usage of amphorae for drainage and field-leveling purposes was an exceptionally extended phenomenon in the period from the second half of the 1st century BC to the first half of the 1st century AD

throughout northern Italy (PESAVENTO MATTIOLI 1992; BANDELLI 1999: 184–185; MANACORDA 1999: 187–189), and in this manner in Istria as well, especially in Pula (STARAC and MATIJAŠIĆ 1991; STARAC 2006).

Unanswered questions

Was there a cult-continuity from the Histrian period?

A certain continuity of the cult place can be presumed on the basis of archaeologically documented structures that stood out on account of their size and constructional characteristics, when compared with the surrounding ones that with the passage of time superseded one another within a limited area inside a ten meter radius around the freshwater spring, during the last 400 years BC (Fig. 5).

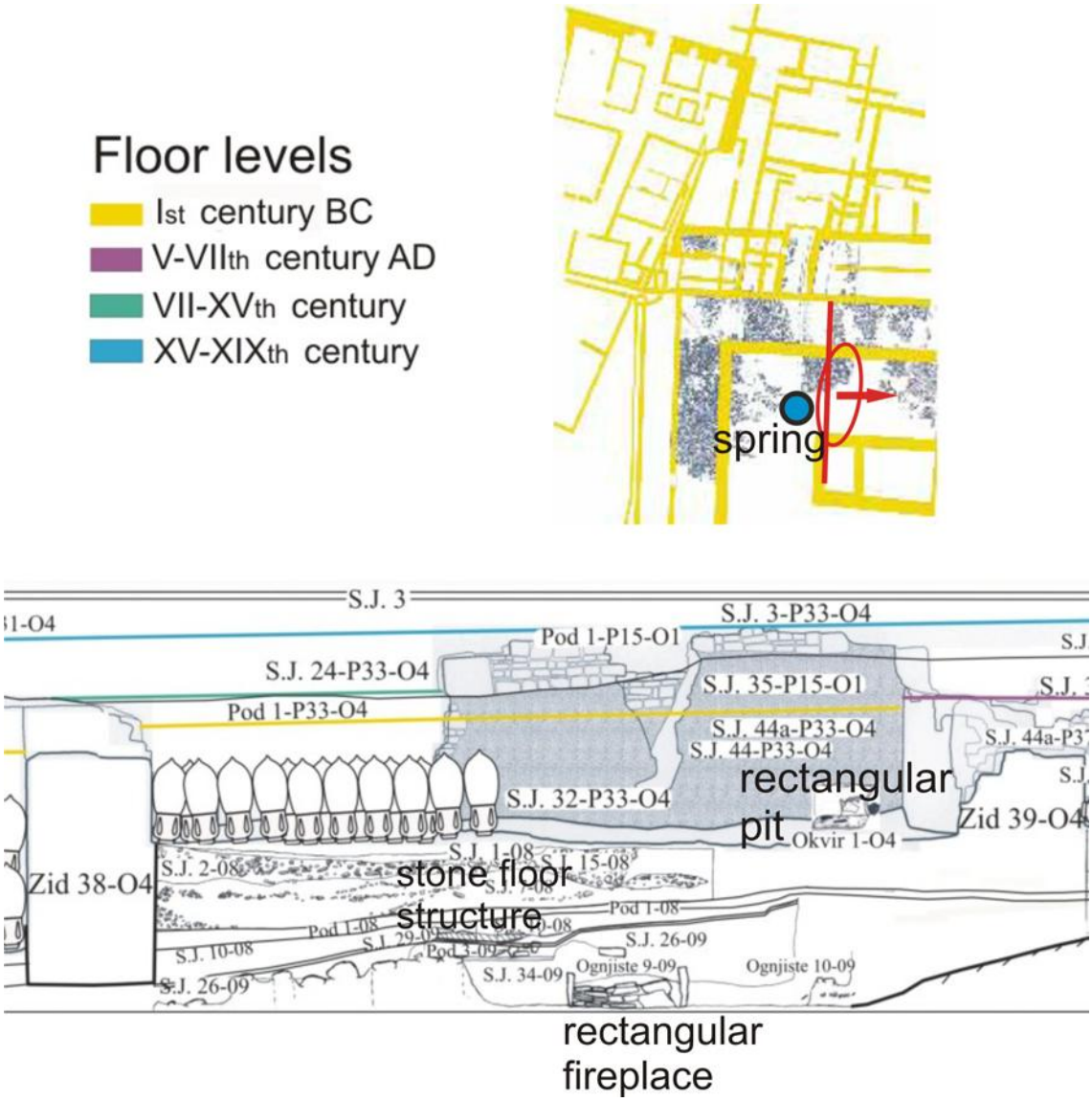

Fig. 5 – Histrian and Roman structures around the freshwater spring.

A large rectangular fireplace lined with vertical stone slabs, which was active in the last quarter of the 4th century BC, was filled-in during the 3rd century BC. A rectangular structure that featured a tile roof, stone flooring, and a drainage waterway was erected on its place in the historical period during the initial armed conflicts and cultural contacts of the Histri with the Romans. The building was abandoned as a result of a fire that broke out around 41 BC, in the course of the Second Triumvirate and during the Roman civil wars that flared up after Caesar's death, only a few years after the founding of the Roman colony of Pola.
In the forties of the 1st century BC, during the erection of a temple and arrangement of its terrace, a rectangular pit featuring plastered walls was dug out on that same spot, which contained burned remains indicating offerings, showing thus the sacred character of the structure. It was on the basis of these data that an assumption was developed, whereby there is possibly a continuity regarding the existence of a sacred place next to the freshwater spring.

Sanctuary of Hercules?

After the founding of the Roman colony, the natural spring was at the heart of a monumental sacral complex connected with different cults that worshiped everything from water, to health and purity. The central spiritual place was reserved for Hercules. A fragmentary inscription mentioning certain public building activities in honor of Hercules was found in the vicinity of the temple foundations in 1900. Another indicative find is a square slab of limestone, whose sides measure approximately half a meter, featuring a cudgel in relief, a recognizable symbol of Hercules, which was discovered in a pile of undecorated blocks of stone, discarded in the northwestern corner of the courtyard.

The end of the Roman Sanctuary

A fire towards the end of the 5th century destroyed all Roman structures, and on the ruins of the public baths an Early Christian church was erected, probably dedicated to St. Lucy (KANDLER 1876; JUKIĆ 2010). The old church was filled-in during the 15th century, only to be replaced by the larger church of St. Theodore. A Benedictine convent was situated above the ruins of a Roman temple, and the area of the former temple terrace became the courtyard of the convent.

Innovations

It was on this occasion, in 2005, that a 3D scanning method was first used in an archaeological excavation in Croatia (Fig. 6).
The conducted research activities provided data that not only radically changed but also enriched the urbanistic picture of Pula throughout its 3,000 year long history, offering thus a precise digital framework for future investigations. The 3-D scanned building remains from the Roman period, coupled with an analysis of preserved architectural elements such as columns, architraves and cornices, provided a starting point for the first attempt to hypothetically reconstruct the Roman sanctuary and domus (Fig. 7).

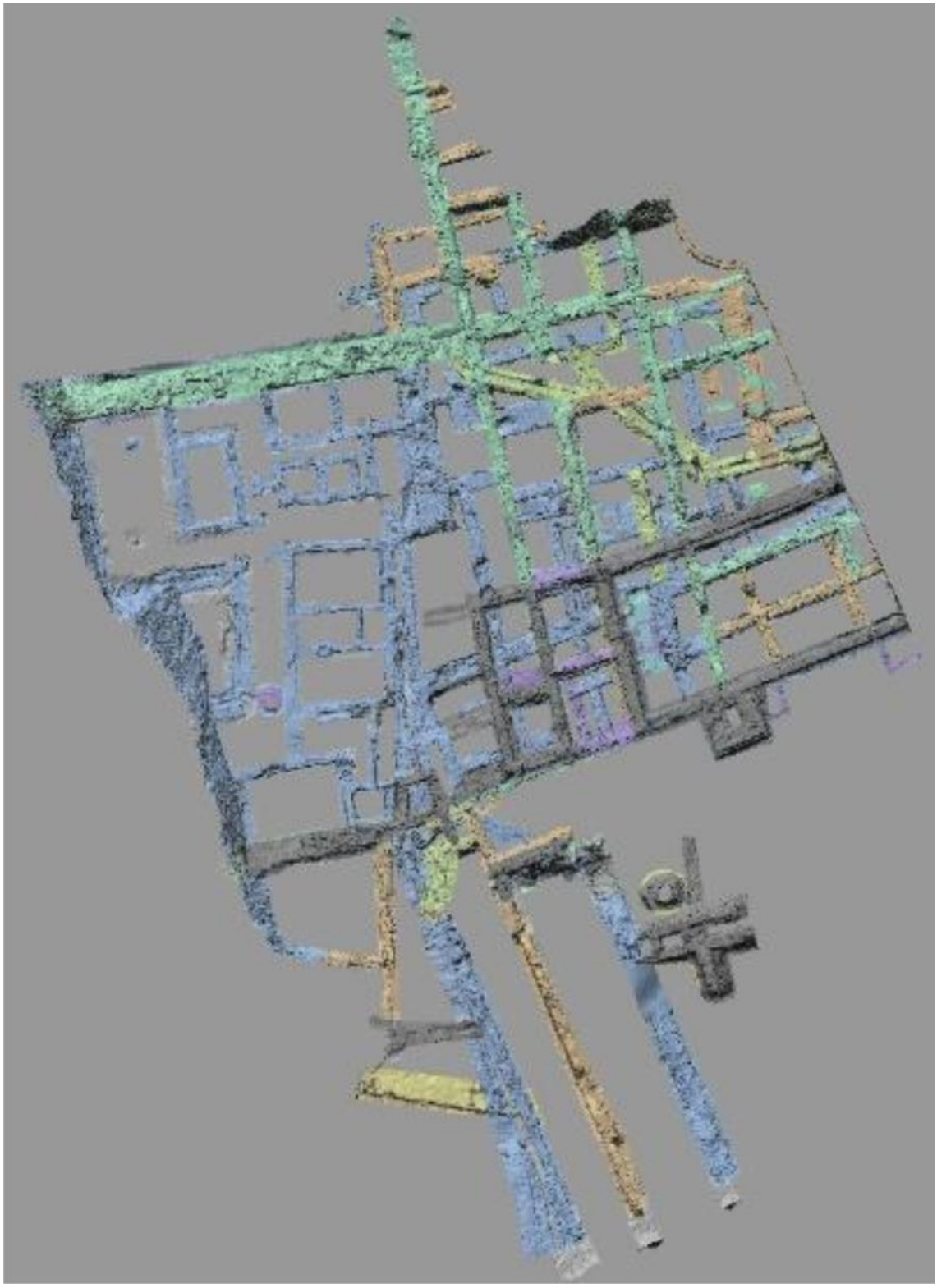

Fig. 6 – Building phases, a 3-D model. The 2005 excavation.

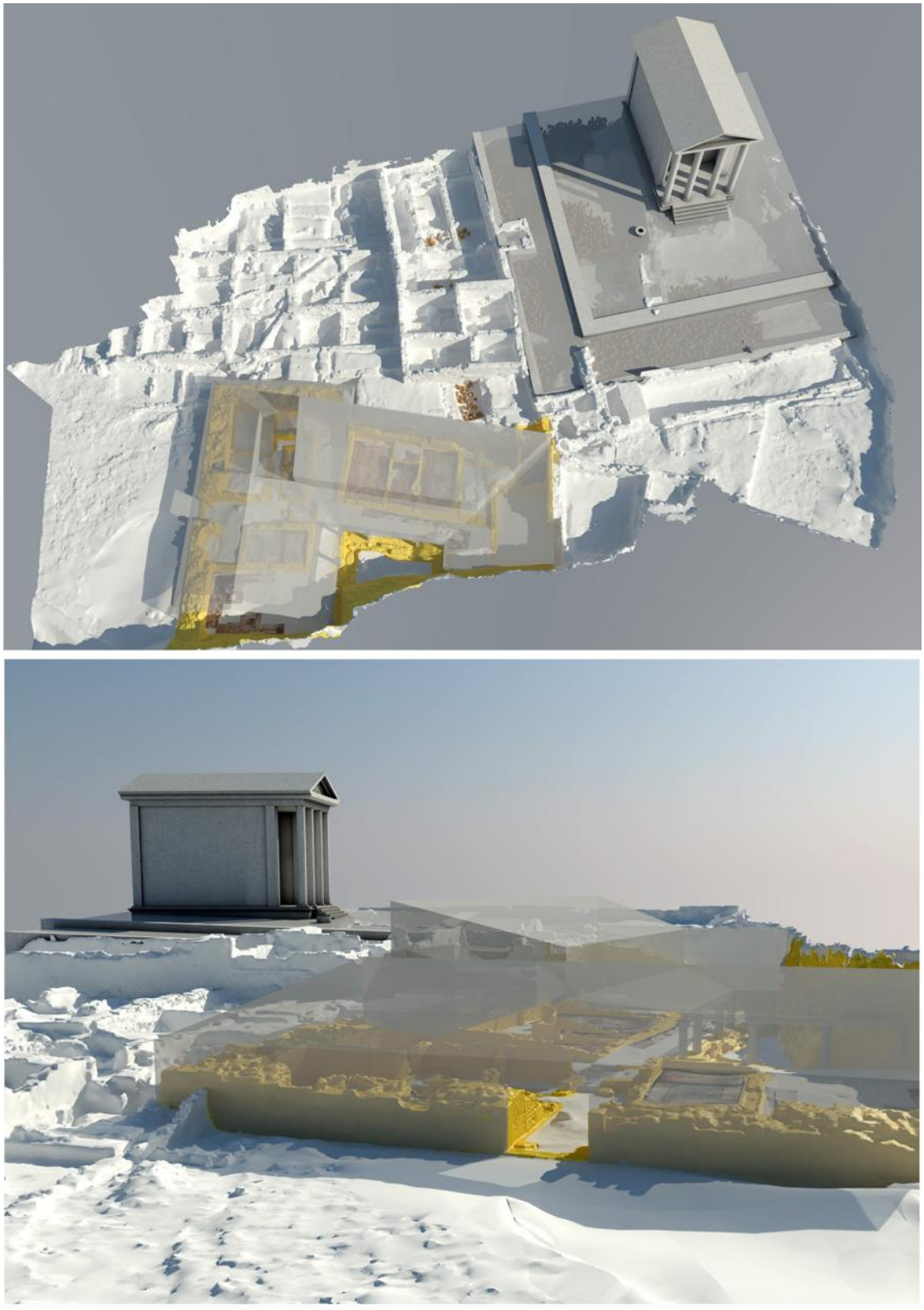

Fig. 7 – Reconstruction of the Roman sanctuary and domus, a 3-D model.

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Pre-excavation research at the site of *Ala I Batavorum* from Dacia

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Abstract: The site where *ala I Batavorum* had its garrison in Dacia is one of the most important auxiliary forts and adjacent settlements from this province. Unfortunately, the field researches undertaken here are scarce and with relatively inconclusive results.
The current paper aims at establishing the main coordinates of the settlement(s) through a series of pre-excavation researches based on modern technologies and techniques. Overlapping the aerial photograph of the site, where the Roman stone structures are visible, on satellite maps of the modern village (Războieni-Cetate, Alba County, Romania), we have obtained an accurate image of the archaeological site. As well, we have managed to determine the topographic coordinates of the fort and to create an altimetric reconstruction of the whole valley, with a profile traced through the fort. These comprehensive studies and the maps and plans obtained help us better understand the Roman settlement, as well as to place in the correct context the rather numerous artifacts accidentally discovered over time.
The main result of our enterprise is accurately placing on a map, for the first time, one of the most important – as well as less known – settlements from Roman Dacia. The plan thus obtained is a most necessary starting point for the planning of future archaeological campaigns.

Keywords: *Ala I Batavorum*, Roman Dacia, Războieni-Cetate, topographical map.

General outline

The village of Războieni-Cetate (Székely Földvár until 1918) is situated on the Transylvanian Plateau, at about 1 km north-west from the bank of the river Mureş. As the river meadow was constantly exposed to flooding, the human habitations – from prehistoric times up to the modern age – have been placed on the eight terraces of the riverfront.
Since the Neolithic period, constant habitation has been registered in the area. The only period of time that does not seem to be represented is the Latène age: the Celtic and Dacian cultures are attested in nearby villages, but they lack at Războieni-Cetate (POPOVICI and VARGA 2010: 13–43). To offer a comprehensive and thus satisfying explanation for this fact is rather difficult, as no major topographical or climatic changes took place during the period.
The Roman conquest of the Dacian kingdom from 106 A.D. and the birth of province Dacia gave new significance to the place. The *ala I Batavorum milliaria* was stationed here – the sole *ala milliaria* from Dacia (PETOLESCU 2002: 61–62). The presence of this particular *ala* is archaeologically attested through inscriptions and an impressive number of stamped tiles. The military element naturally led to the economic and demographic development of the adjacent civil settlement (or settlements). The variety of artifacts stands for the place's prosperity.

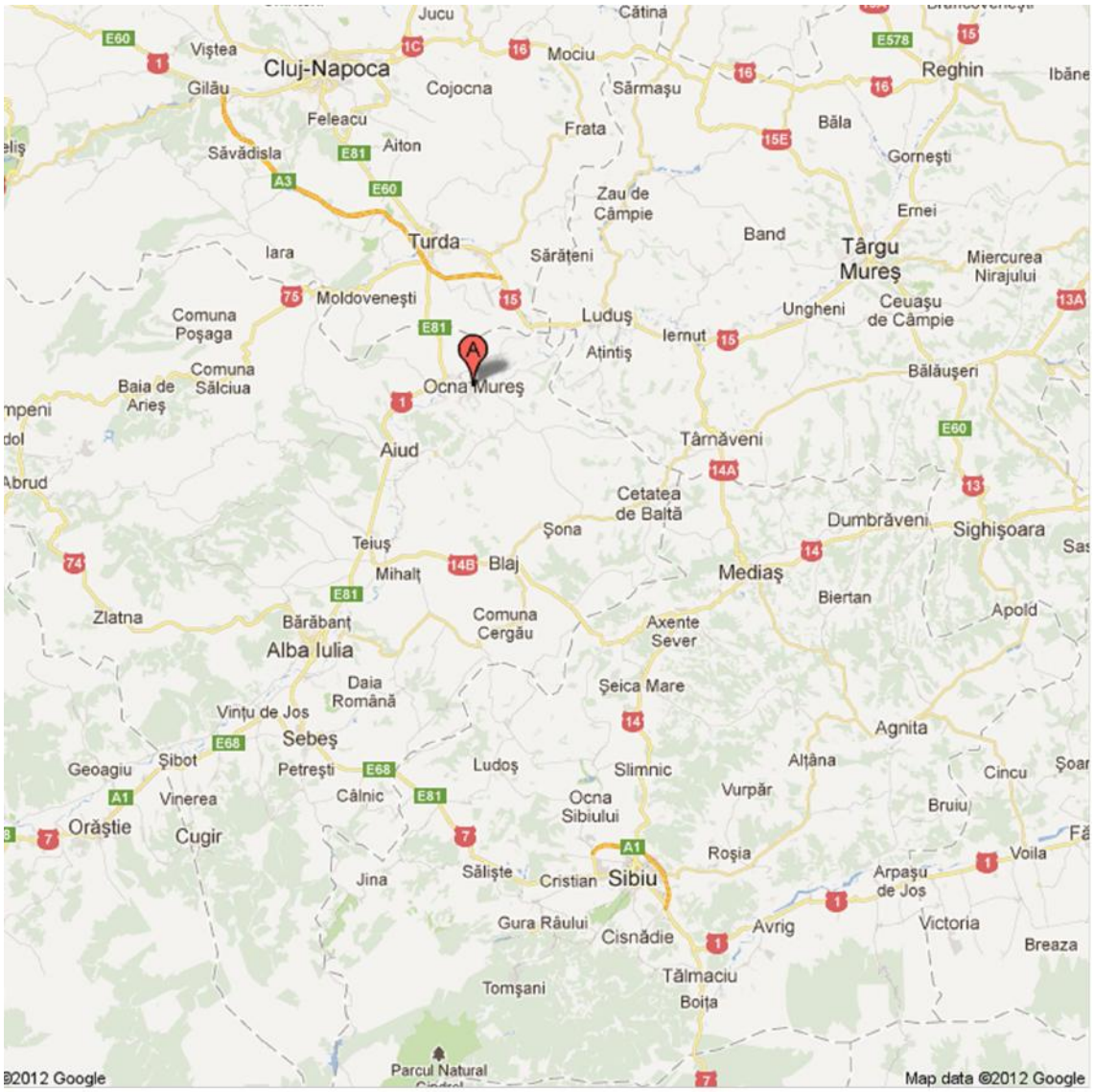

Fig. 1 – Map of the region, with the position of Războieni-Cetate pointed out and the main roads and settlements indicated (taken from Google maps).

Regardless the importance of the site for Roman Dacia, the history of archaeological research is marked by discontinuity and by many immaterialized initiatives.

During the 19th century, the most remarkable achievements were Baron Löventhal’s excavations, finalized through a special exhibition held at the Érdely Múzeum from Cluj-Napoca (TORMA 1860). As well remarkable is the publication of a significant number of artifacts from Count Zichy’s private collection by Téglás Gábor and Téglás István (TÉGLÁS 1888; TÉGLÁS 1898; TÉGLÁS 1911). A detail worth mentioning regarding Count Zichy is the fact that his manor still stands – though in a poor condition – in today’s village; the Roman columns that he reused for supporting a balcony are still visible – and still a part of the construction.

Later on, during the inter-war period, Constantin Daicoviciu signaled stamped tiles, funerary monuments and Roman construction materials on the site (DAICOVICIU 1930; DAICOVICIU 1932). The first modern excavations were undertaken by Ioan Horaţiu Crişan in 1960 (CRIŞAN 1965). His was a rescue excavation,

marked by the discovery of two Roman tombs. During the ‘90s, a team of researchers from Cluj-Napoca (Emilian Bota, Carmen Ciongradi, Ligia Ruscu, Dan Ruscu) conducted several campaigns on the site. Their aim was tracing the limits of the fortress; the precinct walls were identified on the eastern and northern sides and it was thus concluded that the fortified area is larger than formerly assumed (BOTA et al. 2004).

Fig. 2 – The former residence of Count Zichy, with Roman columns supporting the northern balcony – the brick walls are a late addition (Copyright: R. Varga).

The aerial overview

One of the most important progresses registered during the last two decades was the publishing of the aerial-viewed plan of the site by Ioana Oltean (OLTEAN 2007: 159 fig. 5.30). Thus, the stone structures and the plan of the fort are clearly visible. According to this photograph, the area of the fort has been estimated at about 5.9 hectares (POPOVICI and VARGA 2010: 47) – perfectly suitable for the *castrum* of an *ala milliaria* (MARCU 2009: 153) archaeological investigations can answer to this question.

On the other side, the civil settlement obviously has two nucleuses: one north of the fort, in its immediate proximity and the second one in the south – south-west, at about 350 meters from the southern wall of the military construction. It remains still open to discussion if we are dealing with two actual settlements or just one and only.

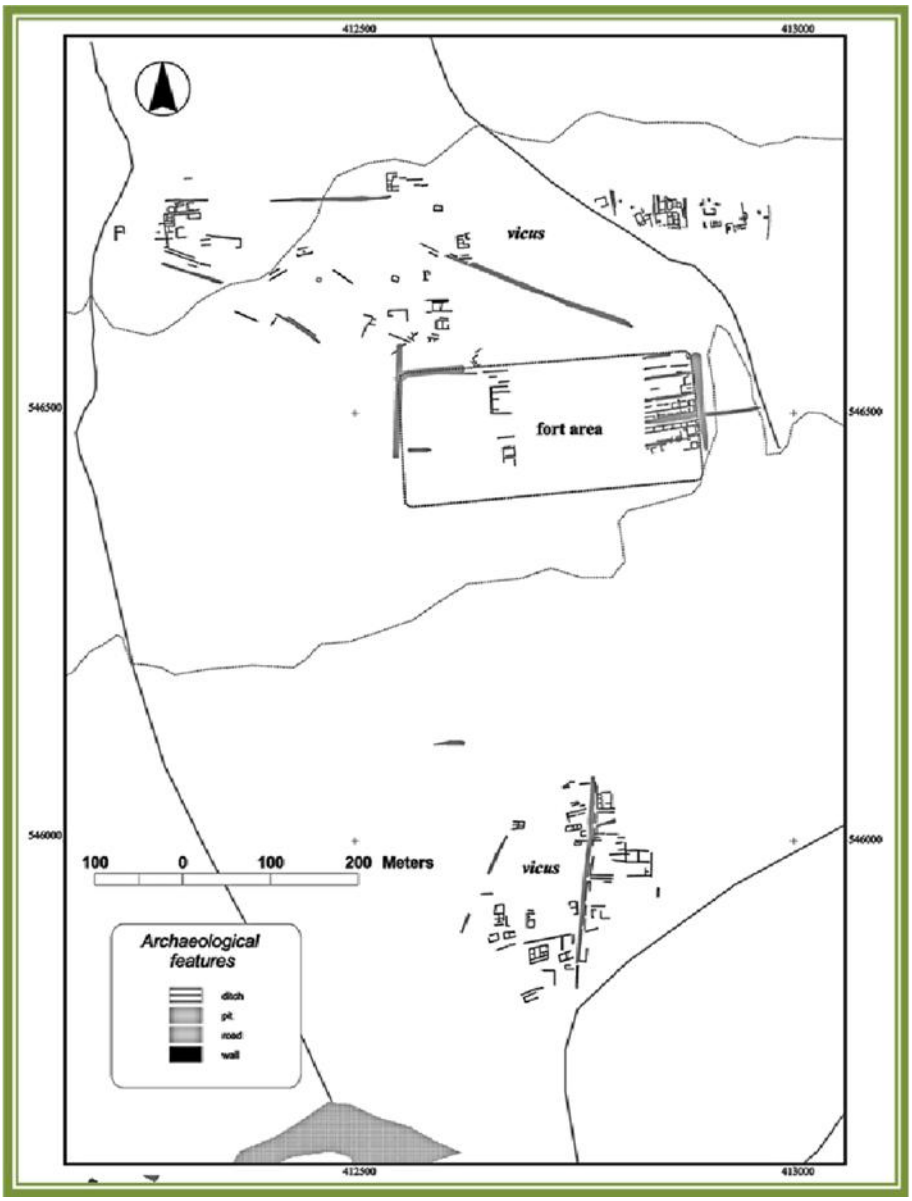

Fig. 3 – The aerial overview of the site (Copyright: OLTEAN 2007: 159 fig. 5.30).

The topography of the site

Topographical investigations led to the altimetric reconstruction of the valley, thus offering a better understanding of the local natural features and conditions. The profile drawn through the fortress leads us to emphasizing on the terrace where the military construction was placed.

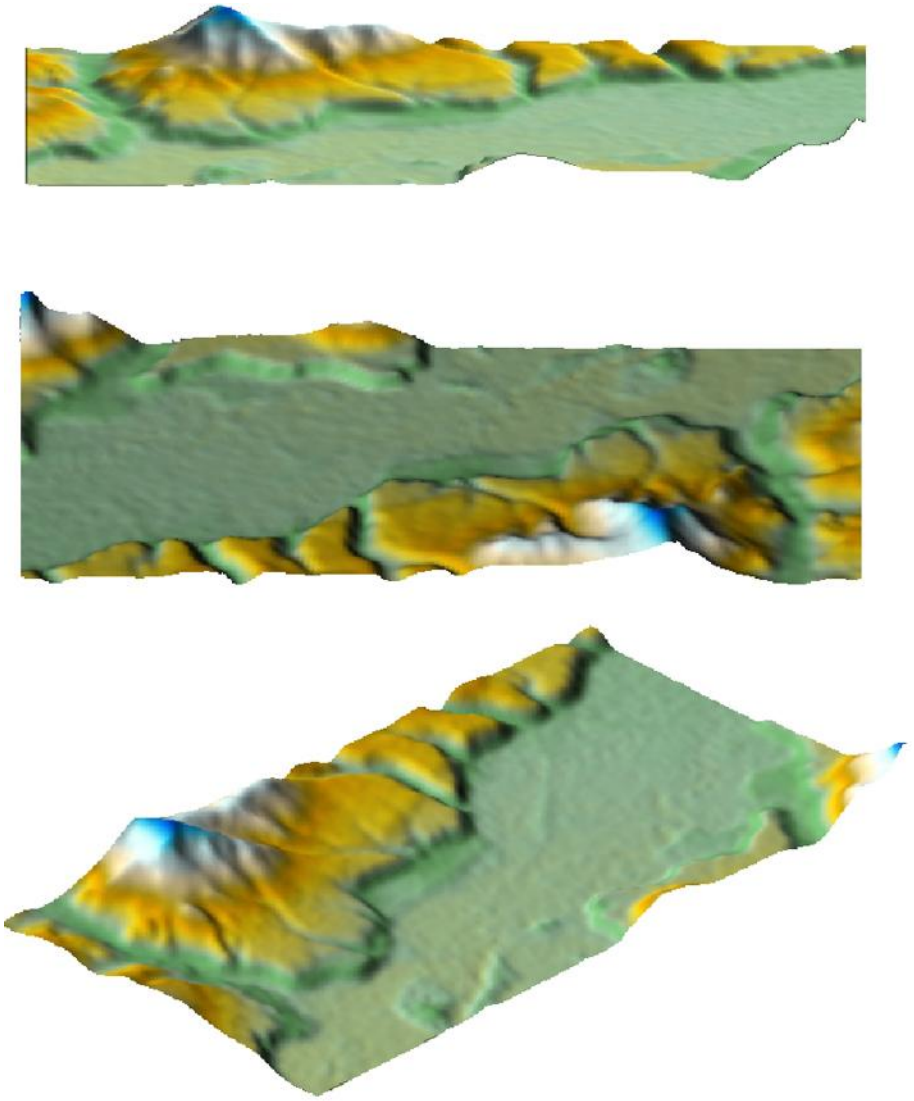

Fig. 4 – Altimetric reconstruction of the valley (Copyright: Mihai Florea, MNIR Bucureşti).

By overlapping the aerial photograph on an on-line map showing the contemporary village, we have obtained a useful – and more interactive – survey of the areas that present archaeological interest. Having these points placed on an up-to-date map helps to identify the practical problems that one might face in excavating certain points. As well, this type of approach is useful in underlining the touristic potential and the possibilities of valorization for each area of interest.

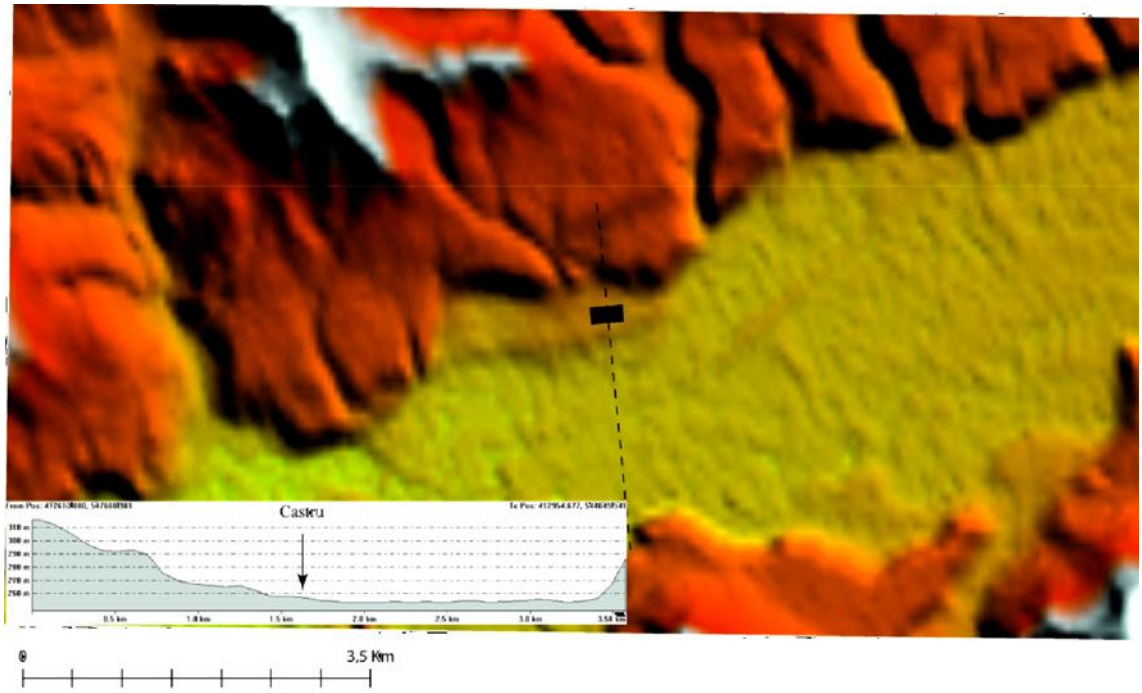

Fig. 5 – Altimetric reconstruction of the valley, with the place of the fortress indicated and an altimetric profile traced through it (Copyright: Mihai Florea, MNIR Bucureşti).

Fig. 6 – Interactive map of the site (map taken from GoogleEarth).

Main artifacts

The artifacts discovered, mainly accidentally, as stated before, concentrate around certain areas. These mark various points of the Roman settlement: the fort, an area north-west of it remarkable through the huge amount of waste pottery discovered and that probably was the “industrial” quarter of the settlement, the

region of the village that corresponds to the second nucleus of habitation visible on the aerial photo, another area south of the village where parts of the Roman road are visible, as well as the perimeter of the necropolises.

The variety as well as the quantity of archaeological artifacts discovered on site is impressive. Of course, the current paper only aims at presenting the most interesting and relevant categories and finds.

Fig. 7 – The inscription dedicated to Hercules Magusanus (Copyright: Rada Varga).

Stone inscriptions

One of the most revealing and up to a point spectacular class of artifacts are the stone inscriptions. Though not remarkable through number, the inscriptions offer us precious inside on the religious and social web of the Roman settlement.

The votive epigraphy is represented by an inscription dedicated to Epona by a certain Aurelius Occon Qutianus (BĂLUŢĂ 1990: 83–87; ILD 417) and an altar erected in honor of Hercules Magusanus (Fig. 7) by L. M. Hadrianus (MOGA 1996: 185; POPOVICI and VARGA 2010: 100–103). This monument deserves a special attention due to the epithet of the deity: as Magusanus, Hercules is clearly associated with the Batavian pantheon (HAUG 1912: 611). Given the context, even if the name of the one erecting the altar is Roman, we can assume his genuine Batavian origins or at least his spiritual integration into the Batavian-dominated environment of the settlement adjacent to the *ala*'s fort.

The funerary monuments are equally important and interesting. Thus, a few fragments of funerary lions have been discovered on site – unfortunately in secondary positions, not in funerary contexts. As well, there have been found parts of funerary *stellae* and a very fragmentary inscription, dedicated to the memory of a certain Se(cun)us (CIL III 934) or Se(dat)us (IDR III/4, 75).

Tegulae

Another category of inscriptions, which hold a totally different meaning, are the stamped tiles. At Războieni-Cetate, the most relevant (and numerically dominant) stamped tiles are those bearing the mark of *ala I Batavorum*[1]. They basically include six types, more or less contemporary (POPOVICI and VARGA 2010: 88). Also worth mentioning are the stamps of *legio XIII Gemina* – the legion stationed at *Apulum* (Alba Iulia, Alba County) – which were probably used among the initial construction materials for the fort. Chronologically the newest group of tiles is the one bearing the mark of *legio V Macedonica* – stationed at *Potaissa* (Turda, Cluj County) from 167/168; these tiles were certainly used for a series of repairs or works of reconstruction.

Fig. 8 – The stamp of *ala I Batavorum* on a tile; the acronym is bordered by a *tabula ansata* (Copyright: Rada Varga).

[1] We express our gratitude towards Professor Ioan Piso, who generously offered us his unpublished study on the stamped tiles from Războieni-Cetate.

Pottery

As expected, the pottery pieces constitute the largest category of artifacts discovered. Beside the numerous fragments of common pots, a few shirts require special attention. Among them, we mention some fragments of *terra sigillata* vessels and moulds, as well as fragments of stamped pottery[2]. The imported fragments are to be connected to *Gallia* and to the production centers of Lezoux. Important as the imported pieces are for revealing a rather high economical state of certain inhabitants of the settlement more interesting and relevant in the given context are some of the locally manufactured pieces. The fragmentary mould presented in Fig. 9 (as drawing, because of the bad state of conservation of the piece itself) is one of the most interesting finds: its decorations seem to have been complex – a construction serves as background for the scene with the hare – and they resemble patterns present on the *terra sigillata* bowl discovered at Micăsasa, Dacia's main fine ware production center.

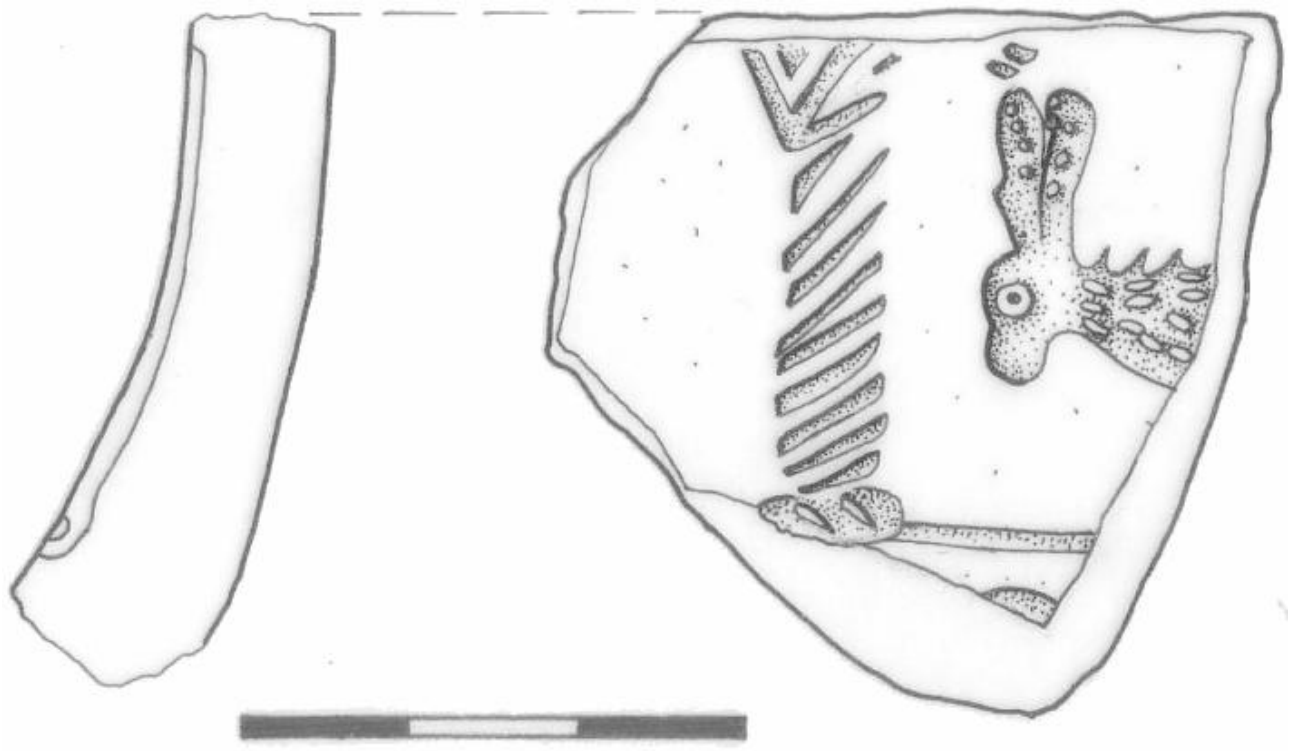

Fig. 9 – Local *terra sigillata* mould (Drawing made by Anca Bîlc).

Another interesting category of fine ware is represented by fragmentary snake vessels. These *crateroi* are parts of the highly under-represented category of cult objects discovered on site (RUSU-BOLINDEŢ and ONOFREI 2010: 416–417; 426–428 Pl. IV–V). Their exact place of provenience or the context of their discovery are unluckily unknown.

A special shirt, coming from a common bowl, is the one illustrated in Fig. 11. After burning, the craftsmen or the owner of the pot inscribed his own name on it: Sedatus, a Celtic origin name, that probably has, as mentioned above, one more attestation in the range of the site.

[2] We kindly thank Dr. Viorica Rusu-Bolindeţ for her minute and comprehensive analysis of the fine ware.

Fig. 10 – Fragments of the snake vessels (Copyright: Rada Varga).

Fig. 11 – Inscribed pottery fragment (Copyright: Rada Varga).

Lamps

Lamps have been discovered and collected at Războieni-Cetate since the 19th century. Among them, imported pieces bearing the marks of craftsmen such as C. Dessius and Sextus (CIL III 8076, 11, a, 28), as well as the Italian lamp producer Fortis (POPOVICI and VARGA 2010: 84). The pottery lamps have various forms and ornaments, not uncommon for Roman Dacia.

One piece requiring special attention is a bronze lamp, rather unique in the province (Fig. 12). Few bronze lamps have been discovered in Dacia and none identical to the piece from Războieni-Cetate (ROMAN and ISAC 2006: 87; 141). The artifact in question is a *bilychnis* lamp of 12 centimeter lengths, 6 centimeters

diameter of the discus and about 5 centimeters height (at the discus level). The piece was cast by lost wax method. Its discus is flat and equipped with a filling hole. The two nozzles appear to have been widened after casting. The lamp sits on a slightly elevated circular base. The handle is placed right under the flame guard. The latter is leaf-shaped and it ends with a spherical molded head.

Fig. 12 – The bronze lamp (Copyright: Rada Varga).

The best analogy from Dacia for this bronze lamp is a piece discovered at Ilişua (Bistriţa County) (ROMAN and ISAC 2006: 87; 141). The piece is typologically dated at the end of the 1st century AD and the beginning of the 2nd (BAILEY 1980: Q1021; Q 1024; BĂLUŢĂ 1976: 167 PL. 2/1); this leads us to the conclusion that we are most probably dealing with a lamp brought inside the province by the first generation of settlers after the conquest.

Terracotta statuettes

The statuettes discovered are few and unfortunately not quite well preserved. Thus, a female head seems to be the upper part of a lid and the lower part of a female body indicates, through pose, a representation of the goddess Venus. The best preserved piece is a child figurine (Fig. 13), most probably a toy associable with a funerary context (TAYLOR et al. 1993; BEU-DACHIN 2010).

Metal artifacts

The group of metal artifacts illustrates the military influence on the settlement. Besides 7 *fibulae*, a few beads (NEMETI 2004: 89–100), a possible *ampulla* and a bronze casket handle, the artifacts are fragments of weapons and military equipment. The presence of military artifacts would have been expected on a larger scale, but the unattractive character of iron fragment and the scarcity of systematical researches are sufficient explanations.

Fig. 13 – Child figurine (Copyright: Rada Varga).

Fig. 14 – Bronze casket handle (Copyright: Rada Varga).

Coins

For what the site represents (the fort of an *ala*, situated in the center of the province), the number of discovered coins is discouragingly small: 26 coins, 8 of silver and 18 of bronze (ARDEVAN and VARGA 2010). The earliest coin comes from Trajan, while the best represented period is the reigns of Antoninus Pius and Marcul Aurelius. The small number of coins from the period of Septimius Severus, generally a prosperous era for Dacia, is of note. The latest coin dates during the reign of Gallienus, thus possibly indicating that the *ala* stationed here throughout the period of the military anarchy.

Architectural and sculptural pieces

The architectural fragments are neither numerous nor impressive. One must not forget that the fort and adjacent stone buildings have constantly been used as construction materials. This trend got particularly accentuated during the 19th century, when the phenomenon of the “wandering stones” is at its peak on the former territory of Roman Dacia (see Fig. 2).

A remarkable artifact is a piece of statue, representing a hand; it is made of limestone and measures 14 centimeters.

Fig. 15 – Limestone statue hand (Copyright: Rada Varga).

Conclusive considerations

The point that focused or interest was, during the existence of Roman Dacia, the site of the most important auxiliary troop of the province: *Ala I Batavorum milliaria.* The military and civilian settlements, today mainly covered by crops, are well visible on aerial photographs. Due to these photos, the coordinates of the fort were established and we were able to place it on the topographical map. As well, its size can now be correctly determined, the camp's area being of about 6 ha large.

Our knowledge on the afferent civil settlement (or settlements) is still somehow lacunose. As no archaeological excavations have ever taken place in the civil parts of the site, we can only remark the existence of two habitation cores, both situated rather close to the fortress's walls. One of the areas might have been an "industrial" district, formed mainly of workshops and craftsmen's shops.

One of the Roman necropolises was identified through I. H. Crişan's excavations during the '60s. Its area is not clearly delimited, but the discoveries connected to it suggest a large burial place, with a series of complex funerary monuments.

For the future, the main stake is identifying the best ways for a proper valorization of the site. This process has to be undertaken on two different levels: a scientific one and – equally important – a touristic and cultural one. The first realistic step is continuing the non-invasive investigation, through GPR researches. Ulterior, archaeological excavations in the civil settlement and the necropolis would be ideal. The chosen areas should be scientifically relevant, as well as potentially interesting and accessible from a touristic point of view. Regarding the artifacts, most of them are comprised in the site's monograph; for the future, we have in view a catalogue with the most beautiful pieces, destined to specialists as well as to the public.

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APPENDIX 2010

Seeing through the shambles

Landscape biography in urban fringes

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Abstract: Few urban landscapes are more dynamic than the urban fringes, the areas that functions as a *landscape interface* between town and country, where urban and rural uses mix and often clash. Despite their dynamism these areas are recognised as valuable, though often neglected assets, which can provide a high quality environment on the city doorstep. Not only do they have a diverse landscape with potential for biodiversity, often they also have a rich, hidden cultural history. With population growth and urban economic needs these areas deserve to be protected, or at least recognised in urban development plans.
The landscape biography tool can be used very effectively to integrate cultural history into the town planning by exploring the characteristics of these areas and connecting local inhabitants with their (partly unknown) past.
In this paper I will give an example of an urban landscape biography for the *Brettenzone*, a typical urban fringe area in the west of Amsterdam, between the port of Amsterdam in the north and the western expansions of the city. Special attention will be given on the use of a historic cartographical GIS developed for this area. This new approach for integrating cultural history into the urban planning in city areas has been developed at the Landscape Department of the Dutch Cultural Heritage.

Keywords: multi-disciplined research, landscape archaeology, urban landscapes, cultural heritage in urban environments, applied historic cartography in GIS.

Introduction

The urban fringe can be described as the landscape interface between town and countryside. It is a landscape that is heavily under threat from the ever growing cities with their specific needs and functions. But, besides these urban needs, these zones are also regarded as highly valuable in terms of nature, leisure and culture (see also SURF, Sustainable Urban Fringes project). To get a (planning) grasp of such areas while doing justice to their characteristics, the government policies, the markets, artists, or pressure groups bent on promoting sustainable or recreational use is not an easy matter. It often leads, and has lead to highly ambitious, but rather inconsistent spatial planning initiatives (SIJMONS and HACCOU 2010).
In this paper I'd like to discuss how a so-called *landscape biography* can be used to get a better understanding of the structure of such an area, and can serve as an inspiration for history-inspired urban planning, giving the area meaning and creating public support. An important tool in this specific *landscape biography* was the making of an historical GIS. The area discussed will be a typical urban fringe in the west of the city of Amsterdam, the Netherlands, called the *Brettenzone*.

Fig. 1 – The location of the Brettenzone in the city of Amsterdam.

Urban fringes, a modern problem or an ancient phenomenon?

Urban fringes are often seen as relatively modern phenomena, since the *urban explosion* mainly happened from the middle of the 20th century.

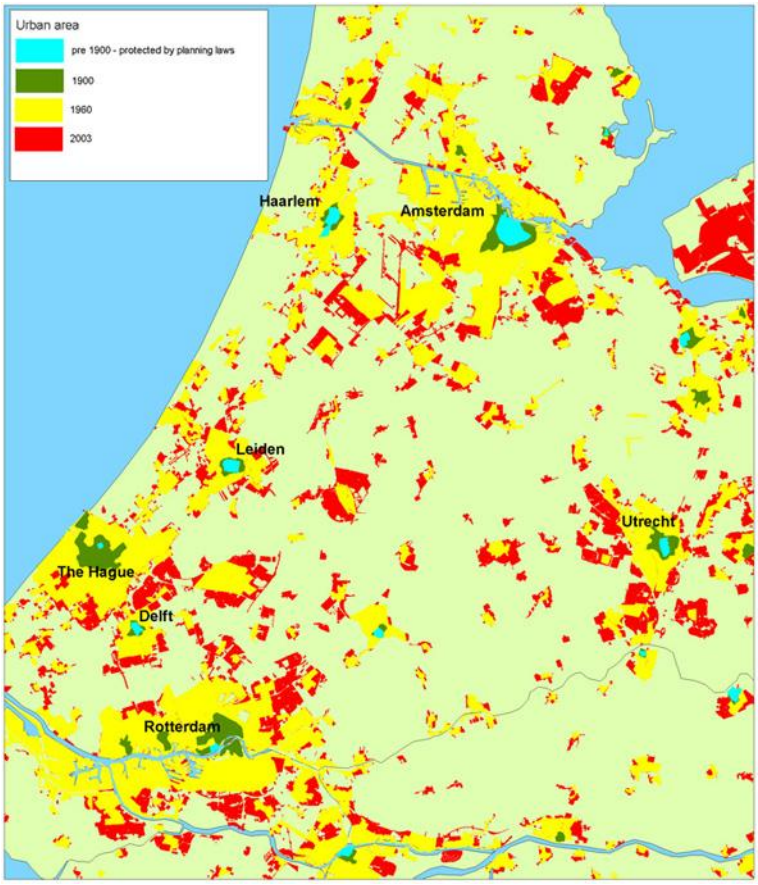

Fig. 2 – The *explosion* of urban areas since the late 1900s.

Before that time it is said that the city-limits simply marked the border between urban built-up areas and the surrounding countryside. But is this a correct image? It’s true that most of the larger cities, at least in the Netherlands, until the nineteenth century had kept their defensive walls as a clearly visible border between town and countryside, and that on most of the 17th century painted cityscapes the countryside runs right up against them.

Fig. 3 – Both Ruisdael (1680), View on Amsterdam from the south (detail) and De Wit (1698), View on Amsterdam from the south (detail) depict the countryside as running right up to the city walls. The windmills in these pictures are standing within the city; on the ramparts.

But that image is highly idealized. Industrialized areas and modern technologies like windmills are, and were, considered no positive contribution to the landscape, so were omitted in marketable *postcard perfect* images, unless they were truly urban and symbolised the city’s power and wealth (i.e. in the city proper or on its walls). Even then, most privately owned (industrial) mills were mostly omitted. On the images in figure 3 the industrial areas outside he city walls are not depicted.

Fig. 4 – Disturbing the landscape, or comparable quantities?

Yet, when we look at historical maps, or even excavation data from the former periphery of cities, we'll see that fuzzy boundaries are almost as old as cities themselves. Looking for instance at a Roman city like Pompeii, well defined by its walls, it becomes clear that there's a huge area of urban shambles outside the city gates. These consisted mainly of burial sites, but also meeting places, villae, even houses and shops made up a large part of them as well.

Also around medieval cities rapidly grew an uncontrolled area blurring the border between town and country. Citizens quickly appreciated (polluting) industries to be placed outside the walls (and preferably leeward of the city for those industries with severe odour nuisance). Food industry and food commerce needed direct unlimited access to production sites (farms) and short lines to their markets (to guarantee freshness) and were set up along the main roads into the city, and often outside the city gates. At the map of the city of Deventer of 1575 by Jacob van Deventer one can see two clearly urban areas marked as *Horrea* (granaries) as well as an industrial estate with several (wind)mills outside the city walls. So even despite their obvious importance to the city they were allowed (or just tolerated) to be outside the city's defences, and this even during the height of the Dutch War of Independence (1568–1648).

Fig. 5 – The city of Deventer by Jacob van Deventer (ca. 1575) (detail) showing the *Horrea* and the industrial area outside the city.

A comparable area can be seen on a 1558 view of the city of Utrecht:

When these medieval cities grew, the old extra-mural areas were incorporated within the growing city. In some cases this meant that these areas were demolished and re-planned, but in some cases the layout of

the old extra-mural areas remains visible in the new quarter (ABRAHAMSE and BATTJES 2000, 106–107). Outside the new city boundaries new extra-mural (often) industrial areas arose as the new urban fringes.

Fig. 6 – Van de Wijngaerde (1598), View on the city of Utrecht (detail).

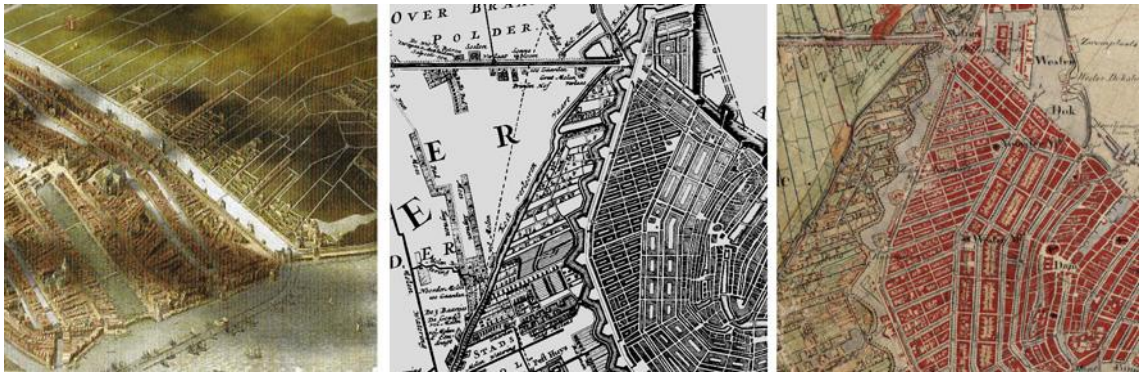

Fig. 7 – Expansions of the city of Amsterdam. Note the extra-mural areas sometimes become intra-mural without changing their principle layout. On the left a detail of the map of Jan Micker (1652), center a detail of the Nicolaas Visscher map of 1700 and on the right the 1849 topographical minutes (detail).

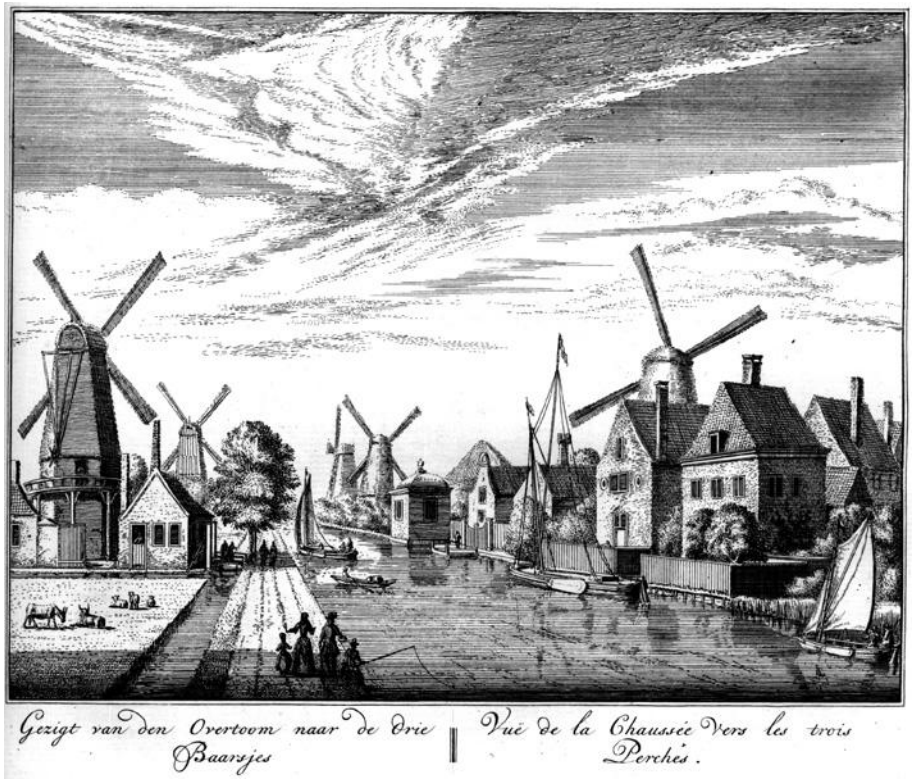

Fig. 8 – The 17th century extra-mural urban fringe west of Amsterdam, just south of the *Brettenzone*.

The *Brettenzone* in Amsterdam

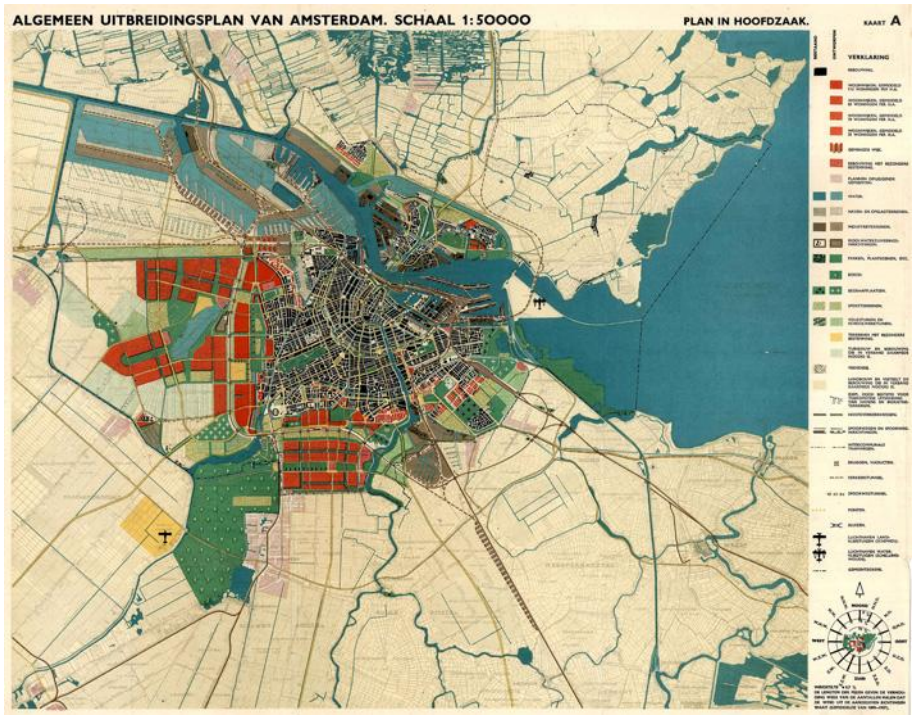

Fig. 9 – The General Development Scheme for Amsterdam by Cornelis van Eesteren (1935) showing the residential areas (bright red) and the office and industrial areas (grey) separated by the green wedges.

In 1929 the architect and urbanist Cornelis van Eesteren was appointed head of the Urban Development department of the city of Amsterdam. This department was set up the previous year to make a General Development Scheme for Amsterdam (Algemeen Uitbreidingsplan van Amsterdam, AUP). This later world-famous plan was presented in 1935. It followed the ideas of the CIAM (see CIAM) and proposed a rigid separation between the urban functions of living, working, recreation and traffic. The newly planned areas of Amsterdam were thought of as separate garden suburbs and office or industrial areas divided by green wedges. From the fifties onwards, the western garden suburbs were swiftly realised with highly designed green areas in between. In this development the *Brettenzone* formed a green barrier between the planned extension of the western port area and the residential garden suburbs. In the rigorous AUP planning the existing infrastructure was to be replaced north, directly adjacent to the docklands. But the replacement of the railroads and the main road to Haarlem proved to be a huge, mainly financial, obstacle. The original AUP plans were abandoned and the *Brettenzone* stayed undeveloped (ABRAHAMSE et al. 2011: 13–14). Nowadays it is a typical urban fringe where old residential areas, infrastructure, offices, allotments and spontaneously arisen *new nature* cover traces of what has been and what was once meant to be (fig. 10). It now truly is an open air museum of good intentions and non-implemented spatial plans.

Fig. 10 – The *Brettenzone* in 1992.

The Landscape Biography concept

Although the term *biography* etymologically refers to living creatures (from the Greek *bios* = life) some scientific disciplines started to use it for non-living matter as well. Cultural anthropologists, for instance, when they describe the long usage-history of (prestige) objects use the term *cultural biography of things*. Objects

like those change hands in their history quite often and their social context may change considerably in the process. Archaeologists happily adopted the term and talk about *biography of places* and *biography of landscapes*. The term *landscape biography* was formally introduced and theoretically specified in 2005 by the Dutch archaeologist Jan Kolen. He considers a *landscape biography* as the continuous interplay of forces between the material landscape on one hand and the social implications, ideas and meanings on the other.

The past five years several archaeologists, historical geographers and architectural historians in the Netherlands have elaborated this theoretical concept. In the Netherlands Organisation of Scientific Research (NWO) scheme *Bodemarchief in Behoud en Ontwikkeling – BBO* (*Preserving and Developing the Archaeological Archive*) several *landscape biographies* were made (ELERIE and SPEK 2010, see also NWO website). Characteristic of these biographies are firstly the emphasis on long-term development and landscape dynamics. Secondly, this approach is aiming at integrating the knowledge of geology, archaeology, historical geography, vegetation history, onomastics, architecture and urban planning history. And finally does the biographical approach give a multiperspective view on landscapes, which means that next to the purely scientific views, the knowledge and perception of inhabitants and users add to the understanding of the landscape (ABRAHAMSE et al. 2010: 273–274).

Such a biography can serve several purposes. An obvious first function is a purely scientific; as a tool to map out the processes that have formed the landscape, including the interaction of the inhabitants with their surroundings. A second function is that of a policy instrument. With a growing spatial pressure on the landscape and environmental awareness terrain administrators and (local) policymakers want to know more about the history and morphology of the landscape for future development. The final function is closely connected to the second: a landscape biography can give important input for landscape design and environmental planning. A biography describes, after all, the most important landscape elements and patterns, and the many cultural and historical values of an area.

To serve these purposes a landscape biography should fit its target group. It should be accessible, user-friendly and readable (MEIJLES and SPEK). This doesn't mean it should be simplified or written towards a fixed (planning) outcome. But it should be comprehensible for people outside a specific scientific field, with all users in mind: politicians as well as planners as well as inhabitants. At the same time the scientific outcome should be shareable, both with other scientists and with planners. A GIS-based approach is therefore almost inevitable.

Building a GIS for the *Brettenzone*-biography

The Amsterdam districts *West* (the late 19th century working-class area *Westerpark* and the pre-war extensions of *De Baarsjes* and *Bos en Lommer*) and *Nieuw-West* (the former garden suburbs *Bos en Lommer* and *Geuzenveld-Slotermeer*) work together to develop the *Brettenzone* area (BOOIJ and VAN RALTEN-LIGTENBERG 2009). On their request the Landscape department of the Cultural Heritage Agency (RCE) in cooperation with the Amsterdam City Archive has made a landscape biography of this area. Decided was that this biography would get the form of an atlas in three parts. The first part would consist of a thematic historical atlas, the second of interviews with people associated with the area and the last would

give a landscape architectural vision on how such an area could be developed doing justice to its history and present use.

For this last part the biography team worked together with Löhmann's Architecture – Urban + Industrial Design (www.loehmann.nl), who used the outcome of the historical research as an inspiration for a vision on developing this area. This vision is not to be seen as a final plan, but as an inspiration to spatial planners of the districts and to users of the area. It aims at connecting the different elements and areas in the fragmented urban fringe landscape, for instance by putting historic infrastructure back in operation.

The core of the landscape biography *Brettenzone* is, as said, a thematic historical atlas. To fully understand this now typical urban fringe not only it's urban history should be depicted, but also its pre-urban rural and geomorphologic past. The first theme and time-slice is the natural landscape around 1000 AD. The second theme is the phase of reclamation of the peat bogs (1000–1200 AD), followed by diking for protection against the sea, as the peat lands began to bed down because of the draining that took place to make agriculture possible (1200–1600). The next theme is that of the first urban influence: country estates for the Amsterdam merchants and new infrastructure, such as the famous barge-canal from Amsterdam to Haarlem (1600–1800).

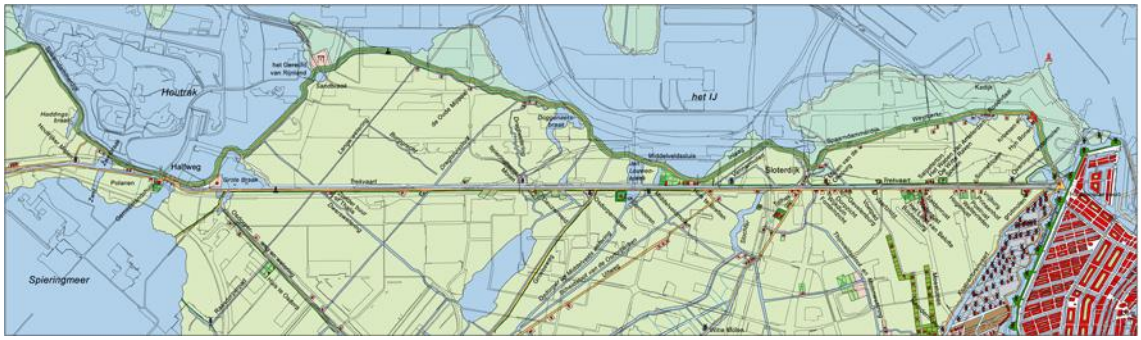

Fig. 11 – The area in the 17th century, with the boat-canal end estates. The many breaches in the dike are clearly visible.

After that the city of Amsterdam grew and more urban functions invaded the area, a semi-rural phase (1800–1934). From than on the area became a truly urban area, with themes like the General Development Scheme for Amsterdam (AUP), the development of the port of Amsterdam, modern spatial planning and, of course, the cultural and historical relics still present in the area.(ABRAHAMSE et al. 2010).

For this we heavily relied on archival and historical sources, both in writing as on maps and charts. For the earlier periods special analyses had to be made comparing (later) maps with geophysical research. And although there is an elaborate corpus of historical maps of the city of Amsterdam, not that many detailed maps were made of its surroundings. In the City Archives, however, lots of smaller maps remain, depicting for instance one owner's reclamation, land expropriation maps for infrastructural projects from the past, breaches in the dike, land development schemes and legal disputes. In order to make the reconstructive maps per theme per period it was necessary to put all this various cartographic sources into one GIS.

Fig. 12 – Examples of archival maps from the 16th century.

This not simply meant georeferencing the scans of the maps. Firstly were few of them in a modern projection, most weren't even based on a known projection system. Secondly, for comparing the mapped features it was also necessary to have them defined, so queries could be made from he maps. This, of course, meant that all the maps used had to be vectorised and provided with a database (see for vectorising method KOSIAN 2009: 27).

This way it was possible to combine, for instance, the drainage ditches from the 1879 map, the original body of the dike from a 1700 map, corrected with partial maps of areas that were later breached, and ownership maps for the land directly outside the medieval town. This formed the basis for a reconstruction of the medieval landscape.

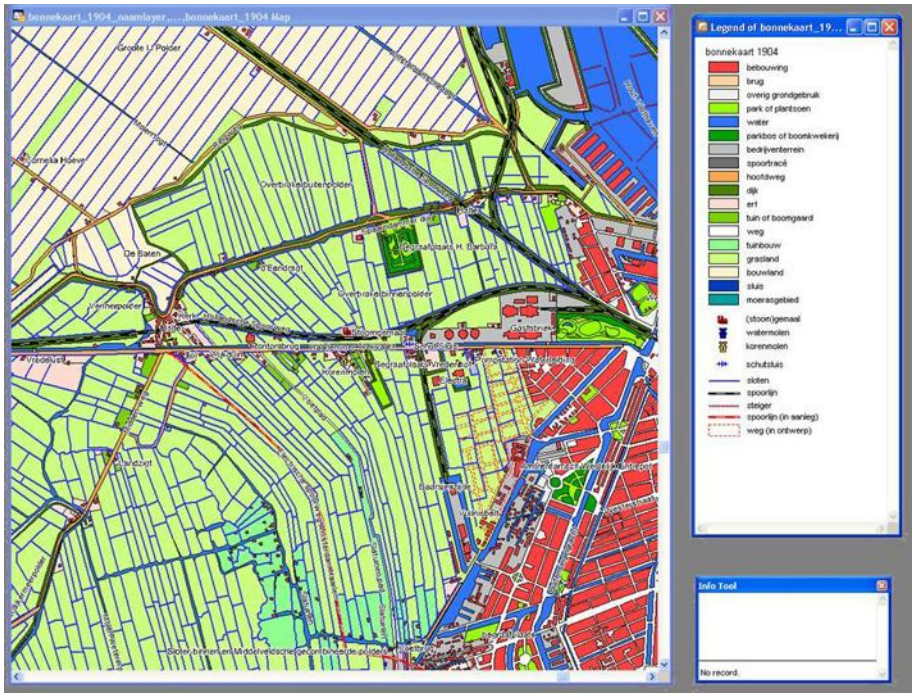

Fig. 13 – The historical cartographic GIS layer for 1879; the drainage ditches follow the lay-out of the old reclamation landscape.

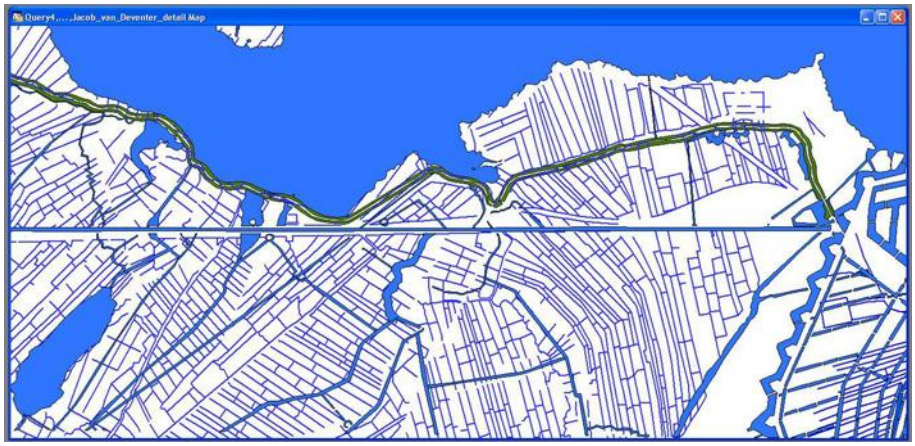

Fig. 14 – The outcome of a query on the 1879 layer for irrigation canals, combined with the outcome of the query on the 1700 layer for dikes and on the 1575 layer for the old canals adjacent to the city. This query would serve as a basis for the map of Medieval land cultivation patterns.

Fig. 15 – The map of medieval land cultivation patterns.

Working along this method, it was possible to have reliable source information for the geometry of the biographical maps, based on historical maps. Since the GIS provided not only the geometry, but also the denotation, the written sources from the City Archive could be linked into the GIS as well. This meant we had a multi-layered, diachronical GIS as a basis for the landscape biography. Since now all historical information not only was accessible, but also placed into the modern projection system, comparison with the modern topographical map was a great help for finding historical relics still visible in the modern landscape.

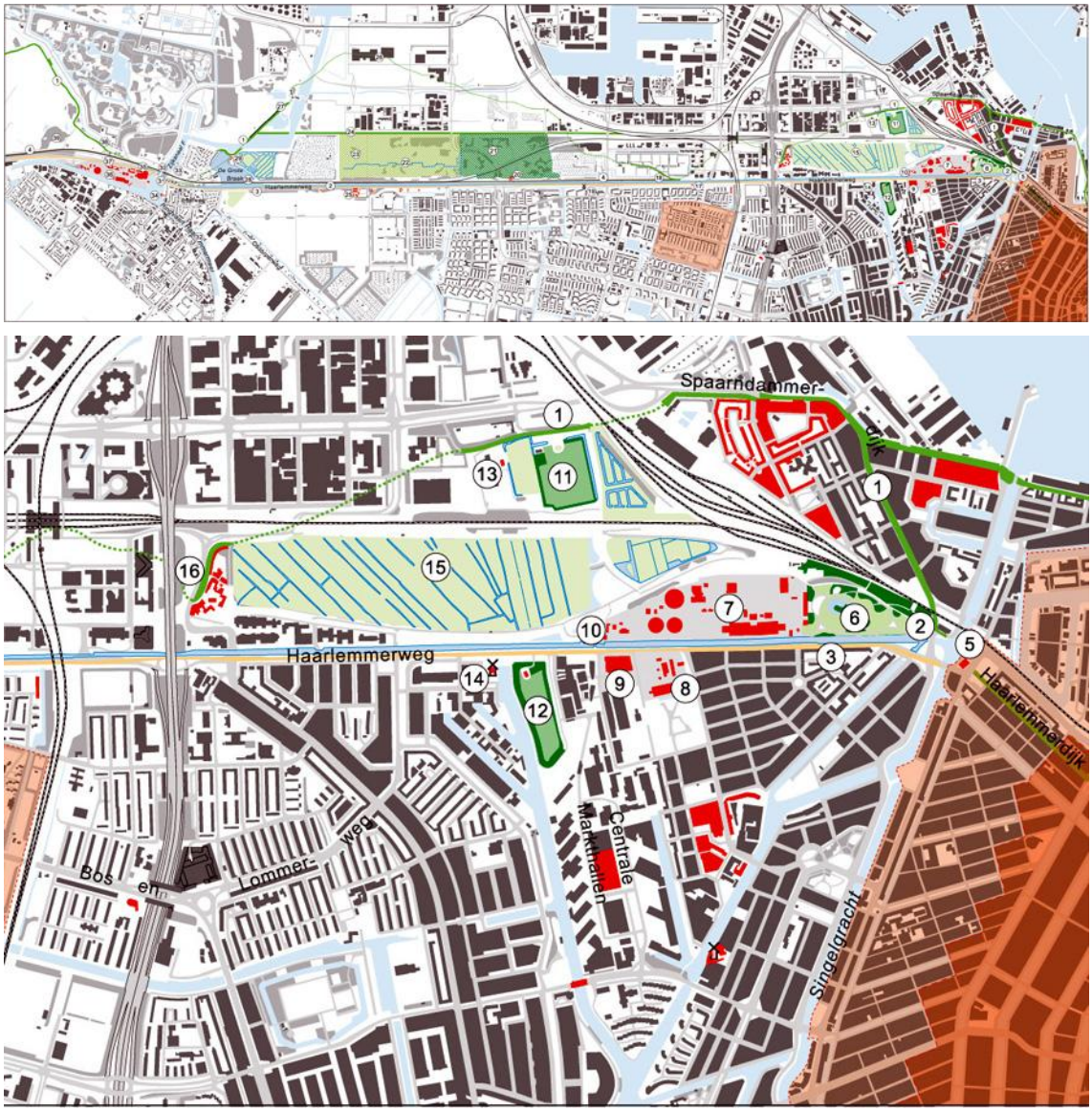

Fig. 16 – Map and detail of the cultural-historical relics in the *Brettenzone.* 1: relics of the old sea dike; 2: the 17th century boat-canal Amsterdam-Haarlem; 3: the Amsterdam Haarlem road, the old towpath of said canal; 5: the *Willemspoort*, a non-defensive city gate; 6: the *Westerpark*, a 1891 landscape park; 7: the *Westergasfabriek*, the former city gasworks, now cultural area inside the old buildings; 8: the former city waterworks, now housing area in and around the old buildings; 9: the former electricity works, now offices; 10: old locks in the boat-canal; 11 and 12: late 19th century cemeteries; 13: late 19th century farmhouse, now functioning as a community centre; 14: windmill *The Bloem*; 15: remaining Medieval parcellation. The area is now functioning as private allotments; 16: the old fishing village of *Sloterdijk*, the western half of the village was demolished for the construction of the motorway around Amsterdam.

Present-day planning and urban design-maps could be overlaid to indicate possible future threats to those relics.

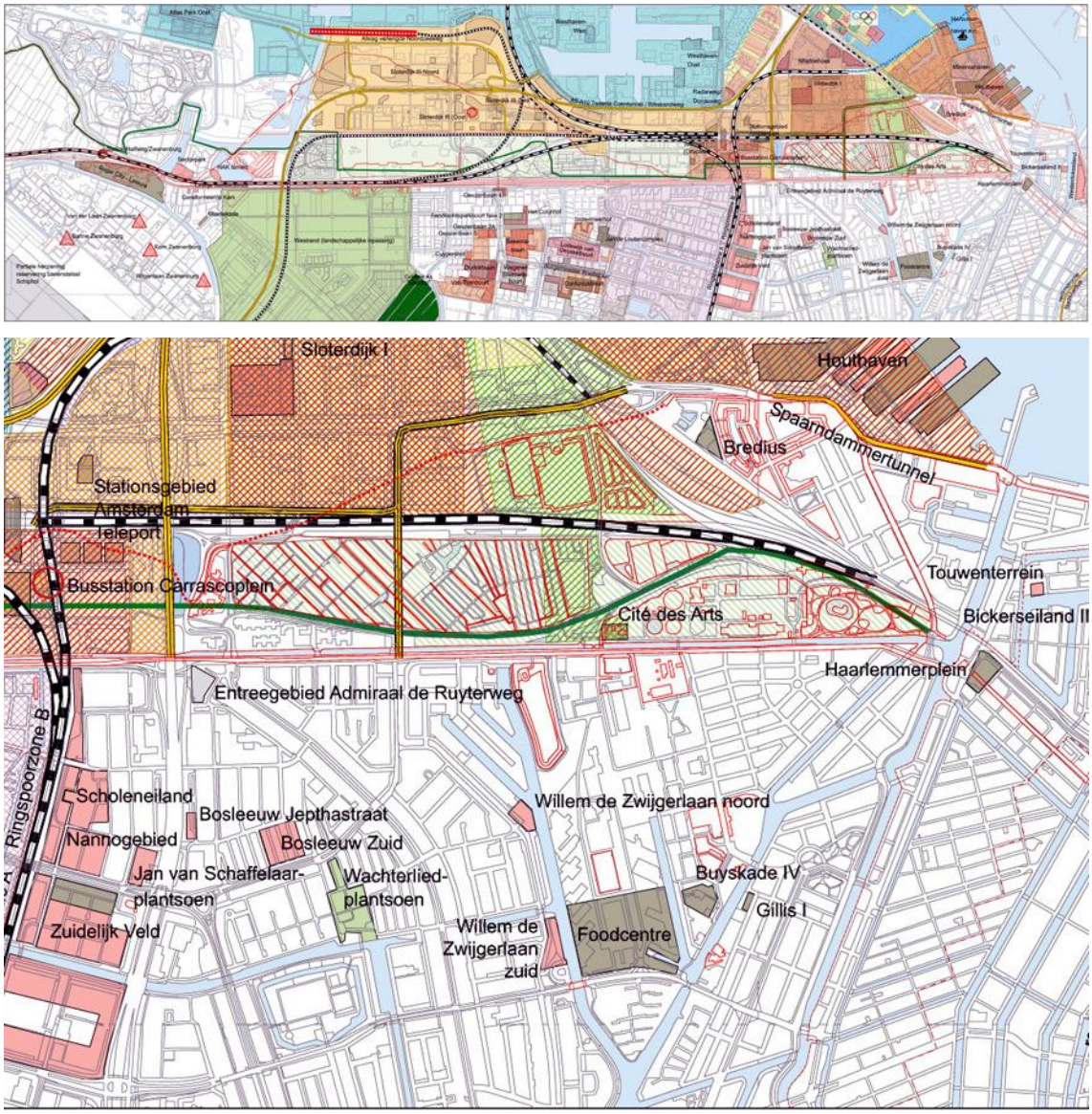

Fig. 17 – Map and detail of the modern development plans for the area, the thin red lines mark the boundaries of the cultural-historical relics.

Conclusion

Although urban fringes are often overlooked, many of them often offer high quality potential for urban development. And even though the spatial pressure on these areas is enormous, it pays to look at them for what they really are; entrees to the city. They often have a rich history, closely linked to the city, and since a lot of their urban functions are not a product of the times (infrastructure, industry) many historical parallels can be given. This not only provides the area with a rich historical and often physical archive, but can also form an inspiration for future development. After all, most of the modern spatial pressure comes from the same needs and for the same functions as in historical times. A landscape biography provides a good basis

for integrating historical use, modern needs, future threats and local perception and can help to increase spatial continuity in these fragmented zones, to really incorporate them into the city. In order to come to this integration it is important to base its whole research onto a diachronical, topical GIS, so historical data and sources can be adequately combined with their modern counterparts.

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SURF project, Sustainable Urban Fringes project. The Sustainable Urban Fringes (SURF) project brings together partners and experts from across the North Sea Region to exchange information and develop a common approach towards the sustainability of urban fringe areas. Urban fringes are the areas between urban and rural landscape. These spaces are often neglected and under threat from growth and expansion and inconsistent spatial planning policy. The project recognises the value urban fringes can bring to local communities creating places where people want to live, work and do business. This can be through strengthening local economies; delivering social benefits and by creating a space for nature. The project started in September 2009, and is set to run for three years. Key initiatives include a review of urban fringe policies and the development of a set of policy guidelines to tackle issues of governance and spatial planning. Project partners are developing their own urban fringe initiatives to establish best practice and share their experiences with project partners and the wider community: http://www.sustainablefringes.eu/AboutSURF/AboutTheProject.asp.