

POSTERSESSION

Height data from archaeological investigations for the reconstruction of the subsoil

3D data from archaeological investigations for the reconstruction of the subsoil

Valeria BOI / Federica LAMONACA / Milena STACCA

Soprintendenza Speciale per i Beni Archeologici di Roma

Abstract: The basis for our test is formed by the solid conceptual and technical foundation provided by the S.I.T.A.R. project, carried out by the Soprintendenza Speciale per i Beni Archeologici di Roma (Serlorenzi and De Tommasi are offering a paper on the project in this venue).

The investigations carried out by public offices as well as by private companies (including both non-destructive and destructive geophysical surveys, preventive excavations, planned investigations, etc.) that are archived in the S.I.T.A.R. databank produce huge amounts of elevation data with variable precision. These data consist of spot elevations derived from total station and GPS readings, and destructive geophysical investigations. Once verified, this elevation information leads to the gradual creation of an increasingly detailed reconstruction of the subsoil.

The integration of this data with those gathered from cartographic vector bases, as well as data from historical maps, multi-temporal satellite images, Digital Elevation/Terrain Models, and preexisting geological and geomorphological research makes the system a fundamental source for the detailed diachronic reconstruction of the morphology of the territory.

The multi-layered city of Rome is the perfect candidate for a historical and topographical analysis of settlement development in different time periods, both because of the density and complexity of its settlement layout, and because its expansion hastened the natural phenomena of erosion and filling. The poster, hence analyses the Esquiline neighborhood which currently retains the urban layout that was in place after Rome was declared the capital of Italy. This layout significantly altered the original morphology of the hill, which was originally characterized by variations in elevation. Because of this, the Esquiline is an ideal case with which to test the potential of this type of analysis.

The above-mentioned analysis can be further refined and then applied not only to Rome, but also to other geo-archaeological contexts with multiple strata.

Keywords: GIS, height data, Urban Archaeology and town planning, DEM.

3D data from archaeological investigations for the reconstruction of the subsoil

A number of 3D data storage and processing systems are currently tested within the SITAR Project, under the direction of SSBAR (Soprintendenza Speciale per i Beni Archeologici di Roma).

The SITAR project aims to establish, maintain and develop a SDI, Spatial Data Infrastructure, in line with the guidelines provided by the E.C. in c.d. Directive INSPIRE issued by the European Parliament in 2007, that has been acknowledged in Italy through the work of two Ministerial Commissions set up in 2007 and 2010,

the Commissione Paritetica nazionale per la realizzazione del Sistema Informativo Archeologico delle città italiane e dei loro territori (2007–08) and the Commissione paritetica nazionale per la realizzazione del Sistema Informativo Territoriale del patrimonio archeologico italiano (2010–11) (VALENTI and SERLORENZI 2010, SERLORENZI and DETOMMASI in this venue).

The aim of this first experimentation on the use of altimetric data is to reconstruct conceptual landscape patterns representing the depth where the principal determined chronological phases are attested, hence for example, the difference between the current surface, the higher level of the documented archaeological stratigraphies, the geological subsoil, enabling to yield spatial patterns describing the territory even in its diachronic variable.

Currently, altimetric data capture and systematization around a case study area, the Esquiline town district (1,960 km²), are processed (Fig. 1). The urban planning metamorphosis that this very ancient neighbourhood went through, as soon as Rome was declared the new capital town of the Italian reign, thoroughly modified its morphological structure, making it the perfect ground for this kind of experiments.

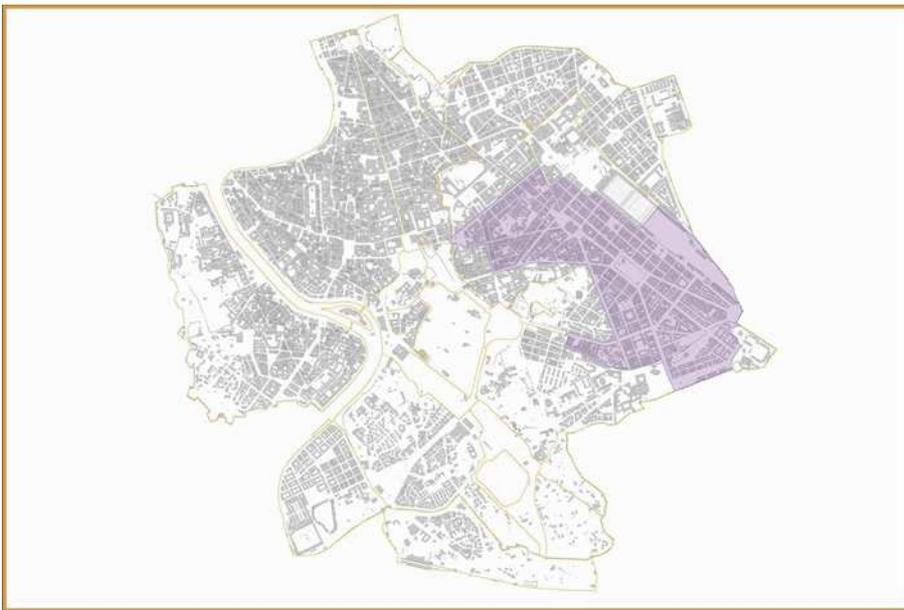


Fig. 1 – Case study area: The Esquiline town district in Rome (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

In order to pursue the aims of the case study here presented, we selected only those archaeological excavations that can be rightly positioned in the current topography and for which we own information about chronology, interpretation and height above sea level (Fig. 2).

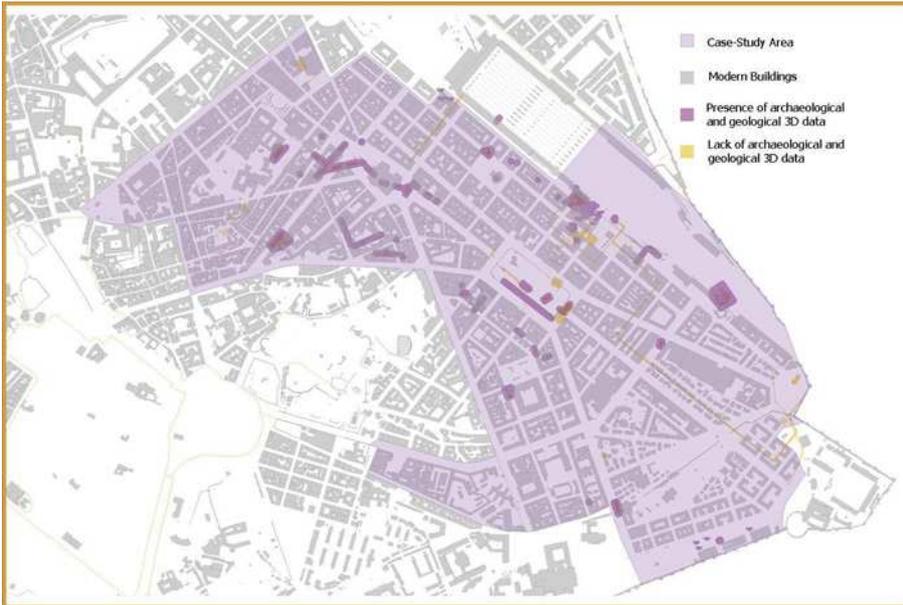


Fig. 2 – Chart of distribution and quality of 3D data in the Esquiline town district (Copyright: MiBAC – Soprintendenza Speciale per i beni Archeologici di Roma).

We also included archaeological excavations lacking height above sea level, but for which we can calculate it starting from the indication of the depth referred to the contemporary surface. As a matter of fact, a preliminary statistic calculated on the data from the archive’s documentation about the area of the Esquiline district shows that in most cases the altimetric informations are expressed in relative heights referred to the contemporary surface (Fig. 3).

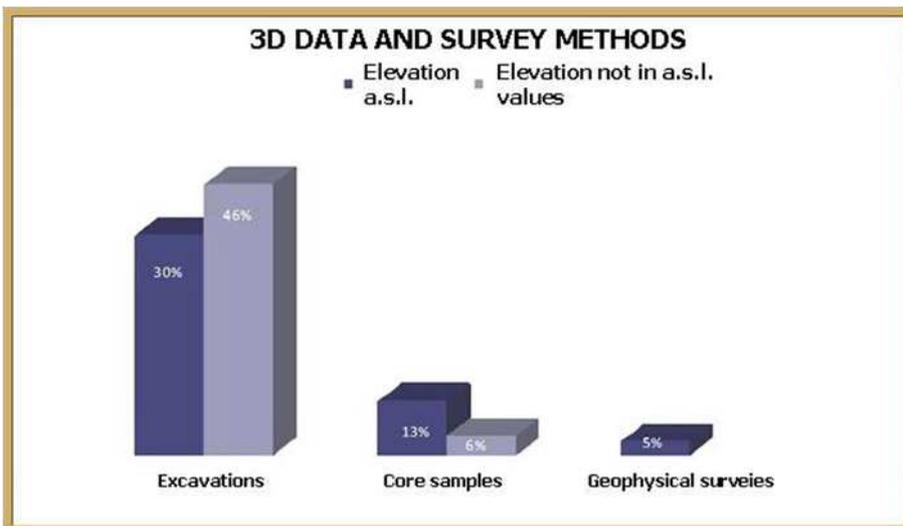


Fig. 3 – Chart of the altimetric data for every type of archaeological survey (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

The SITAR GEO-Database stores altimetric data made of dimensioned points, calculated through surveys carried out with Total Station, GPS and geognostic analysis.

As far as archaeological excavation is concerned, the system acquires measured spots coming from topographic structure drawings and determined layers, with reference to the modern backfill, the archaeological evidence and the geological substratum (Fig. 4).



Fig. 4 – Selection of 3D data from archaeological excavations (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

The same information may be extracted from geognostic enquiries for which one starts with the synthetic reading of corings, in order to extract data on the height above the sea level of the present surface, on the archaeological deposit's higher level and on the geological substratum's upper level (Fig. 5).

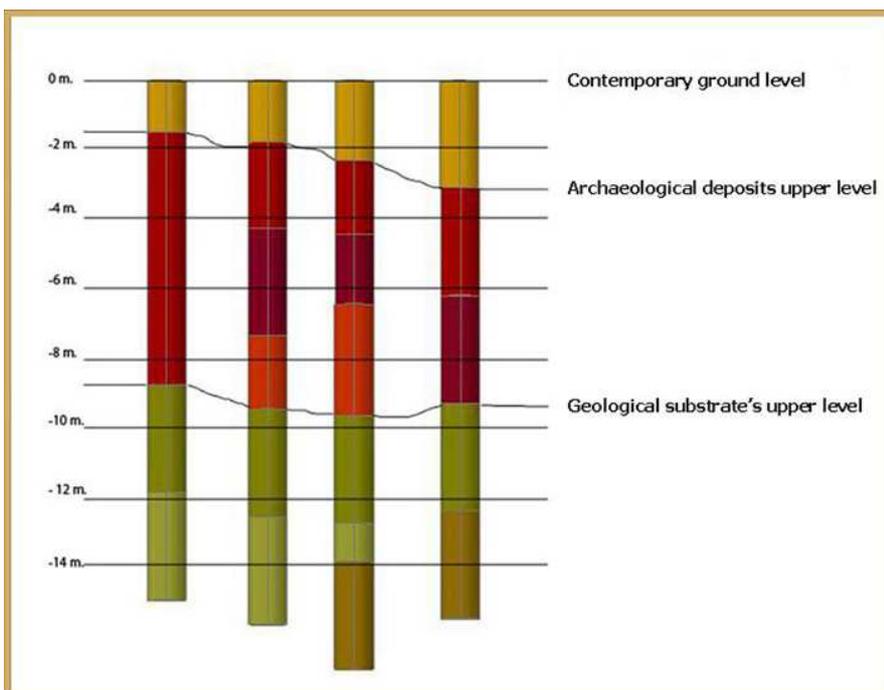


Fig. 5 – Analysis and 3d data extraction from corings (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

In this topographic geo-database, each 3D point is steadily linked to its geological or archeological evidence, thus acquiring all of the descriptive attributes. Therefore each altimetric point can be sorted through its descriptive, chronologic or type information.

These records, integrated with up-to-date topographic bases, historical cartography and geological / geomorphological analysis, can be used to render spatial models describing the territory also under its diachronic variable.

In the case study here presented, we visualize the result of the interpolation of measured spots, resulting from a preliminary archaeological investigation of the Esquiline district area. The trial restoration of surfaces has been realized through the use of different methodologies: we have produced vectorial TIN samples and DEM (digital elevation models) raster, experimenting different interpolation algorithms, to reconstruct a conceptual landscape pattern representing the chronological macro-phase of Roman time (Fig. 6). For the project Autocad Map[®] 3d 2010 and Arc Gis[®] 9.2 are used. Some similar experimentations have already been conducted for the territory of Bologna (PESCARIN 2007) and for a town district in the centre of Rome (DEMETRESCU and FONTANA 2009).

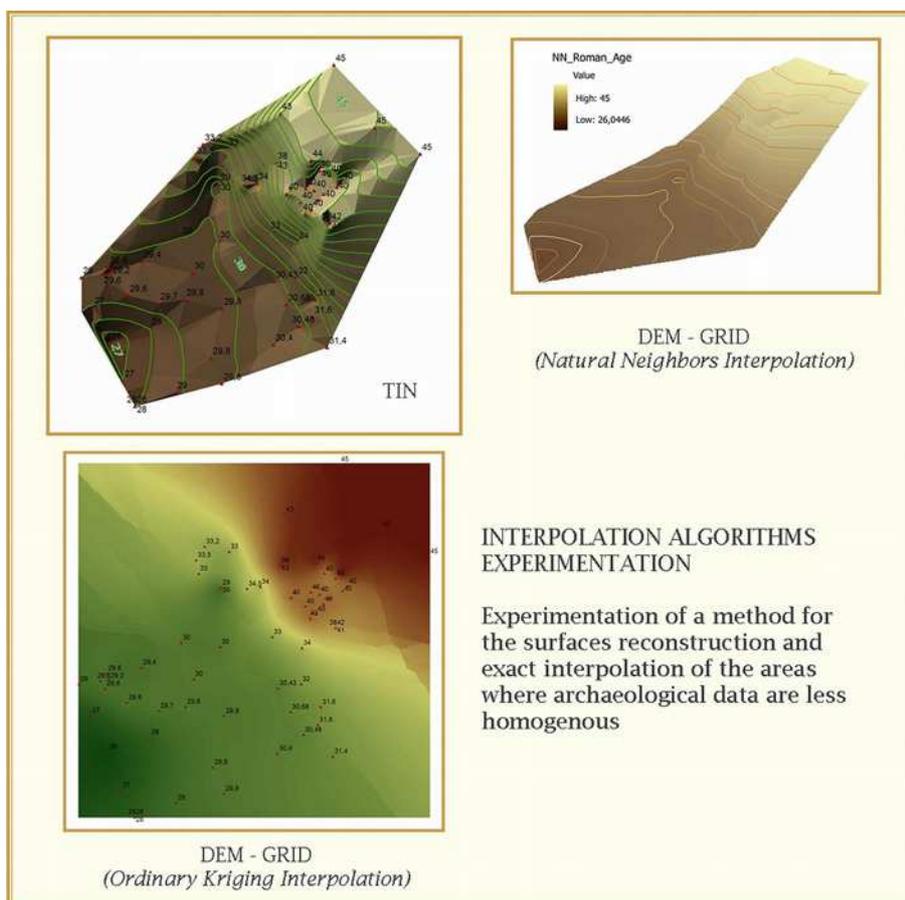


Fig. 6 – Experimentation of different interpolation algorithms, to reconstruct a conceptual landscape pattern representing the chronological macro-phase of Roman time (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

Experimental 3D models creation is carried out distinctly for each area of survey, representing the starting ground to piece together, through interpolation, the surface of any unsurveyed areas. Within the surface reconstruction process for areas where archaeological data are less homogenous, a relevant role is played

by geological *continuous* surface 3D data, based on previous specific analysis, through which data interpolation can be directed and sorted.

During the reconstruction of *experimental* 3D samples, the extensive gathering and elaboration of 3D data referring to the current geological substratum's surface is of basic importance, serving as guide and filter for the interpolation of the archaeological level's data, especially for areas in which the measured spots used for the restoration of the archaeological level are less dense and not homogeneously distributed: in such instances current surface and geological substratum represent the lower and upper space limits circumscribing the experimental sample of the surface that one has to restore.

Surfaces restored in this way do obviously not represent a *realistic surface*, but a *conceptual* model of the landscape morphology in a given chronological phase; one of the first applications of such a restoration of the *3D experimental sample* of surface and structures of Roman time is for example their contextualization in the current topography or the generation of 2D sections that enable the visualization of the surface's pattern on an axis which has been determined by the user (Fig. 7).

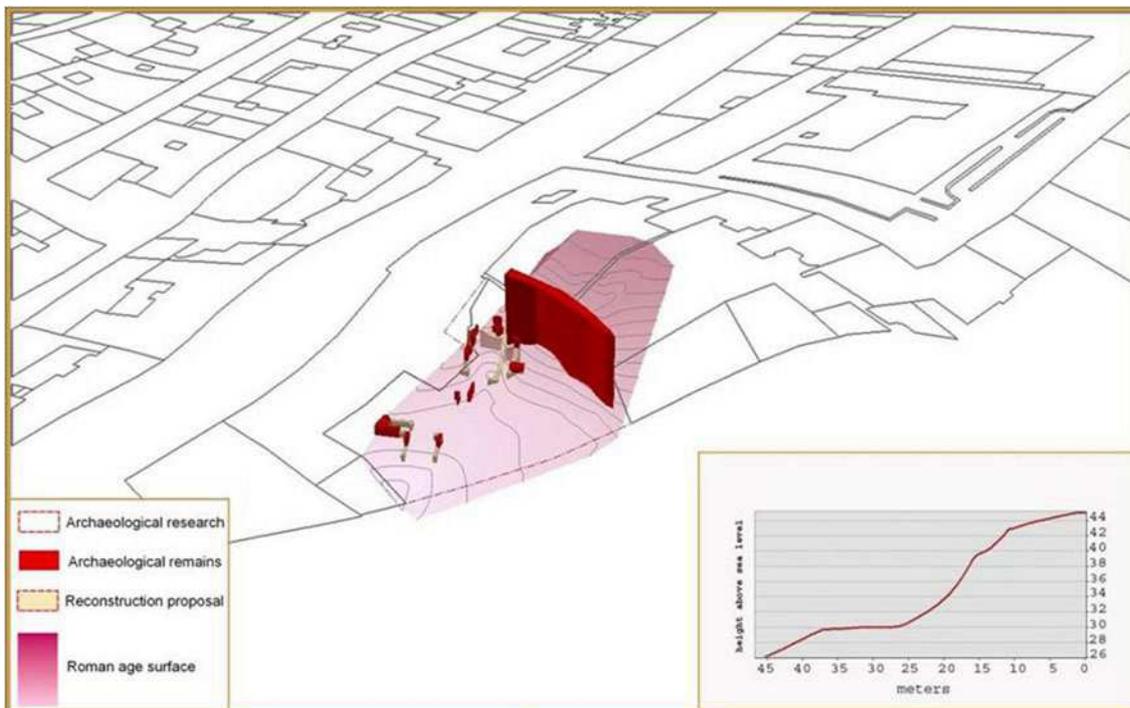


Fig. 7 – Contextualization of surface and structures of the Roman time in the current topography (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

Beyond this one may also process the archaeological deposit's experimental altimetric mapping, derived from a subtraction between the current surface and the archaeological deposit's upper level: this map visualizes to which extent the modern deposit has obliterated the antique structures and quantifies the degree of variations in the territorial morphology during time.

The presented one is an example of this experimentation carried out on the data of a preliminary investigation on the Esquiline district. Different shades of green register areas where archaeological evidence has been attested at a lower level, between 9 and 7 metres ca. Red areas are those in which archaeological evidence is at the minimum depth, between 200 and 80 centimetres ca. from the current

surface (Fig. 8). When accomplished, such a highly accurate 3D database on territorial scale is the ground on which new previsional devices for the Archaeological Potential definition can be tested. A map of the archaeological deposit's depth compared with current ground level, that shows the morphological diachronic variation, sets up a new helpful tool for urban planning and historical evidences protection.

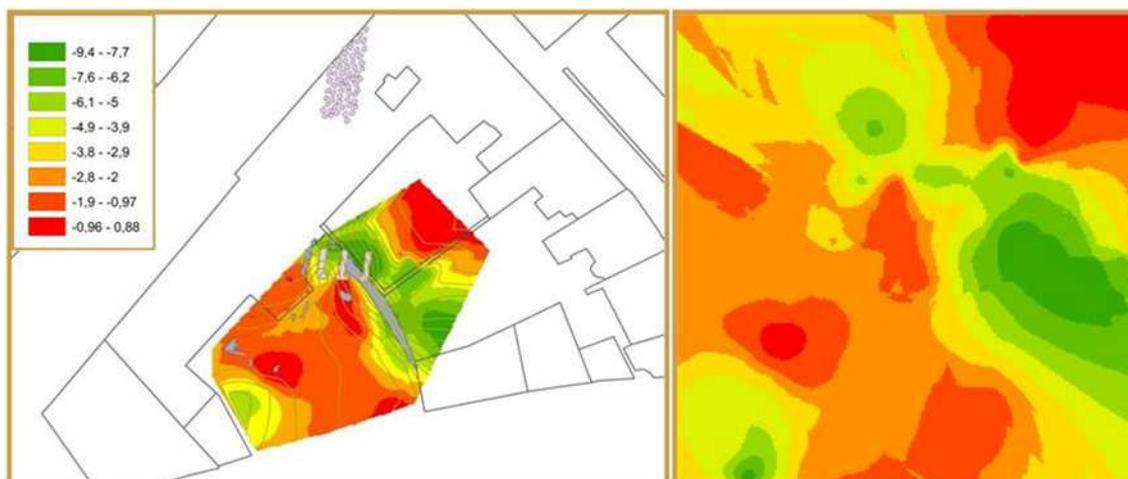


Fig. 8 – Map of archaeological deposit's depth compared with current ground level. Morphological diachronic variations are shown by different shades of colour (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

To this end, the operating standards setup of the scientific and graphic documentation for the new geognostical as well as archaeological investigation becomes essential, in order to assure uniformity and quality of new data that come together in the system: as a matter of fact it is desirable that research carried out on the territory will yield the output of altimetry data full and comprehensive of any relevant morphological variation, made up by a regular grid of 3D points above sea-level and by an overall census of geognostic surveys data.

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Mossyna: The rediscovery of a “lost city” in the territory of Hierapolis in Phrygia (Turkey)

Laura CASTRIANNI¹ / Giuseppe SCARDOZZI²

¹ MiBAC, Ministry of Cultural Heritage and Activities, Roma, Italy / ² CNR-IBAM, National Research Council, Institute for Monumental and Archaeological Heritage, Lecce

Abstract: The archaeological surveys performed by the CNR-IBAM between 2005 and 2007 in the territory of *Hierapolis* in Phrygia, concerned a large area in south-west Turkey, i.e. the valley of Çürüksu River and the high plains of Uzunpınar and Çal. European scholars, who crossed the area between the 19th and the first decades of the 20th century, reported that this territory was scarcely investigated and there was only a poor and occasional interest to discover its ancient towns and villages. The systematic surveys allowed for the reconstruction of the ancient settlement pattern of this territory, with an overall evaluation of all the archaeological remains. Amongst the more noticeable results of the research, the identification of the ancient city of *Mossyna* in the western part of the high plain of Çal, about 1 km south-east of the modern village of Sazak, should be pointed out. In fact, *Mossyna* was certainly the main settlement in the territory north of *Hierapolis*, mentioned in Roman epigraphic texts and Byzantine literary sources. Its location was object of a high pitched debate beginning at the end of the 19th century, that involved the scholars who were interested in the reconstruction of the ancient topography of southern Phrygia.

Mossyna, once founded on a large promontory, has been detected by means of modern technologies such as satellite remote sensing and global positioning systems. During the field work in 2005–2007 it was possible to specify characteristics and entity of the archaeological finds. So, the research showed that *Mossyna* was not just a simple village in the territory of *Hierapolis*, but a booming city already in the Late Hellenistic period and above all in the Roman and Byzantine periods, with a maximum extension of about 54 hectares.

Keywords: Mossyna, Hierapolis of Phrygia, Archaeological Survey, Remote Sensing, Historical Geography.

Introduction: The archaeological surveys in the territory of Hierapolis and the identification of Mossyna

The archaeological survey conducted by the National Research Council of Italy, Institute for Monumental and Archaeological Heritage of Lecce (CNR-IBAM) between 2005 and 2007 in the territory of *Hierapolis* in Phrygia, in cooperation with the Italian Archaeological Mission, concerned a large area (about 700 km²) in south-west Turkey: The valley of the Çürüksu River (the ancient Lykos River), a tributary of the Meander, and the high plains of Uzunpınar and Çal (Fig. 1). In particular, the research concerned mostly the eastern part of the *Lykos* valley (lying between 200 and 300 m above sea level), controlled directly by *Hierapolis*, which was founded over a travertine shelf looking onto the valley, at a height between 350 and 425 m above sea level. The large high plain of Uzunpınar was entirely surveyed. Its height varies between 1150–1250 m above sea level in the southern part and 850–950 m in the northern part; in the south-eastern sector it is

delimited by the Küçükçökelez massif (1,734 m), while a deep river valley (in which the Değirmen Dere and Koca Dere streams flow) constitutes a clear natural boundary between the high plains of Uzunpınar (to the west) and Çal (to the east). The last one was surveyed only in the western sector, delimited to the south-east by the Büyükçökelez massif (1,841 m) and generally lying between 800 and 1200 m above sea level. Both the high plains of Uzunpınar and Çal have its natural northern boundary in the broad loop of the Meander, which here runs between the mountains, and beyond which lie the territories of other ancient cities, i.e. *Blaundos* and *Motella* (to the north), and *Dionysopolis* and the *Hyrgaletici Campi*, mentioned in epigraphic texts and literary sources (to the north-east). The epigraphic documentation that dates back to the Imperial Roman period attests the affiliation of the whole territory surveyed (or its main part) to *Hierapolis*.

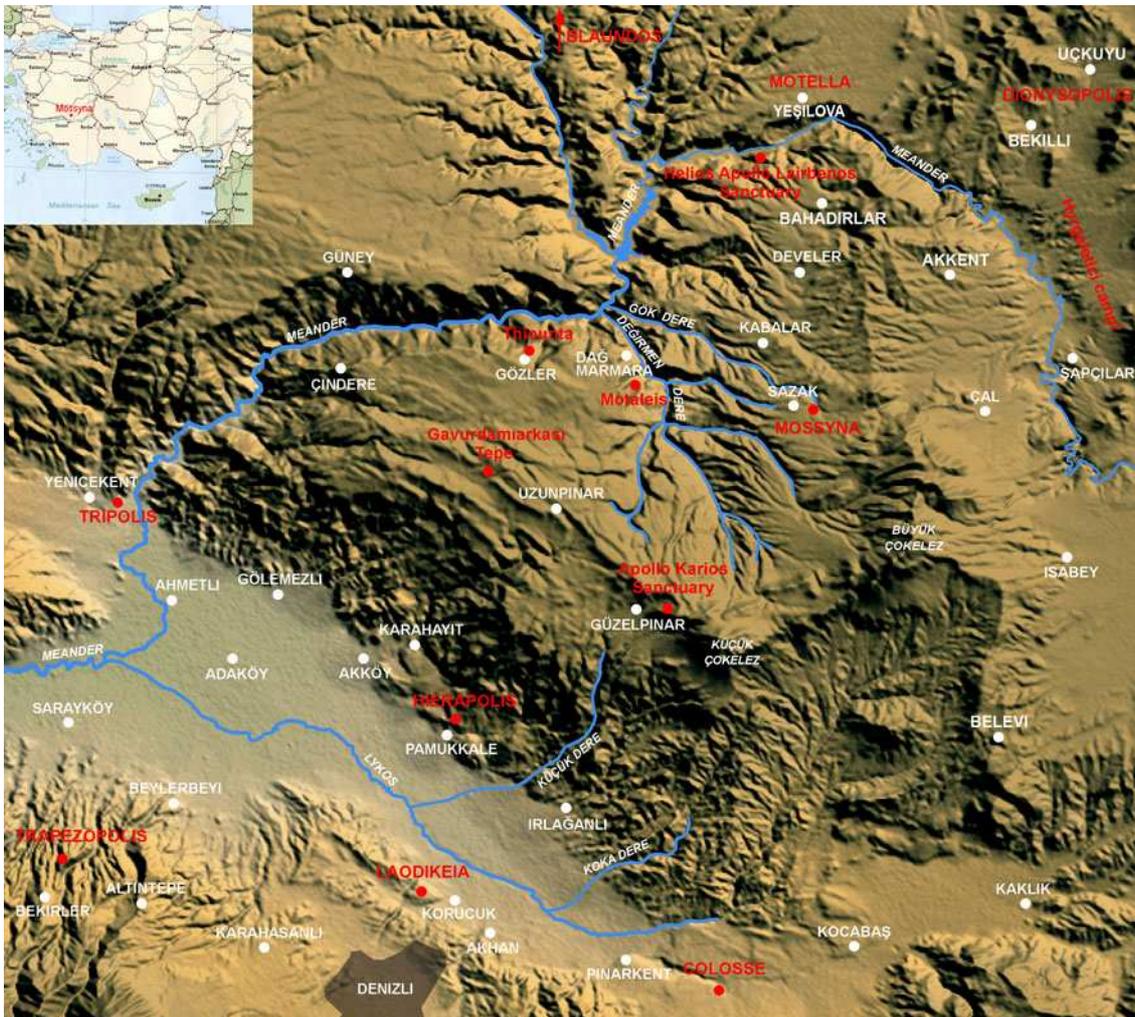


Fig. 1 – Mossyna in the Southern Phrygia: DEM based on Shuttle Radar Topography Mission (SRTM) data.

European scholars crossed (such as F.V.J. Arundell, W.M. Ramsay, J.G.C. Anderson, A. Philippon, W.H. Buckler and W.M. Calder) the area between the 19th and the first decade of the 20th century. After this period this area was scarcely investigated and there was a poor interest in the discovery of its towns and villages; therefore the reconstruction of its geographical history is based on the old studies of W. M. Ramsay (1883, 1887, 1889, 1890, 1895, 1897, 1928 and 1930), partially integrated and corrected by L. Robert (1962, 1963, 1983, 1985) and T. Ritti (2002). Of greatest interest are the just occasionally discovered epigraphic texts by

some later scholars (SHEPPARD 1981; ROBERT 1983 and 1985; CEYLAN and RITTI 1997; RITTI et al. 2000; RITTI 2002; RITTI et al. 2008).

The systematic surveys conducted in the territory of Hierapolis allowed for the reconstruction of its ancient topography during times, with an overall evaluation of all archaeological remains from Prehistory until the Ottoman period. Numerous ancient settlements were identified, in particular of the Hellenistic, Roman and Byzantine periods; in all of them, the strongly rural character of the territory emerged, with remains of installations for the production of olive oil and wine. One of the main settlements identified, positioned and documented, is *Thiounta*, already identified by Ramsay (1883: 376–377 and 392; 1895: 124–126 and 142–144) immediately to the north of Gözler thanks to the discovery of some inscriptions. The remains of this ancient village, with its white marble quarries were recorded in various epigraphs from the necropolis of Hierapolis, occupy a series of terraces (surveyed in 2006 and 2007) that descend towards the course of the Meander, at the northern edge of the high plain of Uzunpınar. Also important is the discovery (in 2006) of the remains referable to the sacred area of the *Motaleis*, a population of the territory of *Hierapolis*, mentioned in some inscriptions of Roman Imperial period; it is located on a terrace situated to the north-west of the Yüksektepe, a modest hill in the west sector of the valley of Değirmen Dere stream, about 2 km to the south-east of the modern village of Dağmarmara; the archaeological finds visible on surface, document the existence of two monumental marble buildings used since at least from 2nd to 4th century AD. Moreover, in the south-eastern sector of the high plain of Uzunpınar, worthy of mention is the discovery of the sacred area dedicated to *Kareios/Karios*, an indigenous divinity assimilated to Apollo by the Greeks who founded *Hierapolis*, which was worshipped in the main sanctuary of the city. The site was identified in 2005 about half way up the north-western slope of the Somaklı Tepe, a hill located just 1 km to the east of the modern village of Güzelpınar; here are the remains of a platform (about 20 x 10 m), on which various fragmentary *stelae* in marble, with dedications to the divinity *Kareios/Karios* and dating between 1st and 3rd century AD, are scattered as result of unauthorised excavations.

Amongst the more noticeable results of the research, particularly relevant is the correct identification of an ancient “lost” city, *Mossyna*. In fact, it was certainly the main settlement in the territory north of *Hierapolis*, mentioned in epigraphic sources of the Roman Imperial period and in Byzantine literary sources: the first ones document a *demos* of *Mossyna*, i.e. a relatively administrative autonomy of the site (probably under the political authority of *Hierapolis*), while the second ones document that the city was seat of a bishop from at least the 5th century to the 12th century AD, under the *metropolis* of *Hierapolis*. The identification of *Mossyna* was object of a bitter debate beginning at the end of the 19th century, that involved the scholars who were interested to the reconstruction of the ancient topography of southern Phrygia. As a result, many conflicting hypotheses concerning the identification of some ancient sites on the high plains of Uzunpınar and Çal were proposed. In particular, Ramsay proposed two different locations of *Mossyna*: firstly on the Yüksektepe (RAMSAY 1883: 377–379), where is the sacred area of *Motaleis* (see above), and later in the central sector of the high plain of Uzunpınar (RAMSAY 1895: 124), 3 km north-west of the modern village, where is another large ancient settlement lying on the Gavurdamiarkası Tepe (called “Geuzlar-kahve” by Ramsay), surveyed in 2006 and 2007.

About this problematic identification, the systematic surveys of 2007 confirmed the location of *Mossyna* on a large promontory in the western sector of the high plain of Çal, about 1 km south-east of the modern village

of Sazak, as already suggested by L. Robert (1983: 53–55), who based his hypothesis on the explorations carried out by W.H. Buckler and W.M. Calder in 1930 (BUCKLER et al. 1933: XIV). The certainty of this location can also be backed by the discovery of epigraphic texts. The most important is a marble base with an inscription of the 1st century AD, in which *Zeus Mossyneus* and the *demos* of Mossyna are mentioned (ROBERT 1983: 54); this base, discovered by Ramsay in the mosque of Sazak (RAMSAY 1883: 385–386; RAMSAY 1887: 350), came from the site of the ancient city, near the village, and is currently located in its central square.

The survey has made it possible to analyze the characteristics and the entity of the remains and of the ancient materials which are visible on the surface or reused in the modern structures of Sazak. The field work was supported by the contribution of modern technologies such as high resolution satellite data and global positioning systems. A considerable contribution to the surveys derived by both "historic" (1960s and 1970s) and recent (2002–2007) high resolution satellite images, in fact there isn't availability of aerial photographs or maps on a scale suitable for the direct exploration of the territory in the studied area; the recent high resolution satellite images were even orthorectified for field work and integrated in a GIS for the study of *Hierapolis* and its territory. The archaeological features discovered during the research were accurately georeferenced by means of global positioning systems.

The research showed that *Mossyna* was not just a simple village, but a large settlement already in the Late Hellenistic period and above all in the Roman and Byzantine ages (when it was certain that the city had administrative autonomy), with a maximum extension of about 54 hectares. (G. S.)

Ancient literary and epigraphic sources: a starting point

The ancient city of *Mossyna* was mentioned in epigraphic sources of the Roman Imperial period and in Byzantine literary sources. The first ones document a *demos* of *Mossyna*, attesting a relatively administrative autonomy of the settlement (probably under the political authority of *Hierapolis*), while the second ones document that the city was bishop's see from at least the 5th century to the 12th century AD.

The most important epigraphic evidence relating to the city is a marble base (Fig. 2) on which is engraved an inscription of the end of the 1st century AD that mentions *Zeus Mossyneus* and the *demos* of *Mossyna* (ROBERT 1983: 54). The text was firstly read by Ramsay in 1883 and 1887 when the base, now located in the central square of Sazak, was preserved inside the mosque of the village (RAMSAY 1883: 385–386; RAMSAY 1887: 350; RAMSAY 1889: 229; RAMSAY 1895: 146, No. 33; RAMSAY 1930: 281–282, No. 2; see also BUCKLER et al. 1933: 95, No. 265). It is a list of financial contributions by a hereditary priest (who had become Roman citizen), for the erection of a statue and an altar dedicated to *Zeus Mossyneus* and the *demos* of *Mossyna*.

A further epigraphic confirmation of the existence of the community of *Mossyneis* is contained in a dedication to *Zeus Bennios* found in a village in the region of *Appia*, current Pinarcik (DREW-BEAR 1976: 254–255, No. 11).

With regard to the literary sources, it must wait until the 5th century AD to have an attestation of the existence of the city of *Mossyna*; indeed, the *Mossyneis* people mentioned by Pliny (*Naturalis Historia*, V, 126) and by

the ancient historian related to the jurisdiction of Pergamon should be considered a different population, as correctly reported by Ramsay (RAMSAY 1895: 123).



Fig. 2 – Inscribed marble base which mentions *Zeus Mossyneus* and the *demos* of *Mossyna*.

The community was mentioned for the first time in 451 AD, when the bishop *Gennadios* attended the Council of Chalcedon. *Mossyna* appears after *Hierapolis* and before *Dionysopolis* in the list of the cities in the administrative divisions of the Byzantine Empire written by *Hierokles* about in 530 AD (*Synekdemos* 655, 3); a Bishop of *Mossyna*, *Johannes*, stood at the Council held in Constantinople from 691 to 692 AD.

Others bishops of *Mossyna* are attested at the Council of Nicaea, dated to the year 787 AD (*Theophylaktos*), in the so-called “Fourth Council of Constantinople” held in the years 869–870 AD (*Eutropios*) and in the following Synod of 879–880 AD (*Konstantin*) (RAMSAY 1883: 371–374; RAMSAY 1895: 121; BELKE and MERSICH 1990: 343). In the *Notitiae episcopatum* (I, II, III, IV, VII, IX, X, XIII), dated between the 7th century and the 12th century, the Diocese of *Mossyna* is inserted in the *Eparchia* of the metropolitan seat of *Hierapolis*; it was previously suffragan of the *metropolis* of *Laodikeia* (DARROUZÈS 1981).

The lack of evidence relating the existence of a mint based in *Mossyna* leads to believe that the city has never mint coins (RAMSAY 1895: 123). (L. C.)

Previous studies concerning the identification of *Mossyna*

The identification of the site of *Mossyna*, mainly based on epigraphic texts discovered by European travelers who crossed the territory north of *Hierapolis* in 19th century, was at the center of a debate that engaged scholars from the second half of 19th century until the years 1960s. An undisputed protagonist of this debate is the Scottish archaeologist W. M. Ramsay, who crossed the Southern Phrygia during several trips in the years 1880s.

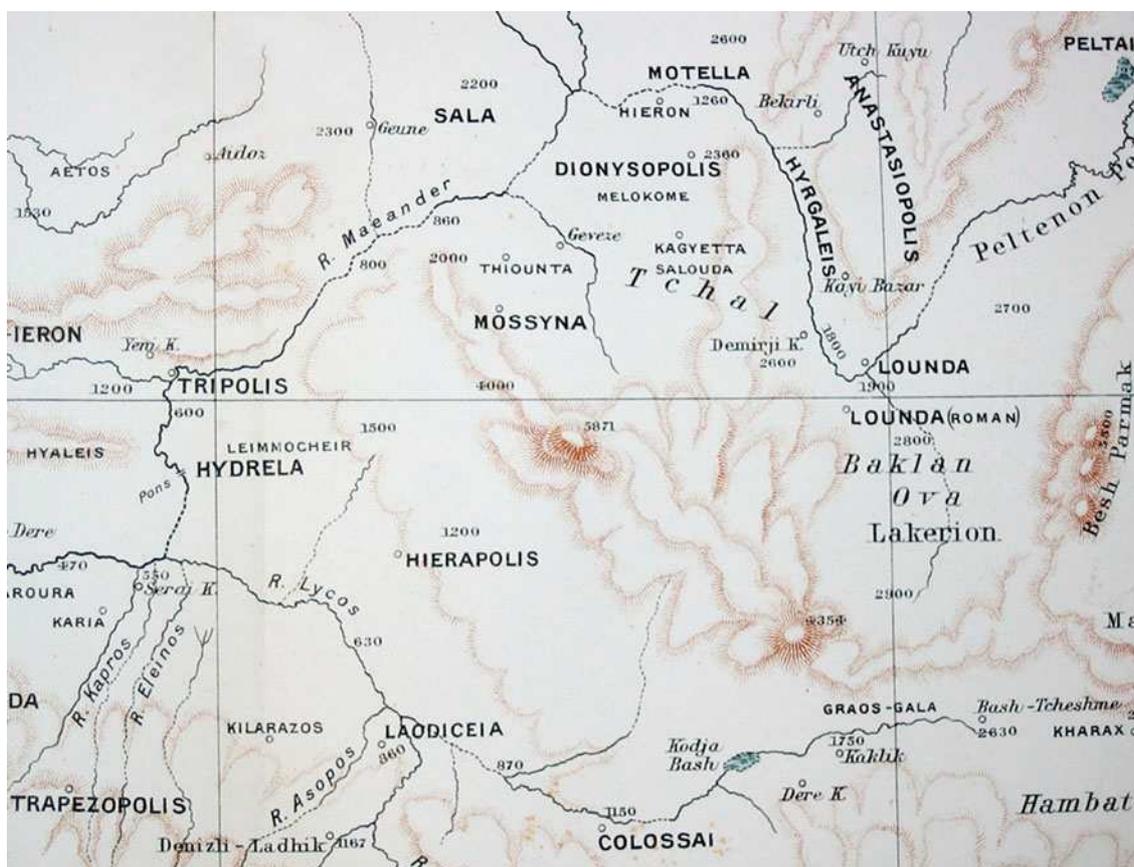


Fig. 3 – Detail of the Map of south-western Phrygia by W. M. Ramsay (1895): *Mossyna* is located in the centre of the high plain of Uzunpinar.

A first localization of the site of *Mossyna* was assumed by Ramsay at the time of his first trip to Phrygia, in 1883, following the discovery at “Gévezé” (current village of Dağmarmara) of “a fragment of a remarkable relief and inscription, recently excavated on the ancient site” (RAMSAY 1883: 377–379, No. 2; RAMSAY 1895: 122–124 and 144–145; RAMSAY 1928: 273–275, fig. 7; RAMSAY 1930: 280–281, No. 1). The ancient site mentioned by Ramsay – who make a systematic refutation of previous theories of Mionnet and Kiepert regarding the localization of *Mossyna* (RAMSAY 1883: 377–379; RAMSAY 1895, 145) – is located about 2 km from the village (to the south-east), in the valley of the Değirmen Dere. In this site (Yüksektepe), where recent surveys in 2006 identified the sacred area of *Motaleis*, Ramsay founded a Greek inscription, which

mentioned the *demos* of a city whose name was completed by the traveler as *Mo[σσύων]*. This integration will be subsequently corrected by Robert in *Mo[ταλέων]* and referred to the *demos* of the community of *Motaleis* (ROBERT 1983: 52).

Between 1883 and 1887, Ramsay discovered the already mentioned inscription (see above) containing a dedication to *Zeus Mossyneus* and the *demos* of *Mossyna*, which at that time was incorporated in the floor of the mosque of Sazak (RAMSAY 1883: 385–386; RAMSAY 1887: 350; RAMSAY 1889: 229; RAMSAY 1895: 146, No. 33; RAMSAY 1930: 281–282, No. 2). Ramsay tried to solve the apparent difficulty posed by the relative distance between “Gévezé” and Sazak, where he discovered the two inscriptions concerning *Mossyna*, and proposed as site of this city another ancient village, located in the central sector of the high plan of Uzunpinar (Fig. 3); the site, named “Geuzlar-Kahve” by Ramsay, was identified during the survey of 2006–2007 on the Gavurdamıarkası Tepe, 3 km north-west of Uzunpinar. According to the theory of Ramsay (1895: 124), from this “*desert and solitary locality*” – using his words – close which “*extensive ruins, chiefly vaulted tombs, of the Roman period*” were, the two inscriptions were transported to the nearby villages (Gévezé and Sazak) to serve as building material.

This second hypothesis of Ramsay concerning the site of *Mossyna* was accepted by A. Philippson (1914), as is evident in his map of Western Asia Minor, where the ancient settlement was located near the modern village of “Usun Bunar” (Uzunpinar); this location was still received also in the map of Asia Minor edited by W. M. Calder and G. E. Bean (1958).

The reconstruction of ancient topography in the territory north of *Hierapolis* proposed by Ramsay was refuted by subsequent discoveries. During their trip in Phrygia in the spring of 1930, the British scholars W. H. Buckler and W. M. Calder founded the remains of an extensive ancient settlement near Sazak, in which they identified *Dionysopolis*; they wrote “*the only extensive ruins reported to us in the whole district were those to which a Sazak villager guided us about a kilometer north-east of that village. There, beside a small tributary of the Meander, one sees only low hummocks in the cultivated fields, but tooled stones and marble are said to be constantly dug up ...*” (BUCKLER et al. 1933: XIV). The site near Sazak was subsequently identified with *Mossyna* by L. Robert (1962: 134; 1983: 53), and his hypothesis was commonly accepted by scholars. The area, however, has never been systematically explored before the surveys of 2007. (L. C.)

Archaeological remains of Mossyna

Archaeological surveys have identified the area occupied by the ancient city of *Mossyna* situated on a plateau about 1 km south-east of Sazak (Fig. 4). The area was already discovered in the spring of 1930 by W. H. Buckler and W. M. Calder, but they mistakenly identified the site with the ancient city of *Dionysopolis* (BUCKLER et al. 1933: XIV), which was subsequently located on the right bank of the Meander, east of the high plain of Çal, near modern villages of Bekilli or Uçkuyu (ROBERT 1962: 127–149 and 356–363; RITTI 2002: 41–42; RITTI et al. 2008: 14–17). The area south-east of Sazak can be identified with the place where L. Robert (1962: 134 and 136), thirty years after the explorations of the two British scholars, has suggested *Mossyna* arose (RITTI 2002: 43). The plateau on which lie the remains of the city, stretches from north to south; it is bounded on the east and the west by deep valleys (Fig. 5) crossed by two seasonal streams, which just at the northern slopes of the promontory go into the Gök Dere stream, a tributary of the Meander.

There isn't, however, a natural limit on the south side of town. On the surface of the fields, intensively cultivated (Fig. 6), is found a large amount of fragments of roof tiles, bricks and ceramic and stone materials (in marble and travertine), covering a chronological period at least between the Late Hellenistic age and the Byzantine periods; many blocks and other stone materials are also piled up along the boundaries of the fields (Fig. 7). Among the most interesting is one cylindrical travertine screw weight, with a central circular socket carved into the upper surface and two additional exterior mortises (Fig. 8); it pertained to a lever and screw press for the olive oil or wine productions (SCARDOZZI 2010: 293–294).

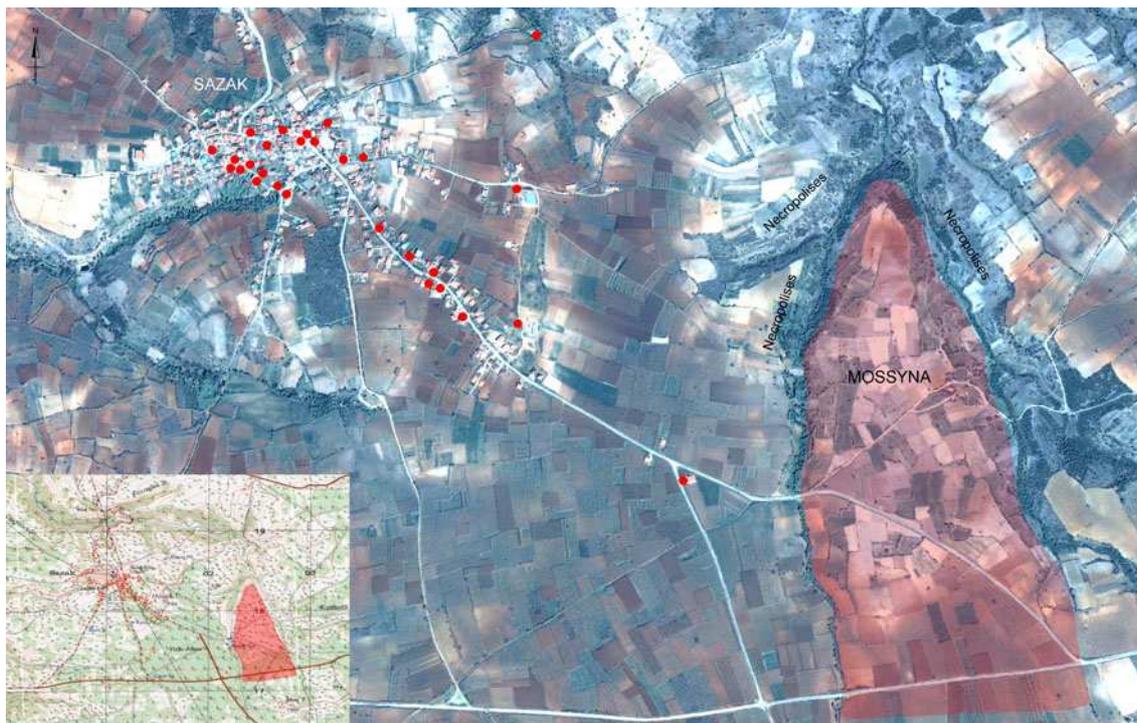


Fig. 4 – Sazak and the archaeological area of *Mossyna* in a pan-sharpened QuickBird image of 2007 (colour composite RGB: Red-Green-Blue) and in a Turkish topographic map on a 1:25,000 scale (General Command of Mapping): the ancient materials (bases, capitals, columns, reliefs, mouldings, inscriptions, etc.) reused in the modern village (in red) and the surface covered by numerous fragments of bricks, tiles, pottery and blocks (in pink) are localized.

On the surface of the ground, structures can not be seen clearly, except for some remains of the walls barely visible. This is due to the fact that the area was used until a few years ago as a quarry for building materials: in fact, practically all the historical buildings of the nearby Sazak village are built using stones from this site, as documented 80 years ago also Buckler and Calder. Inside the village are also very numerous architectural materials in marble and travertine, also inscribed, from the site of *Mossyna* (see below); among them, there is also a marble base with the inscription in which *Zeus Mossyneus* and the *demos* of the same *Mossyna* are mentioned; this inscription allowed the identification of the site (ROBERT 1983: 54). Some information on the structures and the urban layout of *Mossyna* can be obtained through the processing of a high resolution image taken by the QuickBird satellite in 2007 (Fig. 9). In the remote sensing data, few traces of buried and semi-buried structures are visible in the central and northern sectors of the ancient city (Fig. 10). Moreover, some boundary walls of the fields have orthogonal orientations north-south and east-west, suggesting the existence of an ancient urban orthogonal plan. (G. S.)

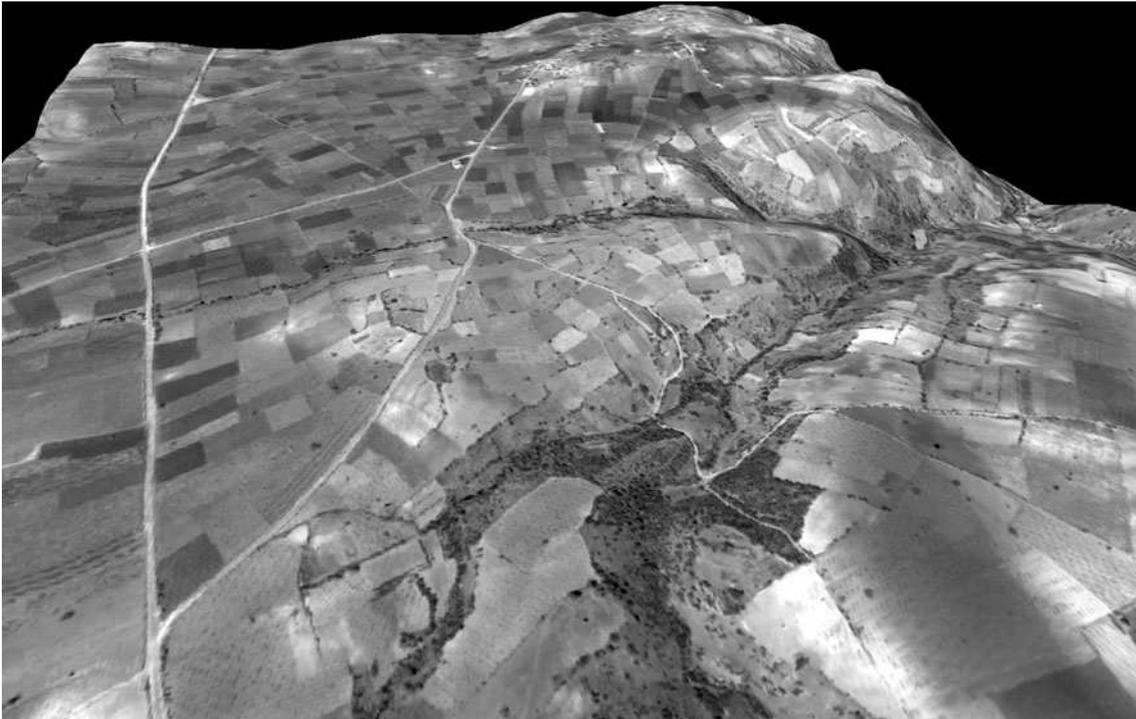


Fig. 5 – The promontory of *Mossyna* in a panchromatic QuickBird satellite image of 2007 draped on a DEM based on SRTM data.



Fig. 6 – The promontory where are the ancient remains of *Mossyna*: a lot of ancient materials scattered on the ground are visible.



Fig. 7 – Blocks stacked along the border fields in the area of *Mossyna*.



Fig. 8 – Cylindrical screw weight from the area of *Mossyna*.

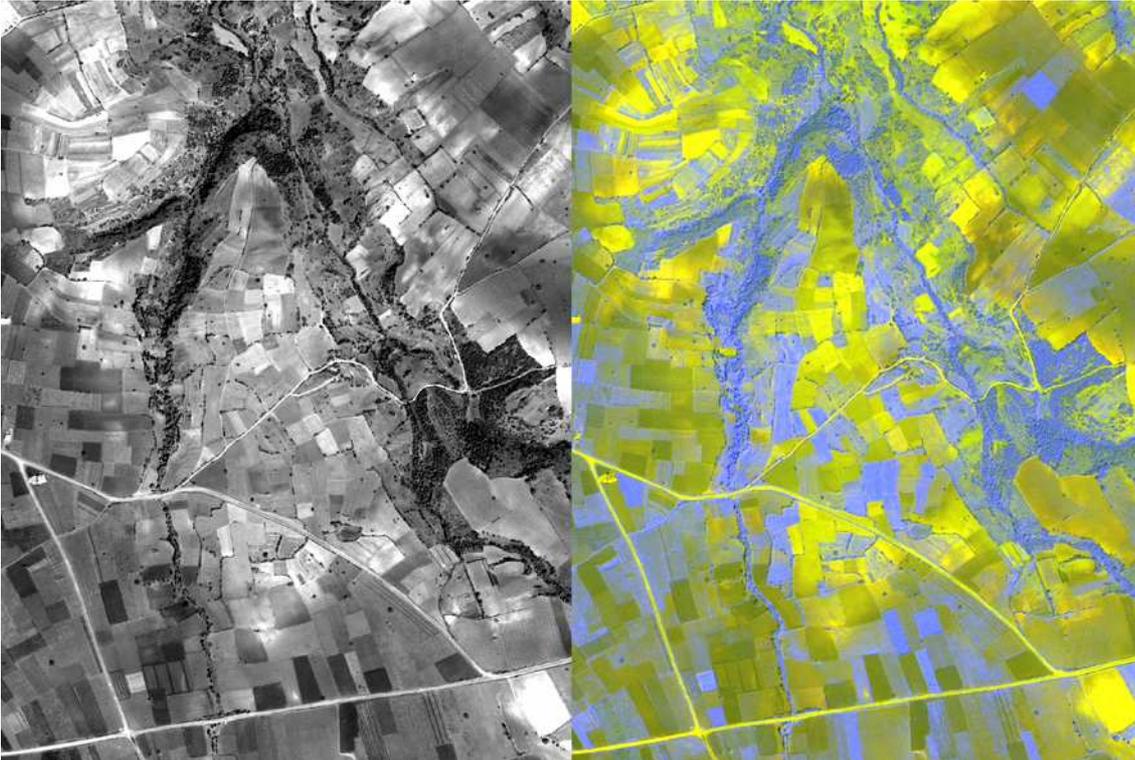


Fig. 9 – The promontory of *Mossyna* in a QuickBird image of 2007: panchromatic (enhanced by linear2 filter) and pan-sharpened (colour composite RGB: NIR-Red-NDVI) data.

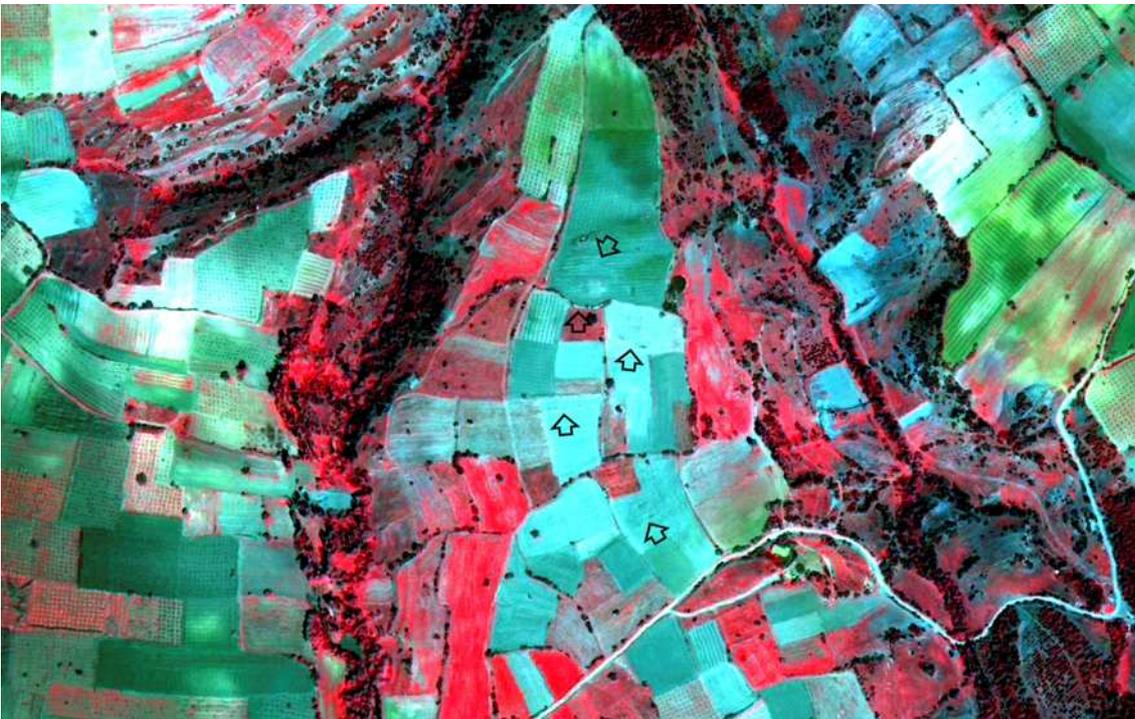


Fig. 10 – The central and northern sectors of *Mossyna* in a pan-sharpened QuickBird image of 2007 (colour composite RGB: NIR-Red-Green) enhanced by Linear2 Filter: the arrows show traces of buried structures.

Archaeological materials from *Mossyna* reused in Sazak

During recent surveys, the presence of numerous ancient materials from *Mossyna* and reused in the modern village of Sazak has been widely documented; they were also attested by previous explorations in the village (BUCKLER et al. 1933: XIV; ROBERT 1962: 134).

Inside the village are several architectural elements in marble and travertine, including some inscriptions (BUCKLER et al. 1933: No. 278, 291, 292, 308; RITTI et al. 2000: 23–25, K9–K13). Among them there is the already mentioned marble base (see above Fig. 2) inscribed with the dedication to *Zeus Mossyneus* and the *demos* of *Mossyna* (ROBERT 1983: 54); the base is now located in the central square of Sazak, near a honorary monument dedicated to Kemal Ataturk (Fig. 11), where are also incorporated other ancient materials, including an architectural slab of Byzantine times, with two crosses in relief (Fig. 12). The inscription has a lacuna in the central part – due to the detachment of a part of the inscribed surface, which seems relatively recent – but it can be integrated with the transcripts of Ramsay (1883: 385–386, No. 8; 1887: 350).

It should be attributed to *Mossyna* also a stele, 82 cm in height, dedicated by a priest to the Emperor Augustus and copied in 1930 (BUCKLER et al. 1933: No. 292) in Sazak, where it was incorporated in the wall of a house (ROBERT 1983: 55); it could not be find during the recent surveys.



Fig. 11 – Sazak: the honorary monument dedicated to Kemal Ataturk, where are reused ancient fragments of marble; near the monument, the base of *Zeus Mossyneus* and the *demos* of *Mossyna* is preserved (A).

Among the numerous inscriptions reused in the modern village of Sazak deserves to be mentioned some inscribed blocks of white marble dating between the 2nd and 3rd centuries AD, confirming the practice of

sacral manumission. Among those is an inscription dating to 241 AD (Fig. 13), found in the courtyard of a house and consisting of a moulded upper and part of a shaft of white marble *bomos* (29 x 55 x 65 cm), attesting to the manumission of the girl *Ammia* (BUCKLER et al. 1933: No. 278; RITTI et al. 2000: K9). It belongs to this group also an inscribed marble, perhaps a small capital of pillars, dating to 232 AD and attesting some *καταγραφαί* from the Sanctuary of Apollo Lairbenos (RITTI et al. 2000: K11), located 14 km north-west of Sazak; further evidence for carrying out this sacred practice is offered by a block of marble moulded in the upper part and showing an inscription dating to the 3rd century AD (RITTI et al. 2000: K13).



Fig. 12 – Byzantine slab with crosses in relief incorporated in the honorary monument dedicated to Kemal Ataturk in Sazak.



Fig. 13 – Cornice in white marble with inscription of the 3rd century AD, currently preserved in the courtyard of a private house in Sazak, attesting to the practice of sacral manumission.

In addition to the inscriptions mentioned above, between the ancient materials reused in the modern village of Sazak there are capitals, cornices, columns and blocks, of marble and travertine, smooth and moulded (Figs. 14–17). Finally, in the eastern periphery of the modern centre, is one rectangular travertine screw

weight with an open square channel and a central circular socket in the upper surface (Fig. 18); it also has two additional exterior mortises and pertained to a lever and screw press for the olive oil or wine productions (SCARDOZZI 2010: 293–294).



Fig. 14 – Two marble Ionic and Corinthian capitals from *Mossyna* currently in the modern village of Sazak.



Fig. 15 – Ancient window jamb in travertine and marble cornice from Sazak.



Fig. 16 – Two ancient *dolia* from Sazak.



Fig. 17 – Ancient reliefs incorporated in a fountain near Sazak.



Fig. 18 – Rectangular screw weight from Sazak.

In addition, a marble column with a Byzantine inscription in which is mentioned a church dedicated to St. Michael was also found during the surveys of 2007 in front of the mosque of Kabalar, a village located about 3 km north-west of Sazak; it come from the area of *Mossyna* (BUCKLER et al. 1933: XIV, No. 307; ROBERT 1962: 164; ROBERT 1983: 54). (L. C.)

Conclusions: Mossyna in the Southern Phrygia

In 2006–2007, surveys on the high plains of Uzunpınar and Çal allowed a comprehensive examination of the archaeological presence of this vast territory and a detailed analysis of the sites linked to the location of the ancient city of *Mossyna*. The archaeological and epigraphic data have ruled out the site to the south-east of Dağmarmara (Yüksektepe), certainly identified with the sacred area of *Motaleis*. The not large extension of the remains scattered on the ground, excluded also the ancient site of "Geuzlar-Kahve" (Gavurdamıarkası Tepe), north-west of Uzunpınar; probably it was not an ancient town but only a large village of the territory of *Hierapolis*.

The location of *Mossyna* about 1 km south-east of Sazak is therefore confirmed by the presence in the village of the base which mentions *Zeus Mossyneus* and the *demos* of *Mossyna*, and by the archaeological evidence in the promontory on which the town was built, where recent surveys have shown that the ancient materials are scattered over an area of at least 54 hectares. This size is much larger than any other ancient settlement found in the high plains of Uzunpınar and Çal, and so it is possible to consider *Mossyna* a city and not just a village; probably for the amount and extent of ancient evidence, Buckler and Calder proposed to identify the site with a city, *Dionysopolis*.

Therefore, the archaeological record elevates *Mossyna* to a rank higher than that generally found in studies that have considered the problem of its location. On the other hand, it isn't a coincidence that it became center of a diocese and its bishop is attested already in the Council of Chalcedon in 451 AD, along with those of *Hierapolis* and *Dionysopolis*; *Mossyna* also appears between these two cities in the *Synekdemos* (655, 3) of Hierokles, compiled around 530 AD, and its bishops are attested in the Councils of 787, 869–70 and 879–880 AD (RAMSAY 1883: 371–374; RAMSAY 1895: 121; BELKE and MERSICH 1990: 343). However, we do not know anything about *Mossyna* during the Roman imperial period, when the archaeological and epigraphic data show a rather thriving site; so, we don't know if its administrative autonomy in the Byzantine period was that even earlier, or if it fell within the territory of *Hierapolis*, as it might imply a certain subordination highlighted by the *Notitiae episcopatuum* (DARROUZÈS 1981); in fact, the list compiled between the 7th and the 12th century, document the Diocese of *Mossyna* inserted in the *Eparchia* of the metropolitan see of *Hierapolis*, such as those of the nearby *Dionysopolis* and *Motella*, the latter located at Yeşilova (ROBERT 1983: 48) (see above Fig. 1).

However should be noted that it is hazardous to anticipate to the Roman imperial age the situation documented by the list of the dioceses of the Byzantine period – from the age of Justinian –, where a whole number of cities that had previously enjoyed legal autonomy, for example *Motella* and *Dionysopolis*, awarded to the two metropolis of *Phrygia Pacatiana*, *Hierapolis* and *Laodikeia*.

The morphology of the high plains of Uzunpınar and Çal, clearly separated from the deep valley crossed by streams Değirmen Dere and Koca Dere, suggests that this natural boundary may have coincided with that of

the Dioceses of *Mossyna* and *Hierapolis*, but we don't know how this boundary may be old and if *Mossyna* was in the Roman imperial period completely independent from *Hierapolis*. An inscription of the second half of the 1st century AD, found in Bekilli (one of the possible sites of *Dionysopolis*: see above), east of the plateau of Çal, beyond the Meander, contains a dedication to the Governor of the Province of Asia *Quintus Plautius Venustus*, set jointly by *demoi* of *Hierapolis*, *Dionysopolis* and *Blaundos*, and by *koinon* of *Hyrgaleis* (RAMSAY 1883: 387, No. 10; RAMSAY 1895: 142, No. 29; RAMSAY 1930: 283, No. 4; BUCKLER et al. 1933: 118, No. 315; ROBERT 1962: 132; RITTI 2002: 41). The text has been used as evidence that in the 1st century AD, the territories of the four communities were neighbours and that there was no autonomous city in the highlands of Uzunpinar and Çal (RAMSAY 1895: 122; ROBERT 1962: 136), where the territory of *Hierapolis* could extend and the *Mossyna* district would therefore also be included. Just in the 1st century AD, however, the dedication to *Zeus Mossyneus* of Sazak also mentions the *demos* of *Mossyna*; this indicates that at least some degree of administrative autonomy with respect to *Hierapolis*, like other communities in its territory, such as those of *Motaleis* and *Thiunteni*, whose villages had extensions significantly lower than that of *Mossyna*. Finally, the status of the documentation available does not allow to know if *Mossyna* had administered its own territory at least until the middle of the 3rd century AD, when *Hierapolis* extended its authority over the Sanctuary of Apollo *Helios Lairbenos*, located on a hill (Asar Tepe) overlooking the left bank of the Meander (about 14 km north-west of Sazak), and on the north-west sector of the plateau of Çal (RITTI et al. 2000: 3–4, 54–55). The acquisition by *Hierapolis* of control over this sanctuary, formerly administered by *Motella*, city located just 3.5 km north-east of Asar Tepe, just north of the course of the Meander, might attest an extension of the control by the city including the plateau of Çal, at least in its western part, and therefore the district of *Mossyna*. (G. S.)

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The Janus Temple from Roşia Montană – epigraphy, architecture and space meaning

Radu CIOBANU

Muzeul National al Unirii, Alba Iulia, Romania

K(astellum) Ansi(enses) (Ansis, Ansum, Anse ?)

Unlike other religious buildings recently brought to light in the Roşia Montană region during the *Alburnus Maior* international archaeological research project, the Janus Temple from Gauri spot is not a completely isolated discovery from an already well known context (PISO undated; WOLLMANN 1985–1986; CIOBANU 1993; PISO 2002–2003) (Figs. 1, 2).



Fig. 1 – Roşia Montana / Gauri and Habad region general view.

To the west from Gauri spot, but not very far away from it, there were discovered several votiv altars, four of them consecrated, by some so called *kastellum Ansienses* residents, to *Janus Geminus*, *Minerva*, *Diana* and *Silvanus*.

The name *Ansi(enses)*, *Ansi*, *Ansum* as it was spelled on the inscriptions mentioned above, comes from a well known settlement supposed to be in the neighbourhood of Ivanova Gravica village in today Croatia. A roman milestone discovered near that village states explicitly that the territories *inter Ansienses et Corianenses* should have been separated right in that area (SEPAROVIC 2005). The territories mentioned by this inscription, in ancient times took part of the Liburnia region and their inhabitants, *liburnii*, lived both in Istria peninsula and its neighboring archipelago and from the northern Dalmatian coast to the river Krka of

today. But such settlements, known as *castella* – *kastella* are often certified also by many inscriptions in Roşia Montană region, but none of them is actually located or investigated. According to the hypothesis advanced by researchers, such fortified settlements (*castella*), usually situated on hills and surrounded by several concentric lines of trenches and stone walls, were defined by a strong ethnic element not a specific location in space or by other relief features. In the ancient Illyria, this kind of settlements are very well known as they belonged to local inhabitants who adopted the model very long ago, beginning with the IV-th century B.C., from the Greek colonists established in the Epyrus region, in the modern Albania (BATOVIĆ 1968; CABANES 1999). Those Illyrians, essentially miners, after the roman conquest of Dacia, were brought by Trajan into his new province in order to exploit the gold resources from here. In this way a part of the ancient Illyrian communities from roman province of Dalmatia moved on in Dacia were they still kept all their traditions, social organisation and religious beliefs. Janus was one of their most sacred gods as he was responsible, as we shall see, for every good or bad luck changes, and the miners were confronted, more than any others, with these.



Fig. 2 – Roşia Montana – The gold mines galleries in front of Janus Temple.

The Janus altar and its donors

Right in the middle of a trapezium enclosure (*peribol* / *temenos*) belonging to the Janus temple it was discovered an altar raised by an Illyrian couple (Fig. 3).

It was erected on a small platform of beaten earth and the text written over the image of the god, on one side, was visible even from the entrance. The inscription contained five rows running as follows : *Janus / Dazas Verzo(nis) et / Nevato / Implai*. [Translation: To Janus / Dazas / (son) of Verzo and / Nevato / (daughter?) of Implaius (have raised this)] (PISO 2002–2003: 211) (Fig. 4).

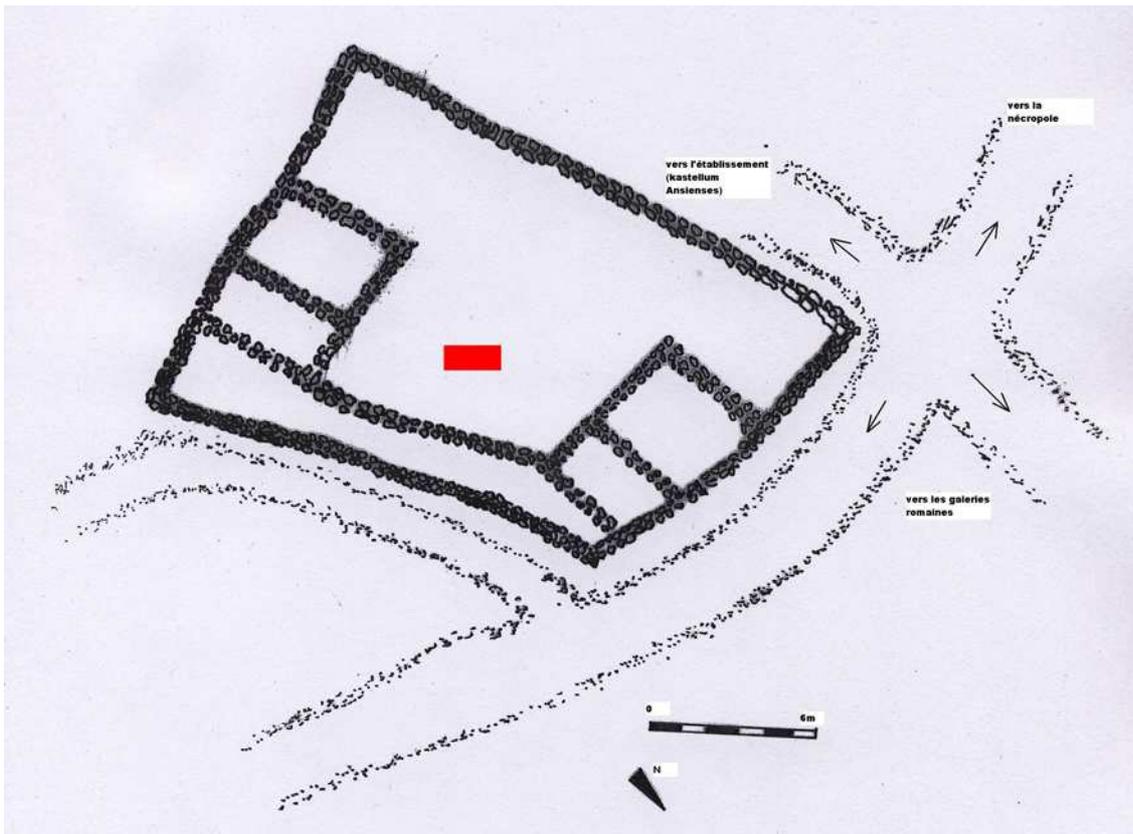


Fig. 3 – Roşia Montană – Janus Temple at the paths crossroad reaching to the gold mines, the necropolis and the *kastellum Ansienses*.

Dazas, or Dassius Dasius variants, is a widespread name only in the central Dalmatia. Verzo, his father's name have been originally attested only in the south west of the province but gradually generalizes everywhere. According to some scholars interpretations, Verzo had also a certain meaning in Illyrian language : the root „verz” was probably a verb, and meant „to be quick” or „to be hot tempered” (PISO 2004). Nevato, probably his wife was not Illyrian but Pannonian because her name is well atested in that province. Her father, Implaius, was probably from south Illyria where this name is more frequently found. It is still hardly possible to believe that this couple financed also the temple construction. In other cases very well attested in Rosia Montana, as the Valea Nanului religious complex, these initiatives were assumed by several communities members, in that case a *collegium Sardiensium*, as they had very limited individual resources to support such those kind of workings (CRACIUN et al. 2003). A last quetion which is about the presence of the Liburnians in the Rosia Montana region, as the *Ansienses* community is attested in four inscriptions discovered in the area. In fact, neither Dasas nor Nevato are Liburnian and in Rosia Montana one possible name could be interpretaded as belonging to that north Dalmatia community.¹

¹ A *Lonius Tizius*, is mentioned on an inscription from Rosia Montanam whose *cognomen* appears also in Istria peninsula and was interpreted as being Liburnian (PISO 2004: 283, n. 75).



Fig. 4 – Roșia Montană – Janus shrine raised by Dazas and Nevato, probably an Illyrian man and his wife.

Janus and his temples from Rome

One of the first roman temples dedicated to Janus was raised on *Argiletum*, a small street in the old forum (Fig. 5). It was one of the most bizarre temples of the antiquity world because its original plan and spatial meanings were closely connected to the god's very special symbolic tasks. Janus himself was first of all an original roman god, which had almost no correspondents among the traditional Greek gods as usual. Among the ancient Greek gods, the scholars could consider only a bridge god, known mostly by literature sources (CAPDEVILLE 1973; SCHILLING 1960).

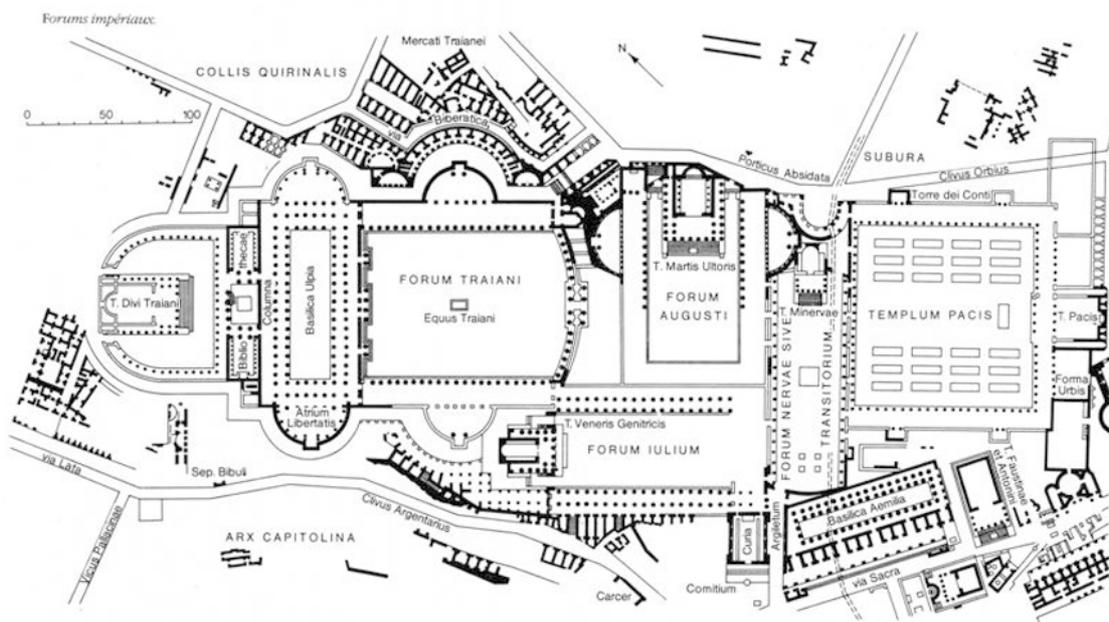


Fig. 5 – Rome / The ancient and the imperial forums with the Janus temple on the *Argiletum*.

According to the title of fundamental paper consecrated to this god, Janus was above all a god of passages, new beginnings, whether in a literal expression, such as for example the ancient Rome's city gate where the first temple was built, or in figurative sense, such the beginning or the end of a life cycle or a new era, as it was supposed to be the temple afterwards, when it was used a symbolic passage between the ancient and the new imperial forums, namely those of Caesar and Domitianus, also known as the *forum Transitorium*. As we know by classical sources, Caesar wanted to give prestige and legitimacy to his own forum by connecting it to the ancient one, exactly by the Janus temple on the Argiletum. Afterwards, Domitianus did in the same way when he decided to build his new forum, inaugurated by Nerva, the *forum Transitorium*. In addition to all this, several coins issued during Nero's reign had on the obverse the same Janus temple in order to stress out in a symbolic way the new *saeculum aureum* that the emperor wished to impose by his own (COARELLI 1994: 86).

These are only some brief considerations regarding Janus temple from Rome Argiletum and as we will see, exactly this kind of symbolic meanings, but at a much more modest level, could be taken into account discussing the Gauri temple, in Rosia Montana.

Janus iconography

We know that one of the first statues of the god was raised, according to the legend, by Romulus himself in the *Argiletum* temple, restored later by Numa Pompilius. This remarkable work of art, known only from classic written sources, such those belonging to Procopy of Caesareea, seems to be the one who established also the god's basic iconography: a two headed statue (*forma biceps, duplex imago*) looking exactly to the sunrise and to the sunset, or in a symbolic way, to the past and to the future, towards an unfortunate end or towards a promising beginning.² He had also some original objects he carried with him: the stick (*virga*) – to keep the way straight – and the key (*clavis*) – to open or to close the back or the front gates (Fig. 6).

On the Janus altar from Rosia Montana the *virga* and the *clavis* are missing but the god looked exactly as its illustrious original from *Argiletum*, towards east and west



Fig. 6 – Roman dinar from Pertinax with the Janus statue on the obverse.

The Janus temple from Roşia Montana (Gauri spot)

The temple was raised at the crossroad giving acces to the settlement, the *kastellum Ansienses* mentioned above, to a large necropolis belonging to it and to the gold mines galleries.

The complex includes a trapezium enclosure (*temenos* or *peribolum*) with two *cellae* on its east and west corners, and a portico on the north facade, along the path reaching to the necropolis and the gold mines galleries. This irregular plan shape was determined by several earthslidings and this situation is well documented in Rosia Montana region, namely at the Valea Nanului temple, consacreted to several gods by a *collegium Sardiensium*. In both cases the original regular plans were altered by earthslidings and the restorations were operated without special care as the settlements had a short existence as the gold sources came to an end and the miners had to move elsewhere to search them (Figs. 7–10). The 3D restauration project was made having in mind some architectural solutions for these kind of buildings already known in the roman empire. First of all, the monument is an enclosed roman temple, with a portico on its principal facade and on the ground its foundations were still visible. Taking into account its dimensions, and having in mind some possible analogies for this kind of monument, as those from the Diana temple from Carnuntum or

² Procopy from Caesarea, *De bellis, (De bello gothico)*, I, 25.

the Mercure temple from Savaria in Pannonia, or the Valetudo temple from Glanum in Gaul, the 3D project tried to present the way the original monument has been altered, from a rectangular shape to a trapezium, due to several transient refections made during the middle of the II-nd century AD.



Fig. 7 – Roşia Montană Janus Temple phase 1, 3D restauration – north facade.



Fig. 8 – Roşia Montană Janus Temple phase 1, 3D restauration – south backyard.



Fig. 9 – Roşia Montană Janus Temple phase 2, 3D restoration – north facade.

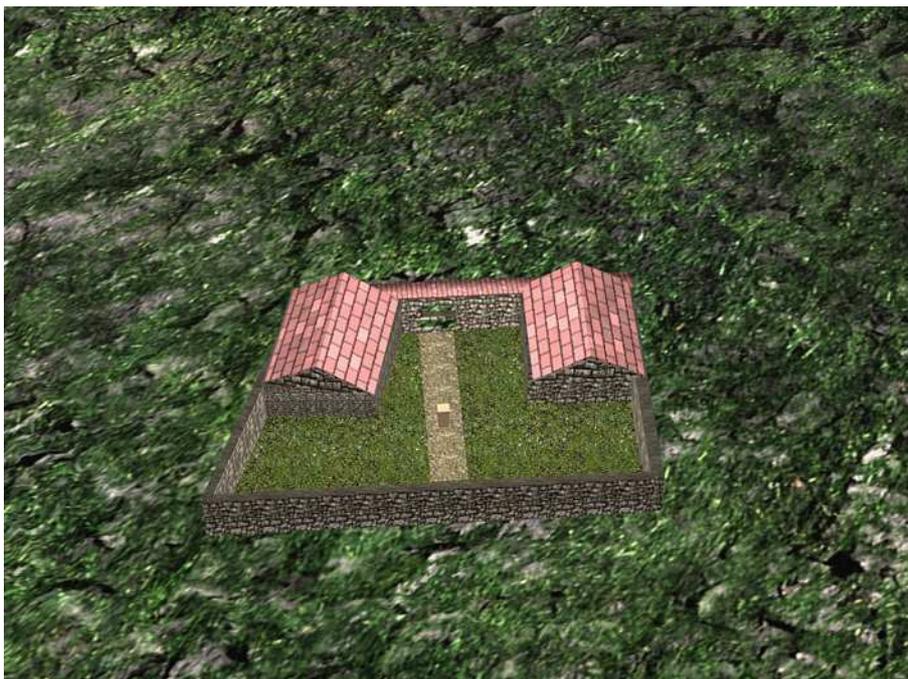


Fig. 10 – Roşia Montană Janus Temple phase 2, 3D restoration – south backyard.

Conclusions

From the etymology point of view there are some interesting problems which clearly explains the god specific meanings. First we can consider that the god's name is based on the root “ya” which is a derivation of an ancient indo European verb “ey” (“to go”). In Vedic Sanskrit we have also “yati” (“to go within a vehicle”) and “yanah” (“path, road”) (CAPDEVILLE 1973: 400; SCHILLING 1960: 95–96). The meanings are quite clear

though: a threshold god, god who could start a new beginning, making possible the link between past and future or afterlife and real life.

As a two faced god, as Ianus is already well known from the rich iconographical sources, we have here in Rosia Montana, the most original and unique architectural solution: a) two *cellae* exactly positioned on a east west direction, as the original Numa Pompilius Rome god's statue was raised in the *Argiletum* temple and b) their entrances situated on the facade *temenos*, quite unusual for a cult edifice. In general, a cult ensemble supposed to offer a different perspective from the *temenos* entrance where the cella is at the end of the principal axis; In this case, the cellae were on the facade portico, The same solution was adopted at the Diana temple in *Carnuntum* or the Mercure temple from *Savaria*, to quote only the exemples attested in Dacia's neighbourhood provinces.

As a threshold god, real or symbolic, Janus was worshipped by the Illyrian communities in Roșia Montană most of all because its great power to ease the passages from the real life (the *kastellum Ansienses* settlement) to the after life (the necropolis), or from a miserable status like the one of the ordinary miners (the past), to a prosperous status after some gold source findings to which they have dreamed of (the future).

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IR Thermography and Ultrasonic Investigations in the Cultural Heritage Field

Giuseppe DIANA^{1,2} / Silvana FAIS^{1,3}

¹ Dipartimento di Geoingegneria e Tecnologie Ambientali, University of Cagliari / ² Vetorix Engineering S.r.l., Marcon and RixGamma S.r.l., Ravenna / ³ Consorzio Interuniversitario Nazionale per l'Ingegneria delle Georisorse (CI.NI.Geo), Roma

Abstract: This paper presents a few cases in which non-destructive IR thermography and ultrasonic techniques have been applied to evaluate the conservation state of valuable finds and monumental structures. From our tests it appears that due to the peculiarities of the two methods, their integrated application can be very useful. In fact, IR thermography, which is highly productive, is limited by its low probing depth, a problem that can be solved by coupling ultrasonic velocity measurements on studied objects.

Keywords: Cultural heritage diagnostics, non-destructive testing, IR thermography, ultrasonic techniques, building materials.

Introduction

Several investigation techniques have been implemented in past years in Cultural Heritage diagnostics and the tendency has been to use non-destructive techniques as much as possible for an adequate assessment prior to any restoration. This paper presents the application of non-destructive Infrared (IR) thermography and ultrasonic techniques in evaluating the conservation state of valuable finds and monumental building materials. As is known IR thermography is one of the most widely used technologies in Cultural Heritage diagnostics. Each material has a specific thermal response that is detectable by infrared measurements. Therefore with a thermographic investigation we can detect a large amount of fundamental data for a precise diagnosis of the shallow parts of investigated objects.

Ultrasonic methods are very effective in detecting the elastic characteristics of materials and thus their mechanical behaviour. They are non-destructive and effective both for site and laboratory tests, though it should be pointed out that ultrasonic data interpretation is extremely complex, as elastic wave velocity heavily depends on moisture, heterogeneity, porosity and other physical properties of the materials.

Methods

Infrared thermography

Infrared thermography is one of the most widely used technologies in cultural heritage diagnostics. Each material has a specific thermal response that is detectable by the infrared measurements. The thermal response of each material can change according to many variables, such as thickness, integrity, conditions

and possible presence of moisture or other bodies of a different nature; then a thermographic investigation can be used to detect an abundance of fundamental information on the shallow parts of investigated objects. Through this technique, it is therefore possible to detect altered or damaged areas. The instrument used on this investigation was the FLIR ThermoVision A40 (Fig. 1).

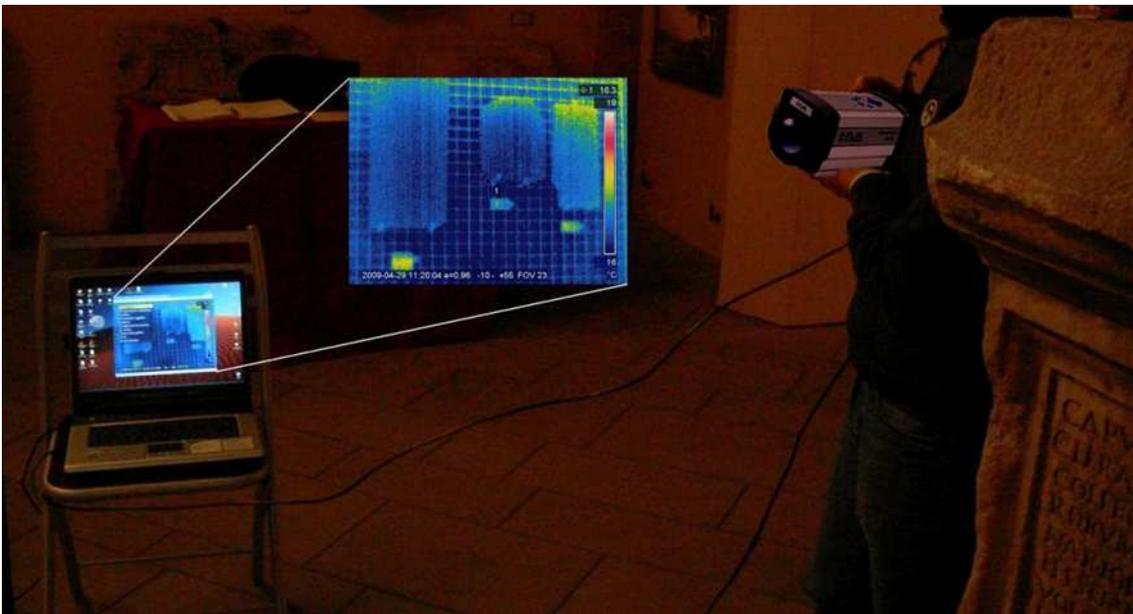


Fig. 1 – FLIR ThermoVision A40.

The ThermoVision A40 infrared camera features an uncooled microbolometer FPA detector with which temperature variations as small as 0.08°C can be detected. Real-time image acquisition at standard video rates (60 Hz) can reveal rapid, thermally transient events and generate images of moving objects. This instrument has a focusing built-in focus monitor (Tab.1).

Field of view/min focus distance	24°x 18°/ 0.3 m
Detector type	Focal plane array (FPA) uncooled microbolometer
Spectral range	7.5 to 13 μm
Spatial resolution (IFOV)	1.3 mrad
Thermal sensitivity at 50/60Hz	0.08°C at 30°C
Focusing	Built-in focus motor
Detector resolution	320 x 240 pixels

Tab. 1 – FLIR Thermo Vision A40 imaging performances.

The ultrasonic technique

The ultrasonic technique is very effective in detecting the elastic characteristics of materials and thus their mechanical behaviour (CASULA *et al.* 2009; CHRISTARAS 1997; FAIS *et al.* 2008).

It is non-destructive and effective both for onsite and laboratory tests, though it should be pointed out that ultrasonic data interpretation is extremely complex, as elastic wave velocity heavily depends on moisture,

heterogeneity, porosity and other physical properties of the materials (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).

Considering the nature of the building materials of the investigated monument, which are mainly carbonate rocks, as well as the constructive types of the masonry, the ultrasonic investigation was carried out in a low frequency ultrasonic (24 KHz), with the aim of detecting damages and degradation zones by studying the propagation of the longitudinal ultrasonic pulses. In fact alterations in materials generally cause a decrease in the longitudinal pulse velocity values. Therefore starting from longitudinal velocity values the elasto-mechanical behaviour of stone materials can be deduced. To this aim, empirical and effective relations between the longitudinal velocity and the mechanical properties of the rocks can be used, by transferring the fundamental concepts used in reservoir rock studies for hydrocarbon research to the diagnostic process on stone materials (ANSELMETTI and EBERLI 1999; EBERLI *et al.* 2003).

In this study the ultrasonic measurements were performed using the Portable Ultrasonic Non-Destructive Digital indicating Tester (PUNDIT) by C.N.S. Electronics LTD and 24kHz piezoelectric transducers.

Experimental results

Case study 1: The gravestone of Rufus (second half of the first century, BC) (Fig. 2a)

IR – thermography measurements carried out at the top (Fig. 2b) and in the columns (Fig. 2c) of the gravestone of *Rufus*, did not reveal specific defects.

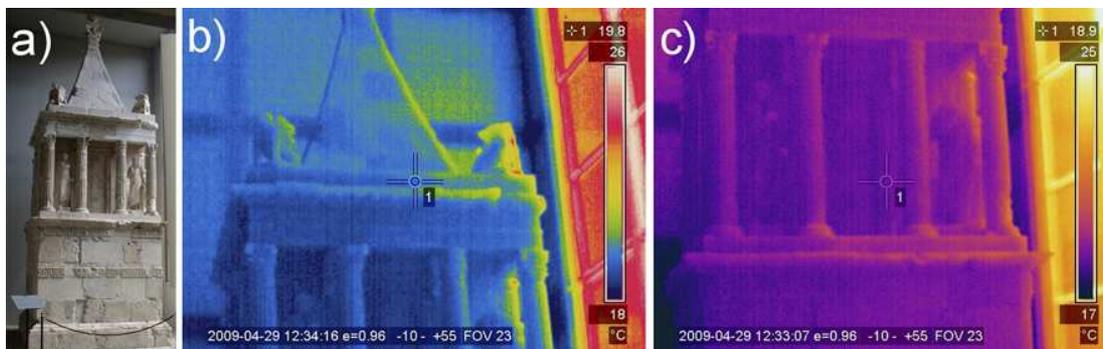


Fig. 2 – Gravestone of *Rufus* (a), thermography of the top (b) and columns (c).

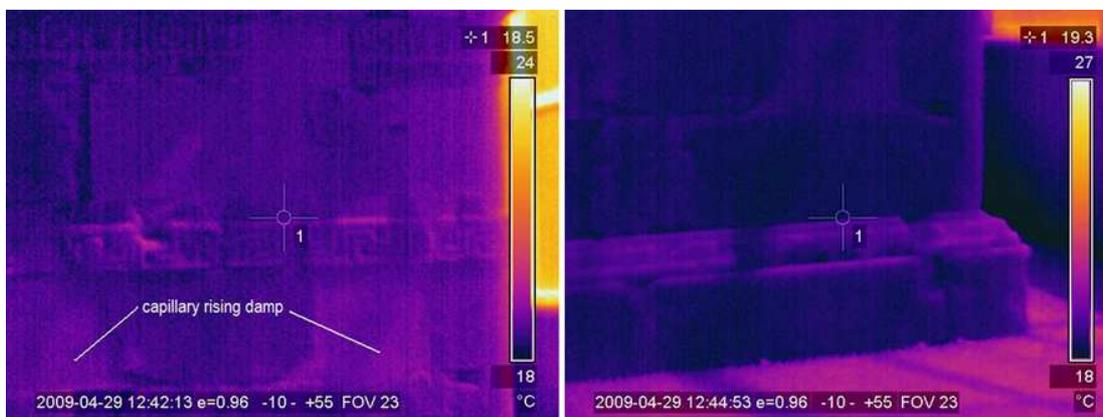


Fig. 3 – Gravestone of *Rufus* (details of the baseline) examined with the thermographic technique.

Only at the base (Fig. 3) did we find small anomalies in the distribution of temperatures. Especially in Greek key that adorns the monument we can see areas where there probably is capillary rising damp.

Case study 2: The statue of Attis (second century A.D.)

Even the statue of *Attis* (Fig. 4 left) from the sanctuary of the Eastern gods, sculpted in valuable marble, was restored in the past and reconstructed with mortars and iron to keep the pieces together. IR-thermography (Fig. 4 right) revealed that, while in good condition, the statue has a slight defect in the external area of the left thigh.

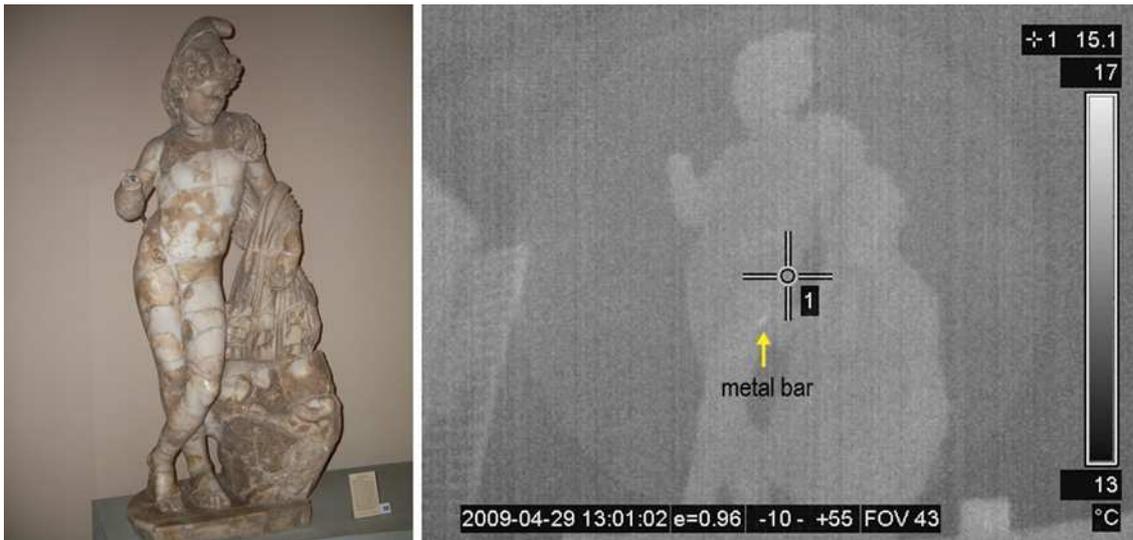


Fig. 4 – Statue of *Attis* (II cent. AD), investigated with the thermographic technique.

This area is more critical, because here, a short metal bar was probably included with the mortar in a very small space. Areas with interfaces between two or more different materials have to be kept under constant control.

Case study 3: The San Lorenzo Church (Historical city centre of Cagliari – Italy)

In situ ultrasonic and IR-thermography measurements were also carried out on the main façade of the church of San Lorenzo (Fig. 5a) in order to check zones of weakness, to detect the elasto-mechanical status of the stone materials (mainly carbonate rock), and to assess their alterability.

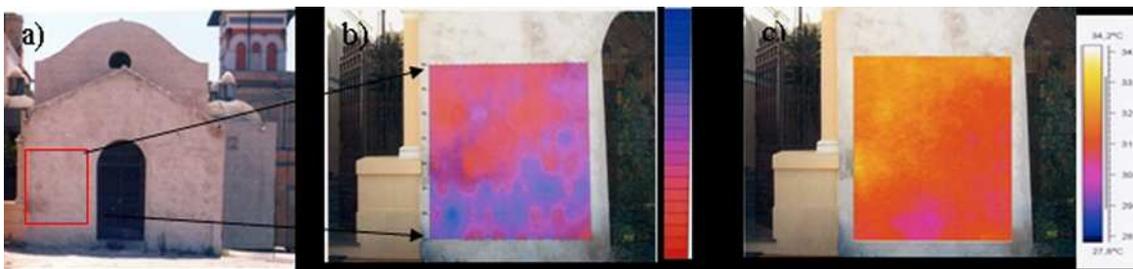


Fig. 5 – a) San Lorenzo Church - investigated sector, b) Ultrasonic longitudinal velocity (V_p in m/s) map by surface technique at 24 kHz, c) Thermal analysis.

Longitudinal pulse ultrasonic velocities were measured *in situ* using the above portable ND indicating tester (PUNDIT) with 24 kHz transducers. The measurements were performed by indirect (surface) transmission, that is, placing the transmitter and the receiver along the same face of the investigated structure. The low velocity areas (red zones) in the map shown in Fig. 5b can be correlated to stone building materials characterised by poor elastic characteristics, while the high longitudinal velocity areas (blue zones) indicate materials with a good elasto-mechanical behaviour.

In particular, the lower part of the investigated sector of the façade is characterised by materials of good elasto-mechanical conditions (higher longitudinal velocity values – blue zones), compared to the materials in the upper part of the investigated sector characterised by poor elasto-mechanical conditions (lower longitudinal velocity values – red zones).

In this case, ultrasonic velocity mapping was integrated with parameters derived from IR-thermography. In fact, a thermal survey was carried out in the same sector of the façade, which had already been investigated by the ultrasonic technique.

In the thermal image (Fig. 5c) the lower part of the investigated sector is characterised by a lower temperature, showing a different thermal behaviour from its upper part, which is characterised by higher temperatures. Therefore in the investigated structure the building materials, which are mainly carbonate rocks, have a different heat dissipation depending on their elasto-mechanical conditions as already observed in a previous work (GRINZATO *et al.* 2004).

The temperature monitoring reported in Fig. 5c shows a good correlation with the elastic behaviour of the lithotypes making up the masonry of the façade. Areas characterised by a good elastic behaviour (blue zones) are generally related to lower temperature values.

Concluding remarks

Since in IR-thermal analysis, the object or structure to investigate is observed in a non-destructive, non-contact way, this technique is less time consuming than the ultrasonic technique, which requires a good coupling between transducers and investigated materials.

The IR-technique can provide a wide field of view and acquire a great quantity of data in a short time with a very good resolution. In the investigation of the Statue of Attis, with the thermographic technique we identified a small anomalous area that had to be monitored continuously, because it was considered critical due to the presence of a metal bar in the marble that resulted from restoration. This is the area where the defect was most likely to occur.

In the investigation of the masonry of the façade of the Church of San Lorenzo, a different thermal behaviour was detected between the different parts of the investigated wall surface. Comparing the thermal image with the longitudinal ultrasonic velocity map of the same sector of the façade, it was possible to relate the different thermal behaviour with the different elastic characteristics of the building materials. Considering the peculiarities of the two applied techniques, we point out that, while the thermographic technique explores the shallow layer of the material, with the ultrasonic techniques the entire masonry or a large thickness of it can be inspected depending on the acquisition data modalities. Compared to thermography, the mechanical characteristics of the building materials can be characterised more easily by measuring sonic or ultrasonic

longitudinal pulse velocity, even though this technique could be time consuming in the case of large surfaces.

The integrated application of two methods of a different nature can improve the diagnostic process. They can be used *in situ* to detect damaged zones or materials with poor elasto-mechanical conditions and to monitor in time any possible changes that should occur in the masonry.

Acknowledgements

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Urban Archaeology and the Re-Constitution of Historical Continuity. The Case of Amasya, Turkey

Leyla ETYEMEZ / A. Guliz BİLGİN ALTINÖZ

METU Architecture Department Restoration Graduate Program

Abstract: Towns with continuous inhabitation are the locus of the collective memory that has been generated by the formations, transformations and continuities in the urban form and use of space through history. Each culture in historical continuity, reshapes the urban topography in relation to the previous periods and their existing components. Thus, each time, a new urban space is created by defining a new integrity between former and latter elements of urban topography. However, mainly after the second half of the 20th century, this natural process of urban formation had been interrupted with the rapid urban development as well as the changes in technologies, tools and approaches of construction and planning. In most of the cases this resulted in the defragmentation and loss of different historical and archaeological layers that constitutes the collective memory and urban identity.

Based on this theoretical framework, in this poster, the historical continuity and urban archaeology of Amasya – a multi-layered historic town in the Northern Anatolia which embraces edifices from Hittite, Roman, Seljukid and Ottoman and Turkish Republican periods – will be analyzed and assessed. Focusing mainly on the problems of the defragmentation and loss of the components of urban form and historical stratification, this poster aims at identifying the physical, visual, and natural constituents of the collective memory, while discussing the strategies to re-constitute the fragmented and lost elements of historical continuity.

Keywords: historical continuity, collective memory, multi-layered Anatolian towns, Amasya.

Introduction

The theme of this study is to research and analyze Amasya in terms of multi-layeredness, assess the historical stratification of Amasya and constitute a base framework for a design in Amasya which is a multi-layered town (Fig. 1).

Multi-layeredness is an archaeological term that refers to more than one layer being together. The concept of multi-layered historical town refers to the presence of the different periods' remains and traces in a town which has been continuously settled since the historical time and where still settlement exists. Multi-layered historical towns are the continuously settled areas that are being settled today and as a proof of the continuous settlement, these areas house the different periods' traces underground or above the ground (BİLGİN ALTINÖZ 2002). Settlements built on remains of different periods have physical relationships with the previous and next periods' edifices inevitably but the historical continuity of the multi-layered historical towns is a point at issue.



Fig. 1 – Multi-layered historical town Amasya (Copyright: Leyla Etyemez).

According to Boyer, in some cases the superimposed historical layers of different time periods can have only physical relations which he explains like “*touching but not necessarily informing each other*” (BOYER 1994: 19). Moreover, he mentions that in some cases the architectural and archaeological remains from historical times translated into contemporary views of the city decompose the city. Then, he adds that the restoration of the former edifices causes “*a hybrid layering of architectural sites and constant migration from one time period to another*” (BOYER 1994: ix).

As a contradictory idea to the Boyer’s, the different periods’ buildings, remains and traces are heritages which can be accepted as spatial and architectural diversities as a result of natural development and continuity of the inhabitation. According to both thoughts the different periods and their physical components constitute the urban form and identity of the city (BILGIN ALTINÖZ 2002). The present urban physical structure that is intertwined with the previous and next periods’ edifices creates the distinctive character of the city.

Location of Amasya

Amasya is located in the inner part of the Black Sea region of Turkey. Samsun in the north, Tokat in the east and south-east, Çorum in the west and Yozgat in the south, are the neighbour cities of Amasya (Fig. 2). The city was established in the Yesilirmak valley, about 400m above the sea-level, which is between the two mountains Harşena and Ferhat (ÖZDEMİR 2003).



Fig. 2 – Satellite view of current Amasya (Copyright: Google Earth, last accessed on 17.02.2011).

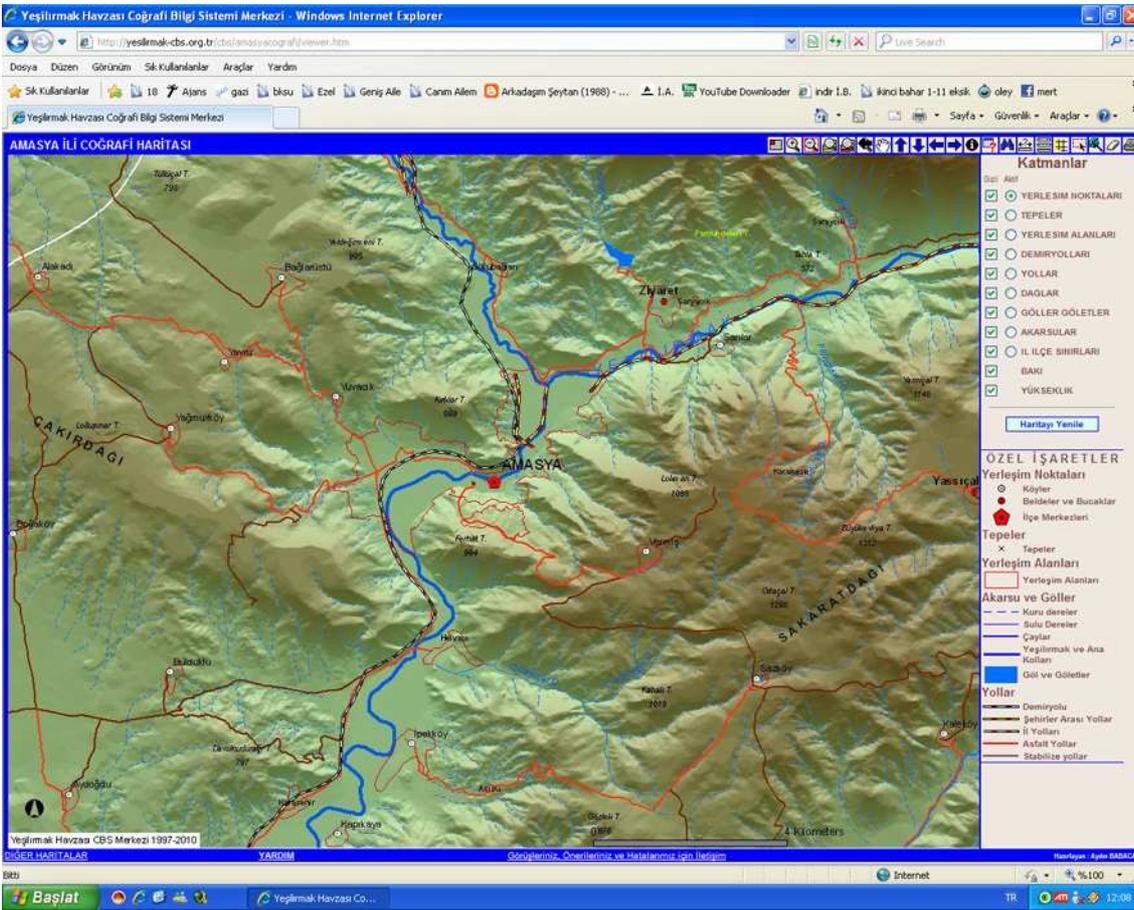


Fig. 3 – Topographic Map of Amasya (Copyright: Yesilirmak-gis database).

Natural and Topographical Aspects of Amasya

The most dominant factor of the natural structure of Amasya is being surrounded with hilly mountains, and the Yeşilırmak River which fractures the land and constitutes the Yesilırmak Valley (Fig. 3). Along the Yesilırmak Valley flat lands were formed by the carried alluvial by the river. Due to its natural structure which provides security and due to its fruitful soil Amasya has ever been the magnet of the region since the early times.

Amasya is on the fault line of North Anatolia and it is in the primary earthquake zone of Turkey. Although the earthquakes were really intensive, a few vital destruction was occurred in Amasya because the city center is located on the strong limestone rocks. The earliest destructive earthquakes were happened in 236 BC and 509 BC during the Roman and Byzantine Periods. Until 16th century there is not any data about the earthquakes. After the 16th century many earthquakes were recorded, the biggest was in the 1668 AD and 1939 AD whose center is in Erzincan.

History of Amasya

In the light of the data gathered from the archaeological research, excavations and surveys the history of the city extends to the Calcholithic Era (5500–3800 BC) (2007a).

In the Early Bronze Age Amasya was the military and the commercial center of the time and in the Middle Bronze Age federal small governments and prinedoms were established and the city is known as “Hatti Ülkesi”. Then, around the 1680 BC the Hittites ruled the city with the name “Hakmiş” and constructed fortress and the city wall. With the migrations and riots a disastrous fire was started about 1190 BC, the evidences of this disaster were found under the Kızlar Sarayı (2007a).

With the Iron Age Phrygians settled on the ashes of the Hittite city by bringing on the goddess Kubaba, Kybele and rock temple. After Phrygians, Cimmerians, Scythians around 700 BC and Medes, Persians around 585 BC ruled the city. During these centuries the city had many fires and invasions. After the Persian rule, Amasya became the capital city of Strap of Cappadocia around 400 BC. By the invasions of Alexander the Great Persian rule was finalized.

After Alexander's collapse Hellenistic Era was started and Amasya became the capital city of the Pontus Kingdom in 323 BC. The rock tombs of the rulers of the Pontus Kingdom were constructed to devote to God's. During the Pontus Kingdom Amasya developed in terms of finance and as a consequence in terms of architecture. Alçak Bridge was constructed and the fortress and the city wall was restored (Tab. 1).

After a longstanding struggles around 67 BC Roman Empire surrounded Amasya by demolishing outer and inner walls of the city, instead they constructed high city walls. Roman bath, temples, cisterns, altars, tombs were constructed. The city became a Roman territory about 4 centuries until the Roman Empire is divided into two.

In the Byzantine Period Amasya became a religious center. Many monasteries, churches, Helkis Bridge and Magdenus Bridge were constructed. Between 527 and 565 AD the fortress and the city walls were restored. Between the 7th and 10th centuries the city was surrounded so many times due to Arab invasions that it could not be extended and developed, besides the city shrunk into the city walls. After 700-yearred sovereignty of the Byzantine, Danishmends conquered Amasya in 1075.

Hellenistic Period	Pontus Kingdom	30-330BC	-capital city -Rock Tombs were constructed -Algak Bridge was constructed -Castle restored, citadel walls were enlarged -developed in terms of finance & architecture
	Persians	330-546BC	-many invasions & fires -capital of Strap of Cappadocia
Iron Age	Medes	546-585BC	
	Kimmers Scythians	585-675BC	
	Phrygians	675-750BC	-restored the Citadel Walls -houses, rock temples
	Late	1200-2000BC	-Hittites ruled the city as the name HAKMIŞ (around 1680BC) -Castle & Citadel Walls, streets, buildings, aqueducts -migrations & riots -FIRE
Bronze Age	Middle	2000-2500BC	-"Hatti Ülkesi" -small governments and principdoms
	Early	2500-3800BC	-military & commercial center
Calcolithic Era		3800-5500BC	-known date of first inhabitation -military & commercial center
Paleolithic Era		13000BC	-the predictions about the beginning of inhabitation.

Tab. 1 – Timeline of History of Amasya (Copyright: Leyla Etyemez).

During the Danishmend Principality Amasya was the capital city of the Principality. They constructed medrese and mosques, also they re-functioned the churches as mosques (Fig. 4–5). With the crusade in 1100 AD the city was destroyed and after about a half century the city was ruled by Seljuks.



Fig. 4 – Fethiye Cami, 1930 (Copyright: Menç 2007: 118).



Fig. 5 – Fethiye Cami, 2007 (Copyright: 2007a: 95).

Amasya was a cultural and a production center during the Seljuk Period. Kunc Bridge, mosques, medrese and baths were constructed. As a consequence of the defeat of the Seljuks in the Köseadağ Battle in 1243, the region came under the rule of the Ilkhanids. They constructed important monumental buildings like Bimarhane, mosques, medrese, zaviye and tombs. Eretna Principality took the opportunity of the throne fights of Ilkhanids rulers and surrounded Amasya in 1341. Although the Seljuks and these three principalities' periods were not so long, they lasted about a century, they constructed many monumental buildings (Tab. 2). Moreover, during these consecutive four periods the buildings were used continuously in terms of function (ÖZDEMİR n.d.: 7–38).

Eretna Pr.	1389AD	-invasions & fires -Saraçhane Mosque -Kadılar Tomb & Fountain were constructed
	1341AD	-Bimarhane -Gökmedrese Mosque&Zaviye -Toruntay, Şadgeldi, Tacettin Altıntaş, Sultan Mesut Tombs were constructed
Ilhanlilar	1243AD	- cultural & production center -Hatuniye, Yukarı Çelebiler, Yıldız, Konak Baths -Hilafet Gazi Tomb -Burmali Minare Mosque&Tombs -Kunc Bridge were built
	1143AD	- capital city -Fethiye Mosque, Hilafet Gazi Medresesi, Ayaş Aga Medresesi, Log Minare were constructed -churches refunctioned as mosques -1100AD with crusade city was destroyed
Seljuk Period	1075AD	- religious center , churches and monasteries were built -509AD earthquake 527-565AD castle&citadel wall were restored -Helkis Bridge & Madinus Brigde were constructed -7th-10th centuries Arap invasions
	395AD	-demolished inner&outer city walls -constructed high citadel walls -temples, tombs, altars, cisterns were constructed (under Kızlar Sarayı) -goddess temple built (under Beyazid Mosque) -roman bath was built under PTT&municipality building
Danishmend	67BC	
Byzantine		
Roman Period		

Tab. 2 – Timeline of History of Amasya (Copyright: Leyla Etyemez).

In 1398 Yıldırım Bayezid added Amasya in Ottoman territories. Amasya was a cultural and an administrative center until Suleiman the magnificent period. The sons of the sultans were educated in Amasya so the city had the name “*Şahzadeler Şehri*”. Religious, cultural, commercial, administrative buildings were constructed mostly during the first 150 years of the Empire. After the 17th century the architectural developments were started to decrease caused by the military defeats. Furthermore, Ottoman Empire started to lose its financial and military power after 18th century due to the developments in the west. Only the caravanserai like commercial buildings were constructed in 18th century in order to accelerate the financial movements in the territory. In 19th century, with the administrative reforms school like new building types were introduced and the urban structure of the city was started to change, somehow by destroying and constructing. The city had many fires and overflows during the Ottoman Empire, the buildings and bridges destroyed and restored so many times. The biggest fire which was set by Armenians was in 1913 (Tab. 3). The fire influenced about

one third of the city on the south side of the Yeşilirmak river and after the disaster the area was left empty for about 25 years (KUZUCULAR 1993) (Fig. 6).

Republic of Turkey	1984	-Log Minare was demolished.
	1965	-Alçak Bridge was demolished again because of the flood and concrete bridge was constructed.
	1946	-Government building burned down.
	1944	-Saraydüzü Barracks was demolished.
	1940	-Meydan Bridge was repaired.
	1939	-White Helkis Bridge was replaced with a concrete one, the Clock Tower was demolished.
	1927	-Kılıçaslan Primary School and Station Building were built and railway activated.
1923	-Meydan Gate was destroyed for the railway.	
Ottoman Empire	1919	-Amasya Genelgesi on 22nd of June
	1915	-the area between Selağzı and Üçler district called "Yangın Yeri" because of the big fire. -Madenus Gate was demolished in order to enlarge.
	1908	-the fire destroyed 600 houses and stores.
	1900	-Saraydüzü Barracks was constructed because of Armenian rebel.
	1898	-the big fire destroyed lots of buildings.
	1881	-Yeşilirmak overflow, the Alçak Bridge destroyed and constructed a wooden bridge on stone piers.
	1865	-Government Building and Clock Tower were built
	1864	-Saray Gate of Alçak Bridge was demolished
	1855	-The Alçak Bridge was damaged, wooden bridge was constructed
	1852	-Kızlar Sarayı was abandoned 1852. -education center -Şehzadeler Şehri
1389AD	-cultural & administrative center until Kanuni Sultan Süleyman Period	

Tab. 3 – Timeline of History of Amasya (Copyright: Leyla Etyemez).

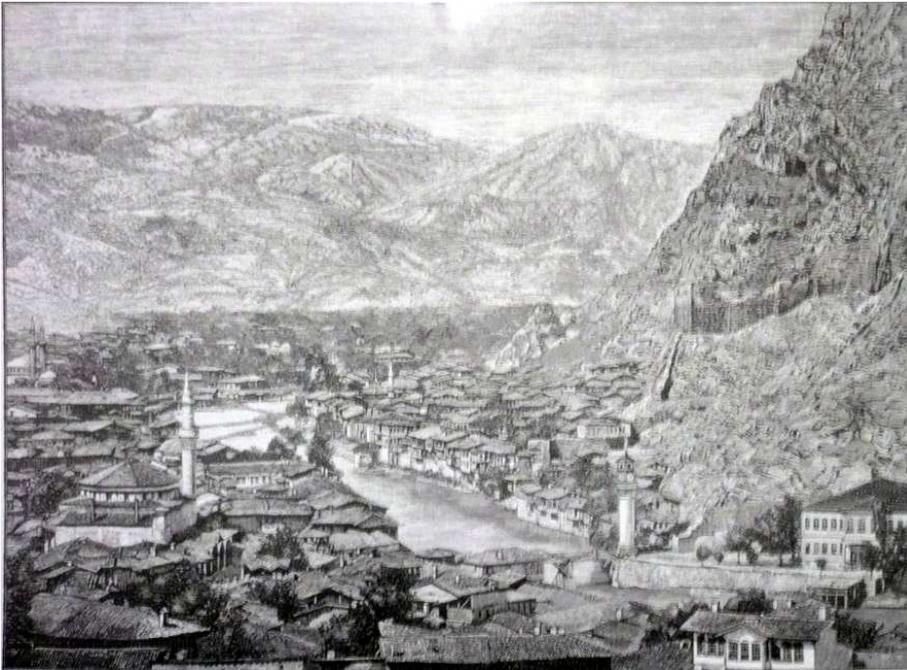


Fig. 6 – Engraving of Hesperos. Leipsia, 1885, v.4: 305 (Copyright: Menç 2007).

On 22nd of June in 1919 Amasya Genelgesi was written by Mustafa Kemal and his companions and foundations of the Republic of Turkey were laid. After the foundation of the Republic the railway construction was started in Amasya and activated in 1927. Although Amasya has unique values about history and natural morphology, the planning studies started in 1928, first development plan was prepared in 1945 (1981: 444) and the Conservation Plan Decisions for Transition Period for Urban and Historical Sites in Amasya was prepared in 1981 and it is still valid. In 1948 there occurred an enormous overflow and a large area was influenced. For the victims of the disaster, small modest one-storey 100 houses were constructed in the area where the Armenian fire was set. This houses were used for 40 years (Fig. 7).

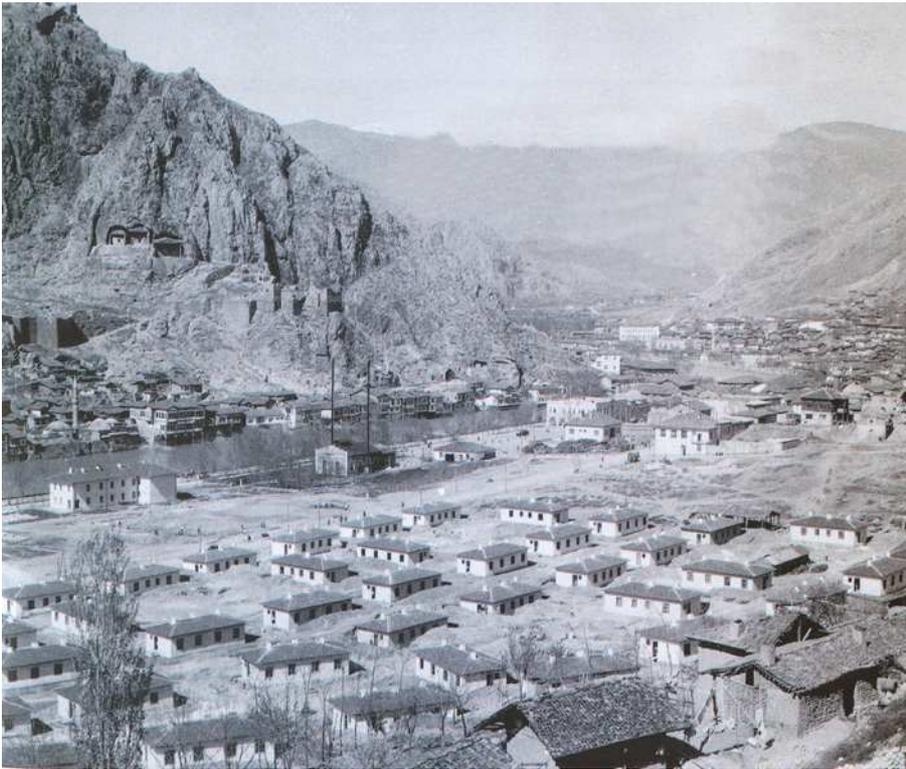


Fig. 7 – 100 Evler (Copyright: Menç 2007: 171).

Multilayered Town Amasya

Under this subject the diachronic plans and stratification of Amasya will be explained. The layers of the periods will be shown on the plans that are taken from Iller Bankasi. Not only the remained edifices from the periods but possible settled are and demolished edifices will be shown although they are hypothetical. Finally in light of the plano-volumetric view of Amasya the assessments of different quality areas will be shown. From the gathered data the diachronic plans of Hittite Kingdom, Hellenistic Period (Pontus Kingdom), Roman Period, Byzantine Period, end of 14th century, Ottoman Empire and current plan of Amasya will be shown.

Diachronic Plans of Amasya

Amasya is located on a land between two hilly mountains and fractured by a river. Because of its topographical and natural features it is continuously settled. The settlement started from the peak of Harşena Mountain by Hittites building the fortress and city walls in order to the secure the city. Firstly the city enlarged

only through the city walls during the Hittite Kingdom. Because of the topographical properties of the area there could only be a hypothetical street that is parallel to the river and according to the Kuzucular there is a bridge far away from the settlement on the north-east that links the street coming from Tokat to Samsun. One more thing is the hypothetical aqueduct which comes from the south-west and goes to the north-east and passes from the south side of the river (Fig. 8).

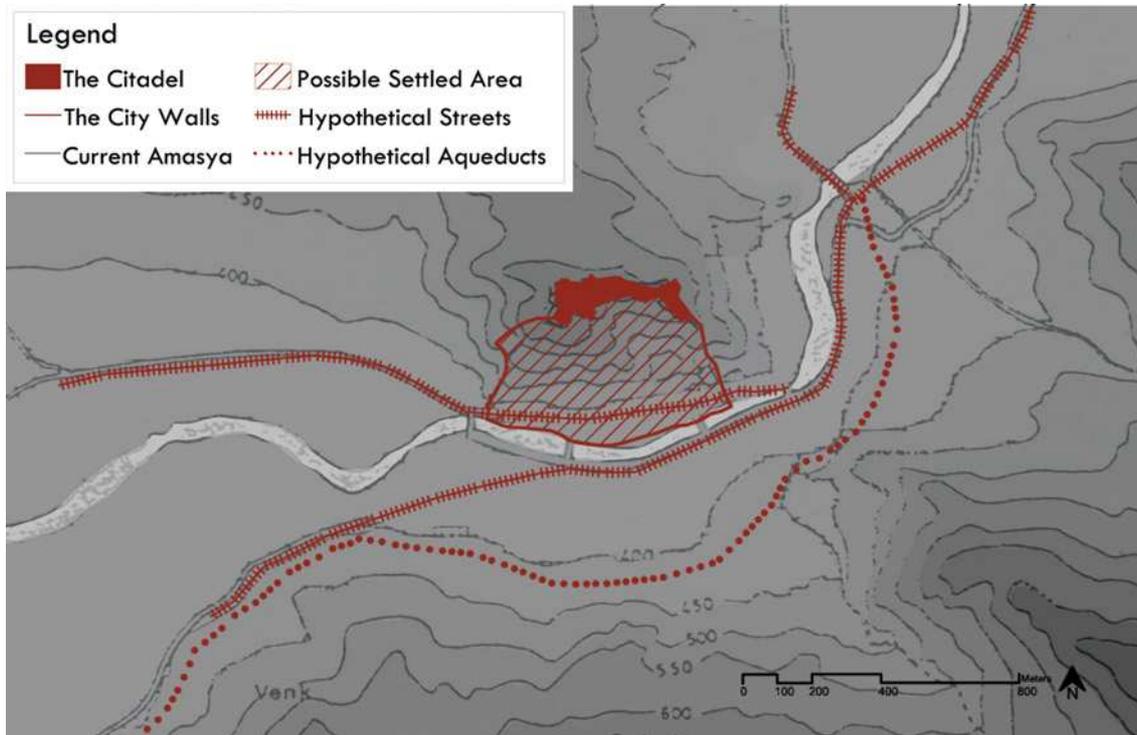


Fig. 8 – The Hittite Period of Amasya (Copyright: Leyla Etyemez After İller Bankası Halihazır Haritaları ve Genel Kurmay Başkanlığı).

During the Hellenistic Period the city can be said that it enlarged towards the outside of the city walls and towards the south of the river by referring to the Alçak Bridge which was constructed in this period. To addition to the edifices of Hittite Kingdom the rock tombs and the palace was constructed in this period, that shows the city developed its organization in terms of administration. Moreover, as Strabon says the settled area on the south of the river is a rural, slum area with a low density (Fig. 9).

The city reached the topographical thresholds of the site during Roman Period. It can be understood from the coins during Roman Period Amasya was an important and rich city. So they should have developed the constructions works and re-construction works but it is only known that a roman bath and a Goddess Temple was constructed where the II. Bayezid Complex and the Municipality building exist now and under the Mosque of the Complex we can see some construction materials which are estimated that those belong to Goddess Temple (Fig. 10).

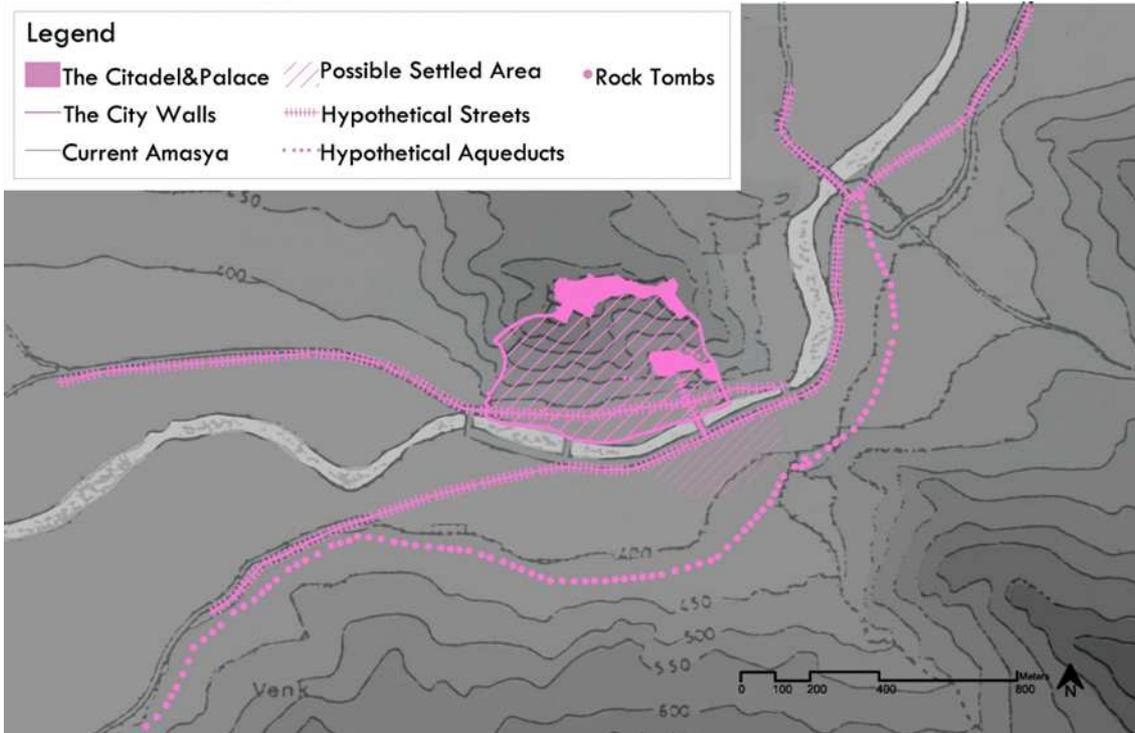


Fig. 9 – The Hellenistic Period of Amasya (Copyright: Leyla Etyemez After İller Bankasi Halihazır Haritalari ve Genel Kurmay Başkanlığı).

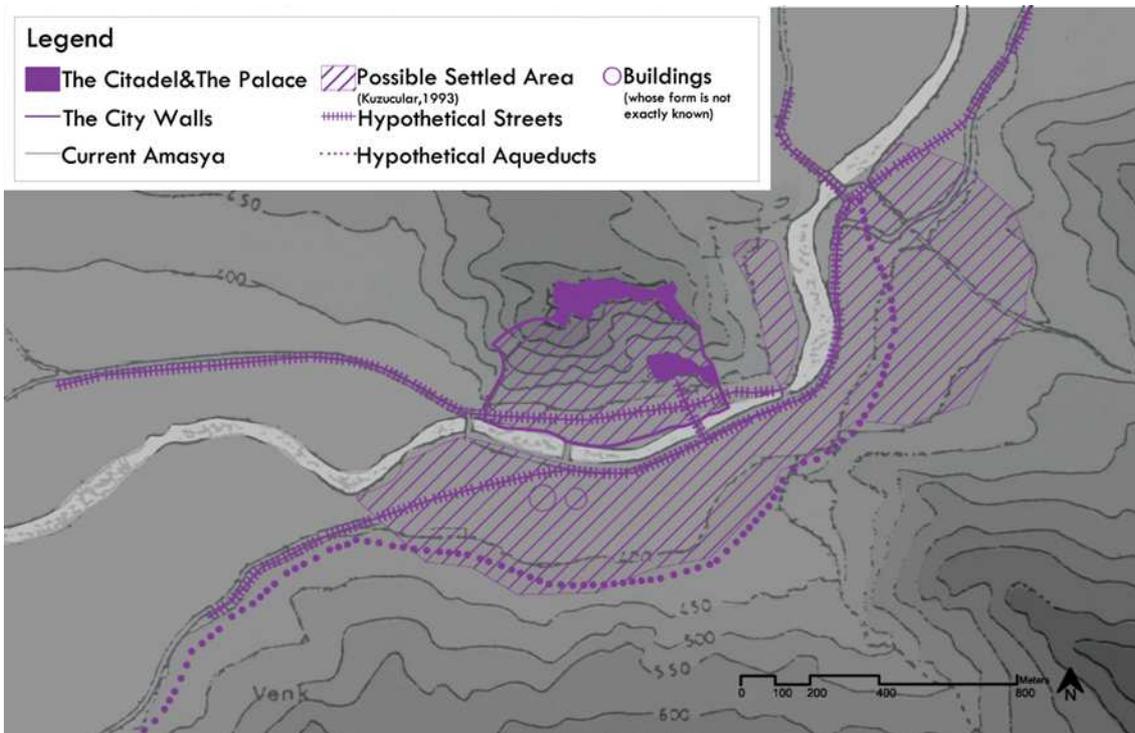


Fig. 10 – The Roman Period of Amasya (Copyright: Leyla Etyemez After İller Bankasi Halihazır Haritalari ve Genel Kurmay Başkanlığı).

Because Amasya was a religious center in the Byzantine Period many churches is thought to have been constructed. A few of their names is known and the locations of this churches are being guessed. Besides the remains in the city walls the only in-situ remain from this period is Fethiye Mosque which was a church

and converted into a mosque in Danishmend Period. Furthermore, Strabon says for this Period different from the Pontus Kingdom the south of the river which is a slum area has a high density. After 7th century Arab invasions were started and the city started to shrink through inside the city walls. Between 7th and 11th centuries inside of the city walls of Amasya became a refuge due to its topographical aspects (Fig. 11).

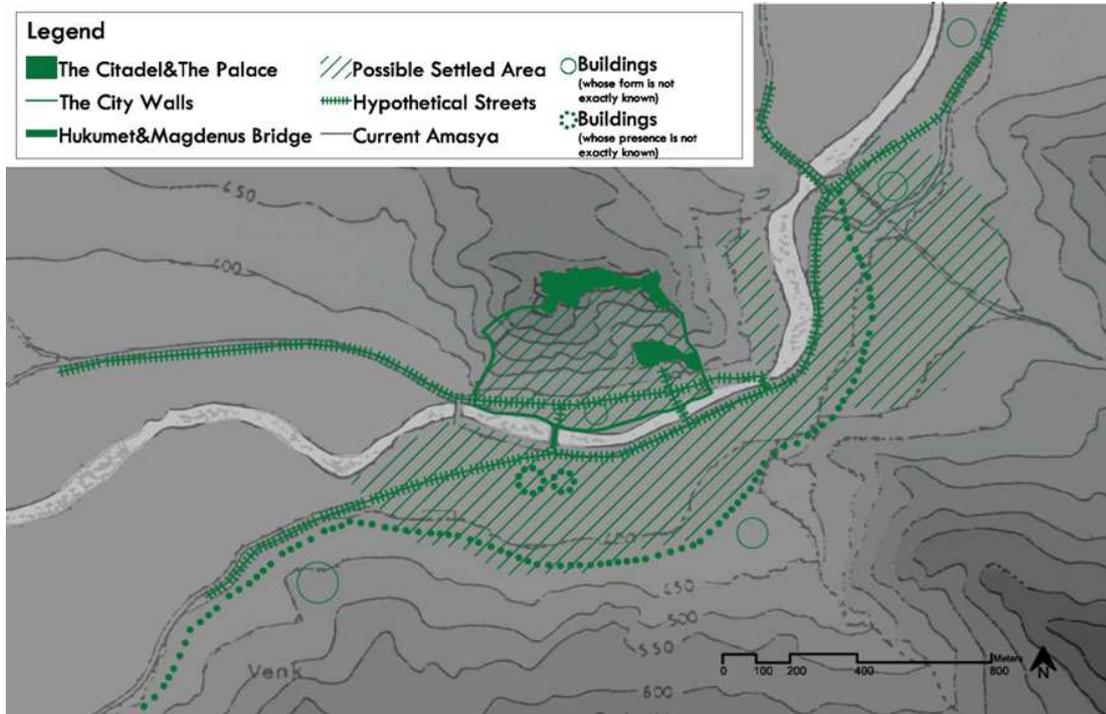


Fig. 11 – The Byzantine Period of Amasya (Copyright: Leyla Etyemez After İller Bankasi Hali hazır Haritalari ve Genel Kurmay Başkanlığı).

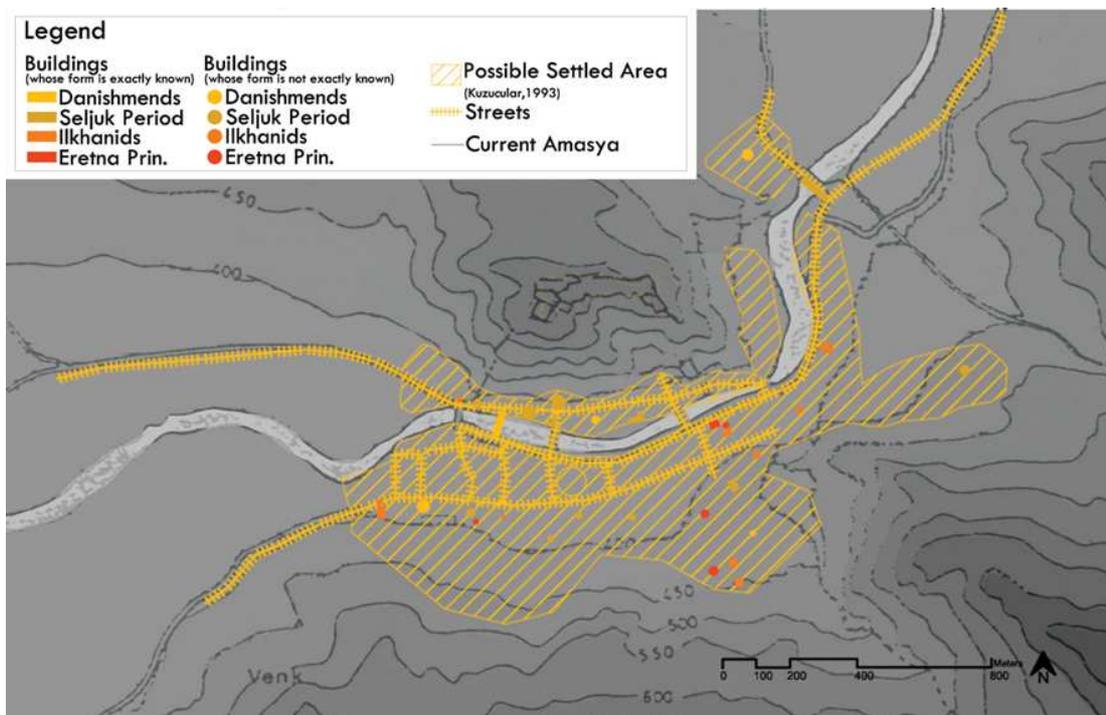


Fig. 12 – The Principality and Seljukid Period of Amasya (Copyright: Leyla Etyemez After İller Bankasi Hali hazır Haritalari ve Genel Kurmay Başkanlığı).

After Byzantine Period Turkish Principalities conquered the city until the 14th century. In sequence Danishmends, Seljuks, Ilkhanids and Eretna Principalities, each of them lasted for about a century. Their expansion areas are likely the same and they constructed the same type of buildings. It can be said that they acted as they were the continuation of each other in terms of urban form and architecture. Many important monumental buildings were constructed in this period (Fig. 12).

Ottoman Empire is a long period of time. Mostly the construction activities took place before the 17th century. The city enlarged its largest limits towards the topographical thresholds. Then the city started to enlarge towards the east-west direction where the topography allows the expansion. As the same with the other Anatolian cities, a little masjid or a zaviye is constructed, the population around this buildings increases, then the in between areas of this centers are filled organically. The same procedure was valid for Amasya, too (Fig. 13).

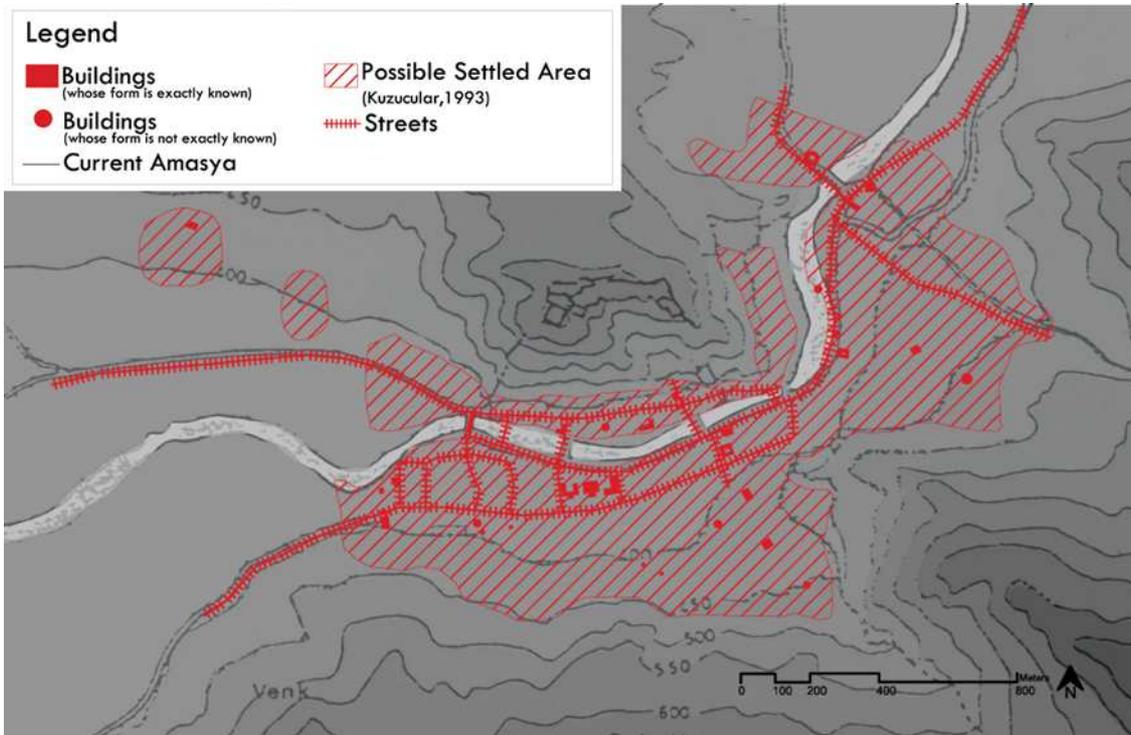


Fig. 13 – The Principalities and Seljukid Period of Amasya (Copyright: Leyla Etyemez After İller Bankası Halihazır Haritaları ve Genel Kurmay Başkanlığı).

After the foundation of the Republican Period the city naturally went beyond the topography and continuously got larger. Starting from the construction of the railway road, mainly after the second half of the 20th century, this natural process of urban formation had been interrupted with the rapid development well as the changes in technologies, tools and approaches of construction and planning. In most of the cases this resulted in the defragmentation and loss of different historical and archaeological layers that constitute the collective memory and urban identity. In the current town there are registered buildings and conservation sites and their conservation projects are proposed individually. Even the conservation sites are not linked (Fig. 14).



Fig. 14 – Satellite view of current Amasya with conservation sites and registered buildings (Copyright: Leyla Etyemez after Google Earth, last accessed on 17.02.2011).

Plano-volumetric view of Amasya

As it is mentioned above Amasya is a multi-layered historical town which has been settled since the end of the Palaeolithic Age. The town has been continuously inhabited since that date and in-situ remains and traces of different periods are underground and above ground. Each layer of the time periods are analysed and the diachronic plans of this periods are tried to produce in order to superpose layers and produce the plano-volumetric view of the city. By the help of the stratigraphic sections the analysis will be taken further to see Amasya's distinctive character which can be accepted as a multilayered town not only in the sense of verticality but being one within the other due its physical morphology (Fig. 15).

Assessment of Different Quality Areas of Amasya

By the use of the superposition of the plans the continuous, transformations and the interruptions will be assessed and based on the same analysis different quality areas; identity areas, risk areas and reserve areas can be determined.¹

The river has been a constant identical urban element for all periods, hence the identity area of Amasya is undoubtedly the river, the riverbank and its hinterland. As a result of the superpositioning of the periods' plans, the area which is defined by the two bridges; Magdenus and Alçak on the west and east, is the identity area of multilayeredness (Fig. 16).

¹ This methodology is discussed and experimented by A. Guliz Bilgin Altınöz in her Masters and PhD theses (BILGIN 1996; ALTINÖZ 2002).

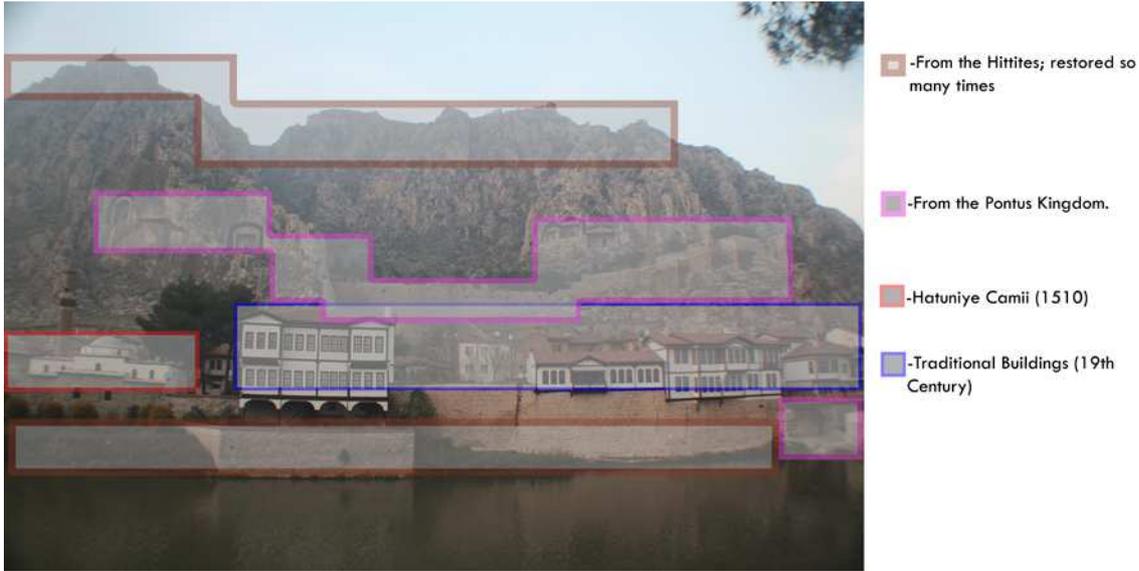


Fig. 15 – Multi-layeredness of Amasya (Copyright: Leyla Etyemez).

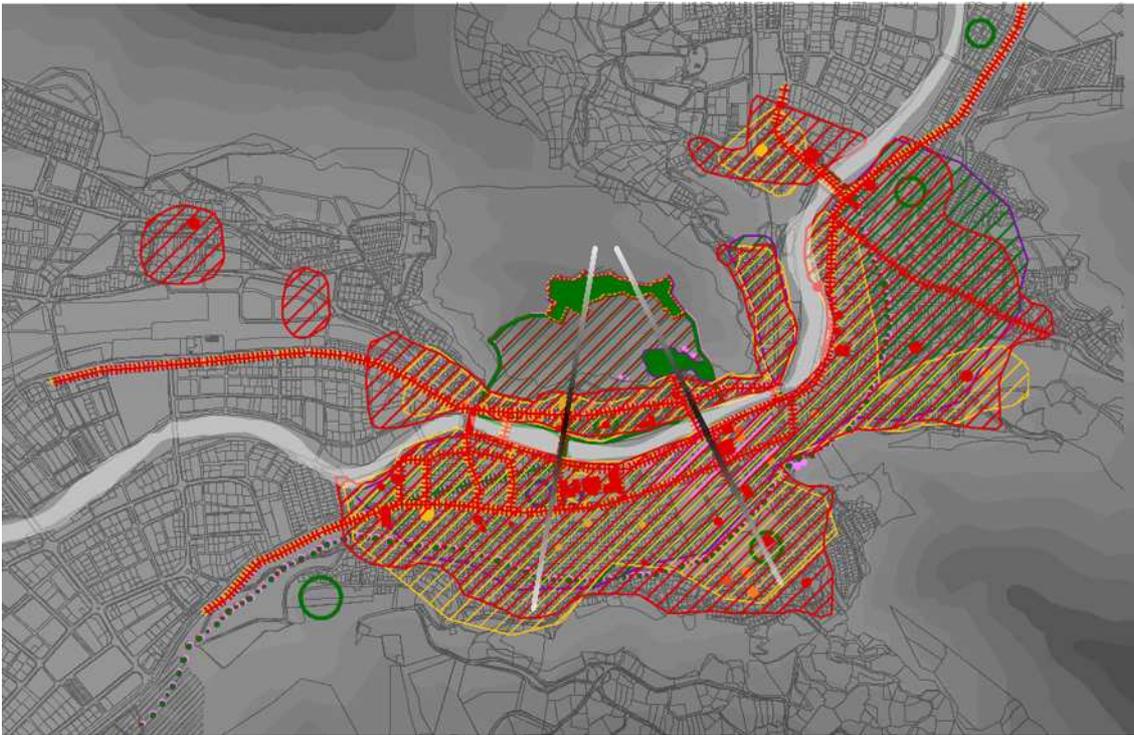


Fig. 16 – Assessment of multi-layeredness and the river of Amasya (Copyright: Leyla Etyemez After İller Bankası Halihazır Haritaları ve Genel Kurmay Başkanlığı).

The reserve areas could not be exactly defined because of the lack of information. But it can be sad that the north side of the railway road on the skirts of the Harşena Mountain and the skirts of the Ferhat Mountain on the north are the reserve areas due to the landslide hazard.

The risk areas will not be explained and shown in detailed manner in the scope of this study. Only the risk areas which are inside the identity area that is shown above will be explained. Firstly, the Alçak Bridge which is the earliest one in Amasya is a multi-layered urban element. The city wall which is also acts as a retaining wall for the riverbank contains remains from all periods. The railway road itself can be said that an addition of

a period which created a physical boundary of the area that allows passages by only 2 accesses. The area where the II. Bayezid Complex exists has been always used with a religious purpose in different architectural forms. These examples can be increased for Amasya but they are sufficient in the majority to take the area as a site to design.

Project Area

The Problem of the Area

Most of the cases of urban development results in the defragmentation and loss of different historical and archaeological layers that constitutes the collective memory and urban identity of the town. For the case of Amasya, some implementations were done consciously or unconsciously to present the history of Amasya but the problem is that the implementations and presentations were only intend to address only for one Period or one event or one person. Although Amasya has a unique distinctive value of having a natural morphology intertwine with the archaeological, historical and traditional edifices, the applications that were done on the riverbank and in its hinterland cannot be accepted. Because they addressing only to a specific phenomenon or period and ignoring the others or ignoring not only the multi-layeredness but also the history of Amasya.

The project Idea

As it is mentioned above that the river has been continuously an identical urban element for all periods, hence undoubtedly the river, the riverbank and its hinterland has a big potential to make a project. The idea of the project consist of re-evaluating the multi-layered character of the riverbank and its hinterland and the historical continuity. The project will aim to present the layers and make the multi-layeredness distinguishable and perceivable, to make people to experience and understand the historical continuity and to constitute the collective memory.

The railway sits on the earliest street of the town, the river and the Mustafa Kemal Paşa Caddesi define an area where have the potentials of stratification and defined as identity area. In the scope of the project this area will be re-evaluated in terms of physical conditions. In details as shown on the plan and the photograph on the left the river bank will be re-designed (Fig. 17).

The pedestrian route will be re-organized which comes from the city center passes over bridges and through the traditional houses towards the Kızlar Sarayı. The Magdenus Bridge will be replaced with a contemporary one. The riverbank which is now full of Sehzade's busts and the light poles will be re-designed with respect to the vista and the panorama of Amasya.

In details, as shown below the north side of the railway will be excavated and the edifices will be presented. Possible historical residential edifices will be available for the experiences of the visitors (Fig. 18).



Fig. 17 – Project Area (Copyright: Leyla Etyemez).

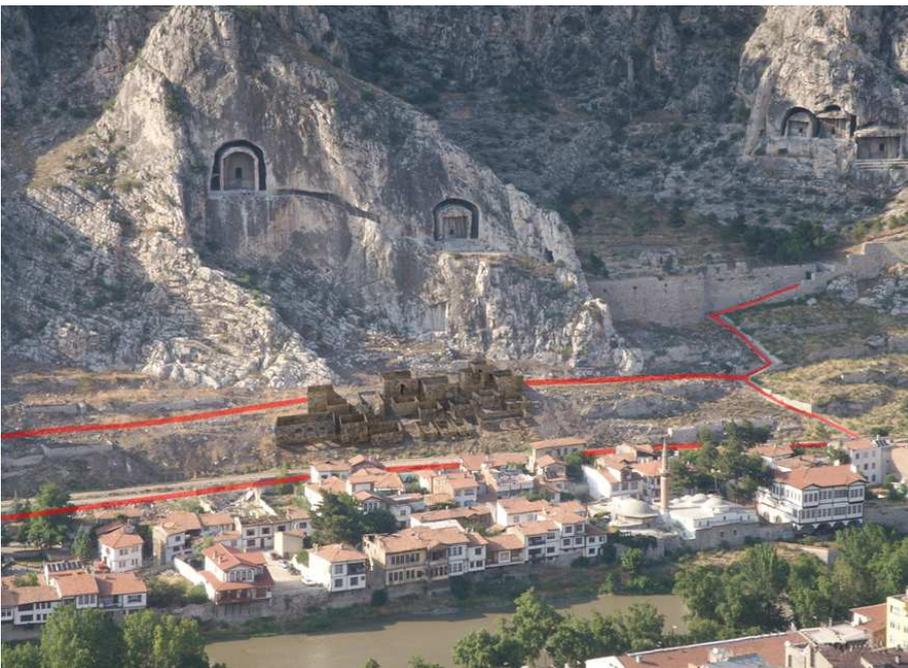


Fig. 18 – Project Area (Copyright: Leyla Etyemez).

The south bank of the Alçak Bridge will be re-designed by decreasing the levels towards the river reaching to the edifices of the antique bridge. To highlight the multi-layered character of the bridge the water level of the river will be decreased by the help of the regulators outside the settlement. The visitors will be able to have the opportunity to experience the edifices of the antique bridge and the layers of the multi-layered historical town Amasya (Fig. 19).



Fig. 19 – Project Area (Copyright: Leyla Etyemez).

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Assessment of the Conservation State of Masonry Structures in Monumental Buildings by the Integrated Use of Non-Destructive Ultrasonic Techniques and Mineral Analyses

Silvana FAIS^{1,2} / Paola LIGAS¹ / Marcella PALOMBA³

¹ Dipartimento di Geingegneria e Tecnologie Ambientali, University of Cagliari, Cagliari, Italy / ² Consorzio Interuniversitario Nazionale per l'Ingegneria delle Georisorse (CI.NI.Geo), Roma, Italy / ³ Istituto di Geologia Ambientale e Geingegneria del C.N.R. – Sezione di Cagliari, c/o Facoltà di Ingegneria, University of Cagliari, Cagliari, Italy

Abstract: Integrated in-situ Non-Destructive (ND) ultrasonic techniques and mineral analyses were carried out to assess the conservation state of masonry structures in monumental buildings. In situ measurements of ultrasonic longitudinal pulse velocity, were carried out in a representative monument in the historical center of Cagliari (Italy), to detect the elasto-mechanical conditions of the building materials. Ultrasonic measurements by surface or indirect transmission were performed using the *step by step* and refraction modalities. These different acquisition modalities were very effective in detecting the shallow altered areas of the building materials (*step by step* modality) and defining the thickness of the alteration (refraction modality). Based on the results of the ultrasonic investigations, a sampling was planned in the critical sectors of the façade to determine the mineral composition of mortar, bricks and building stones, as well as type and intensity of alteration. The collected samples were investigated by optical studies and X-Ray Diffraction (XRD) method.

The integrated analysis of the acoustic and mineral data evidenced the correlation between the different acoustic signal propagation velocities and the intensity of alteration and type of materials. The analysis also provided significant quantitative information on the preservation state of the building materials.

Keywords: Non-Destructive ultrasonic techniques, mineral analyses, masonry structures, monumental buildings.

Introduction

In recent years Non-Destructive (ND) acoustic techniques, and particularly the ultrasonic techniques, have become very effective *i)* to provide significant information on the conservation state of building materials, both in laboratory and on site conditions, *ii)* to locate the best sampling sites, on which to carry out laboratory analyses and tests. In fact altered and weakened zones of the structures, as well as microfractures and flaking of the materials, represent potential defects, and are generally characterized by lower acoustic velocity values than those measured on unaltered materials. Therefore, acoustic velocity can be used as one of more reliable means of *in-situ* characterization of building materials (CASULA *et al.* 2009; CHRISTARAS 1997; CONCU *et al.* 2003; FAIS *et al.* 1999, 2002, 2005, 2008, 2010; GALAN *et al.* 1991).

This paper reports the results of a study carried out using the integrated ultrasonic and mineral techniques to assess the conservation state of the façade of the monumental building of Palazzo Regio. Figure 1 shows the location of the investigated sectors.



Fig. 1 – Palazzo Regio façade: location of sectors investigated by ultrasonic and mineral techniques.

The ultrasonic measurements were performed using the Portable Ultrasonic Non-Destructive Digital Indicating Tester (PUNDIT) by C.N.S. Electronics LTD using 24–54 kHz transducers. The data acquisition was carried out using the indirect or surface technique (transmitter and receiver on the same face of the investigated object).

The mineral studies were performed by X-Ray Diffraction (XRD) and optical techniques on microsamples collected from the shallow part of the walls and some representative sectors inside the walls, to determine the mineral composition as well as type and intensity of materials' alteration.

Ultrasonic investigations

The ultrasonic investigations were carried out in the masonry wall of the façade of Palazzo Regio (Fig. 1), which shows several zones strongly affected by alteration phenomena. The investigation was carried out using 24–54 kHz ultrasonic range to define the thickness of the altered surfaces, and detecting any mechanical discontinuities and/or damaged zones, through the study of the velocity anomalies (lower velocity) in the propagation of the acoustic signal. During the data acquisition phase, different data acquisition techniques were implemented, and several tests were performed with the aim of selecting the proper acquisition geometry, such as the transmitter-receiver distance (offset), the distance between receivers, etc. Ultrasonic techniques were performed using the *step by step* and refraction modalities, by indirect or surface transmission (transmitter and receiver on the same investigated surface) (CHRISTARAS 1997; FAIS *et al.* 1999, 2005, 2008). The *step by step* acquisition technique was applied using different offsets (15 and 30 cm), to check the elastic conditions of the different materials (mortar and masonry) within the shallow part of the masonry. Figure 2 shows the results obtained by the *step by step* technique on the lower, middle and upper parts of Panel 11 of the façade using offsets of 15 (Fig. 2 a, b and c) and 30 cm (Fig. 2 d, e and f).

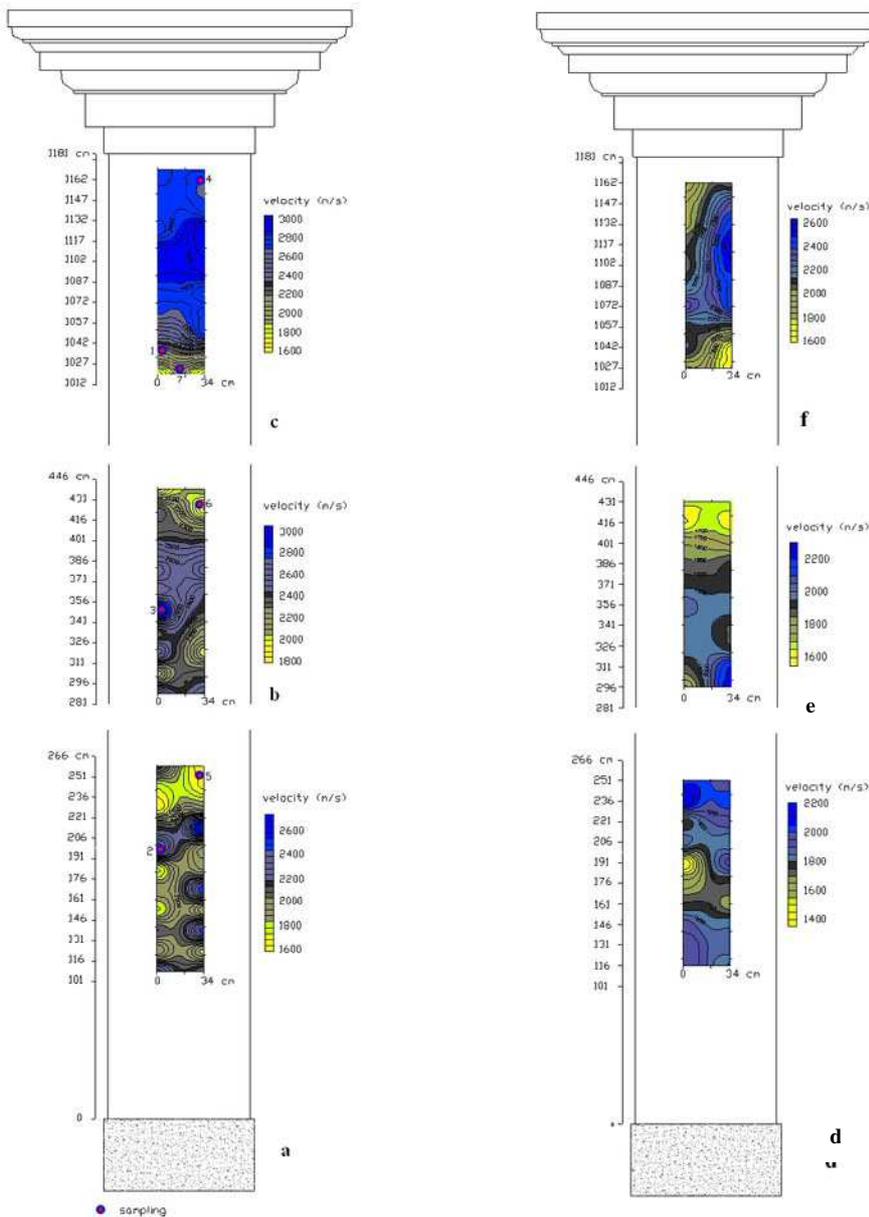


Fig. 2 – Velocity maps of the longitudinal ultrasonic pulses, by the application of the “step by step” acquisition technique in the panel P11. Left side: with offset of 15 cm: a) Lower part, b) middle part, c) upper part; right side: with offset of 30 cm: d) Lower part, e) middle part, f) upper part (1–6: sampling points).

Figure 3d, e and f shows the thickness-velocity sections obtained by refraction on two parallel profiles (Fig. 3a, b, c). As a whole, two ultrasonic units with different elastic behaviour were detected. The shallow unit, characterized by velocity values ranging from 1000 to 2000 m/s and thickness between 2 and 7 cm, can be related to the shallow altered zone, which includes different layers of mortar. The deep unit has a velocity ranging from 2000 and 2800 m/s, and can be related to the underlying masonry. The thicknesses of the shallower unit have been interpolated to obtain the maps shown in Figure 3 g, h and i.

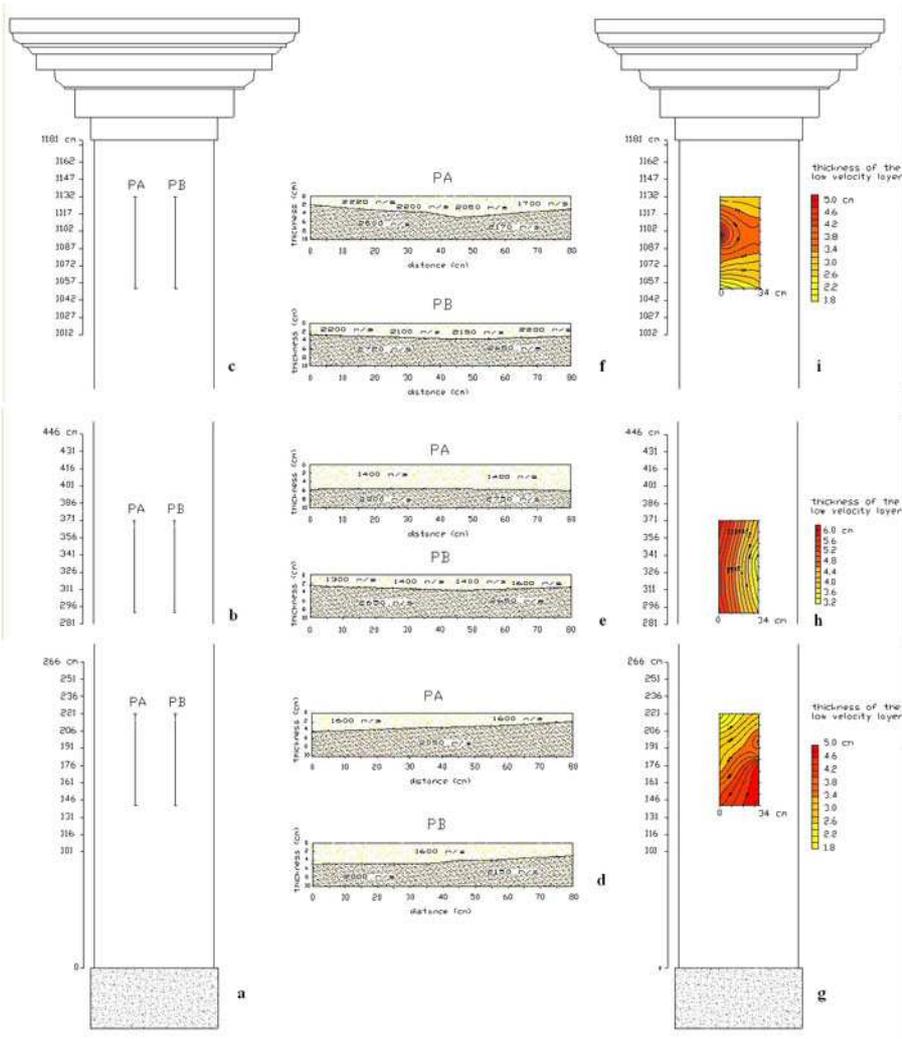


Fig. 3 – Results of refraction methodology application in the panel P11. a), b), c) location of refraction profiles; d), e), f) thickness – velocity sections; g), h), i) maps of the thickness of the low velocity layer.

Mineral investigations

Based on ultrasonic investigations and macroscopic observations, a sampling was planned to acquire information about the mineralogy and intensity of the alteration of building materials. Several mortar, bricks and building stones' microsamples, the essential components of the masonry structure, were collected from both the surface of the façade, and some representative sectors inside the walls. The sampling points were strategically located in the zones characterized by different acoustic signal propagation velocities (Fig. 2) to correlate these zones with the intensity of alteration and the type of material.

The mineral studies were performed by optical and XRD techniques on over forty surface microsamples. Based on the results of the ultrasonic study, two microcores (C1 and C2, Fig. 4), up to 40 cm inside the wall, were carried out in a critical sector of the façade. Although collected in a draught period, the incoherent limestone (C1) was imbued with water. The brick (C2) showed no evidence of alteration or presence of humidity. Mineral studies performed on microcores are indicated by grey lines in Figure 4.

Macroscopic observations revealed that mortar, about 10 cm thick, consists of three different layers more or less altered. Microscopic observations evidenced that *i*) the external layer (EL) is made up of a very altered fine-grained matrix, including mono- and polymineralogical clasts, *ii*) the middle layer (ML), also affected by a significant alteration, is characterized by a rather homogeneous grain size, *iii*) the inner layer (IL), generally less altered than the other two, consists of a homogeneous grain size. Microscopic observations of the building stones confirm they are mainly represented by limestones, which include variable amounts of sand fraction. By optical scale, the bricks were not affected by evident alteration phenomena. The macroscopic and microscopic features of the materials, which form the microcores C1 and C2, are quite similar to those of the materials collected at the surface.

Microsamples of mortar, bricks and building stones, collected both on the surface of the façade, and by two microcores (Fig. 4), were also investigated by the XRD technique. Table 1 summarized the mineral composition of the sampled materials.

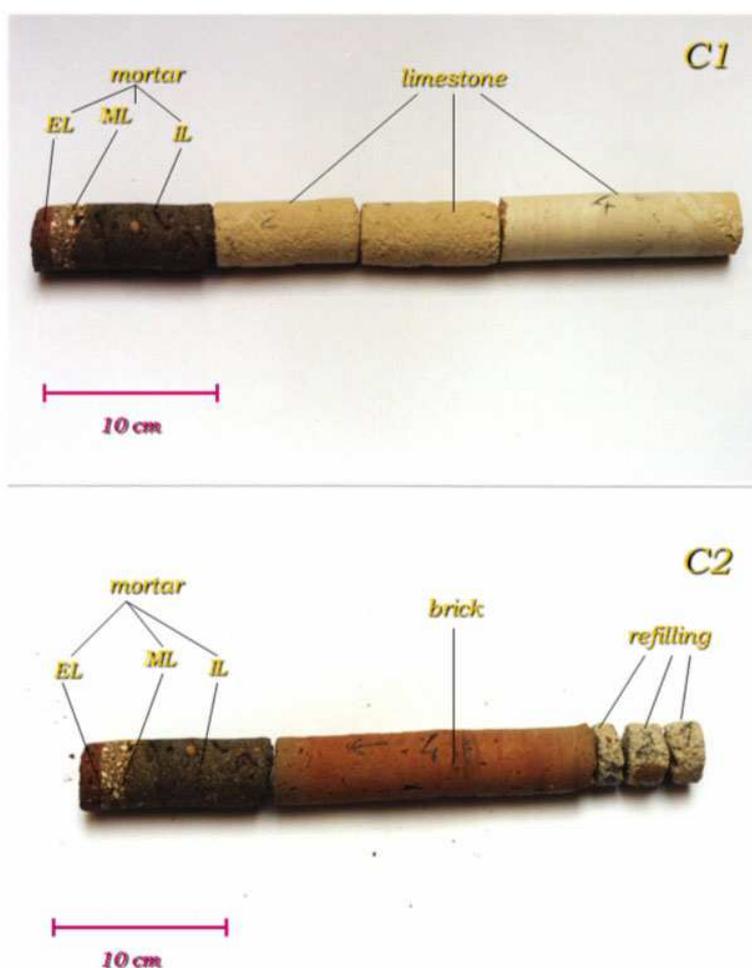


Fig. 4 – Microcores collected in a critical sector of the façade. Mineral studies were performed on the points indicated by grey lines.

The mortar mineral composition of the different materials is described in the following, and summarized for all analyzed samples, in Table 1.

core	building materials	qz	pl	Kf	ca	gy	il
	Mortar (EL)	^		tr	*	^	tr
	Mortar (ML)	^	^	^	*	tr	tr
	Mortar (IL)	*	*	*	^		
	stone block	^		^	*	tr	
	brick	*		^			
C ₁	Mortar (EL)	tr		tr	*		
C ₁	Mortar (ML)	tr	^	tr	*		
C ₁	Mortar (IL)	*	^	*	^		
C ₁	stone block	tr		^	*		
C ₁	stone block				*		
C ₂	Mortar (EL)		tr		*		
C ₂	Mortar (ML)	tr	^	^	*		
C ₂	Mortar (IL)	*	tr	^	tr		
C ₂	brick	*		tr	tr		tr

Tab. 1 – Representative mineral composition of building materials collected at the surface and by microcores, from XRD analysis. Legend: qz = quartz, pl = plagioclase, Kf = K-feldspar, ca = calcite, gy = gypsum, il = illite. * main minerals, ^ minor minerals, tr trace minerals.

Representative XRD spectra for each building material are shown in the follow.

EL, consists of main calcite, and minor quartz. Traces of illite, K-feldspar, plagioclase, and gypsum can locally occur (Fig. 5); *ML* generally shows a more complex mineral association; calcite occurs as main mineral; quartz, plagioclase and K-feldspar occur as minor components (Fig. 6). Gypsum and illite somewhere occur in traces; *IL* is made up of main quartz, plagioclase and K-feldspar (Fig. 7). The main minerals somewhere occur as minor minerals, and can be in association with abundant calcite. Traces of illite and gypsum can occasionally occur. Calcite is the main mineral of the limestones (Fig. 8), locally in association with minor K-feldspar and quartz. Minor gypsum was also detected in some samples. Bricks show a very simple mineralogical association (Fig. 9). Quartz, in association with trace amounts of the other minerals occurring in mortar, is the main mineral. In some samples, also minor amounts of illite can occur. The mineral composition of the microcore materials is similar to that of the materials collected on the walls' surface (see Table 1).

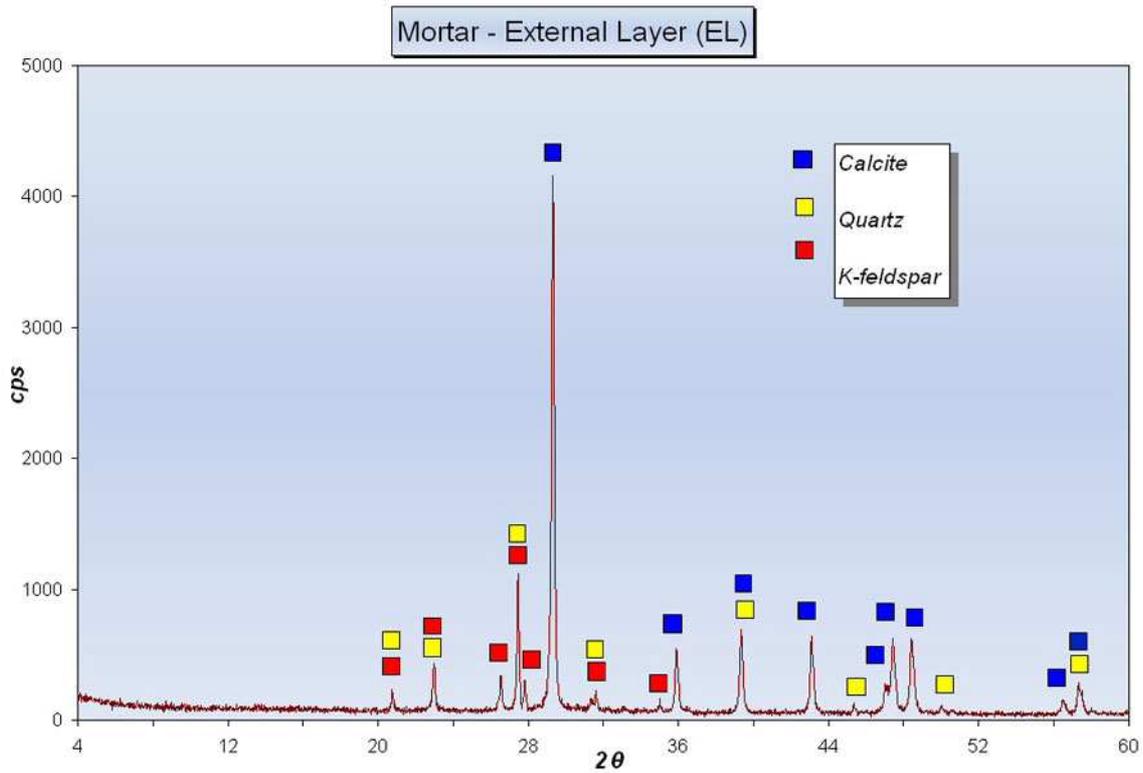


Fig. 5 – Representative XRD spectra of investigated building materials: Mortar – External Layer.

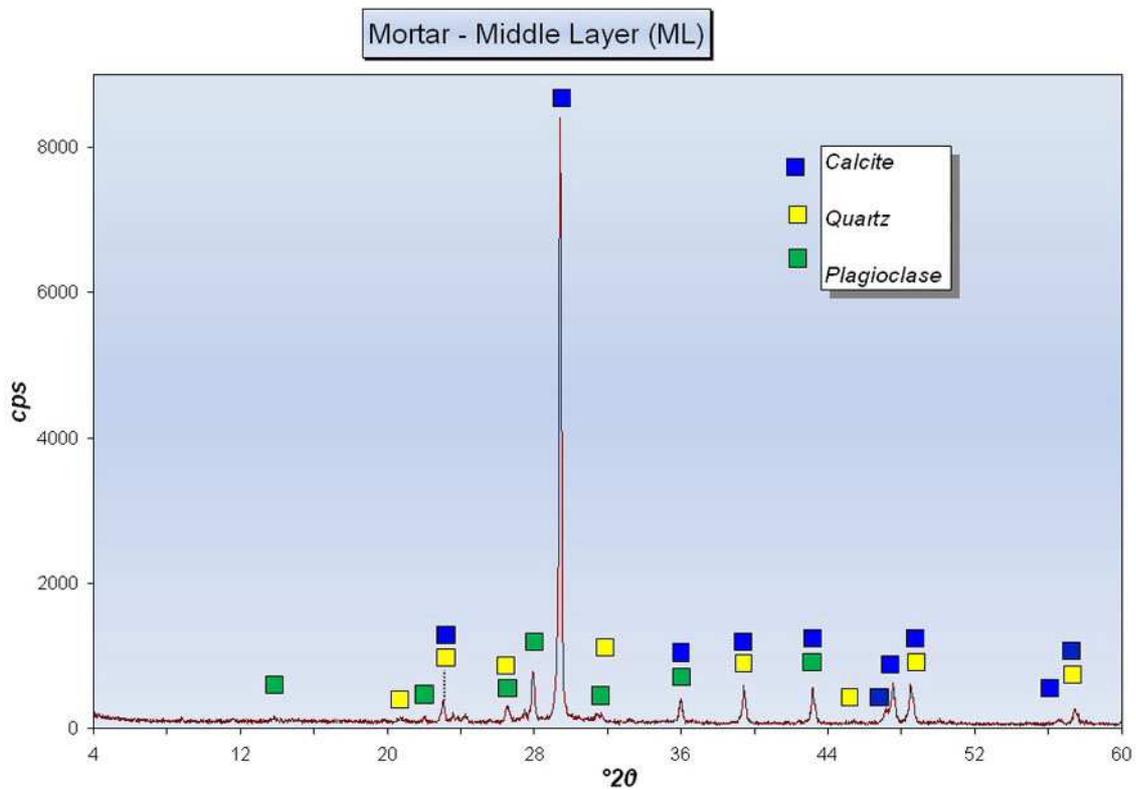


Fig. 6 – Representative XRD spectra of investigated building materials: Mortar – Middle Layer.

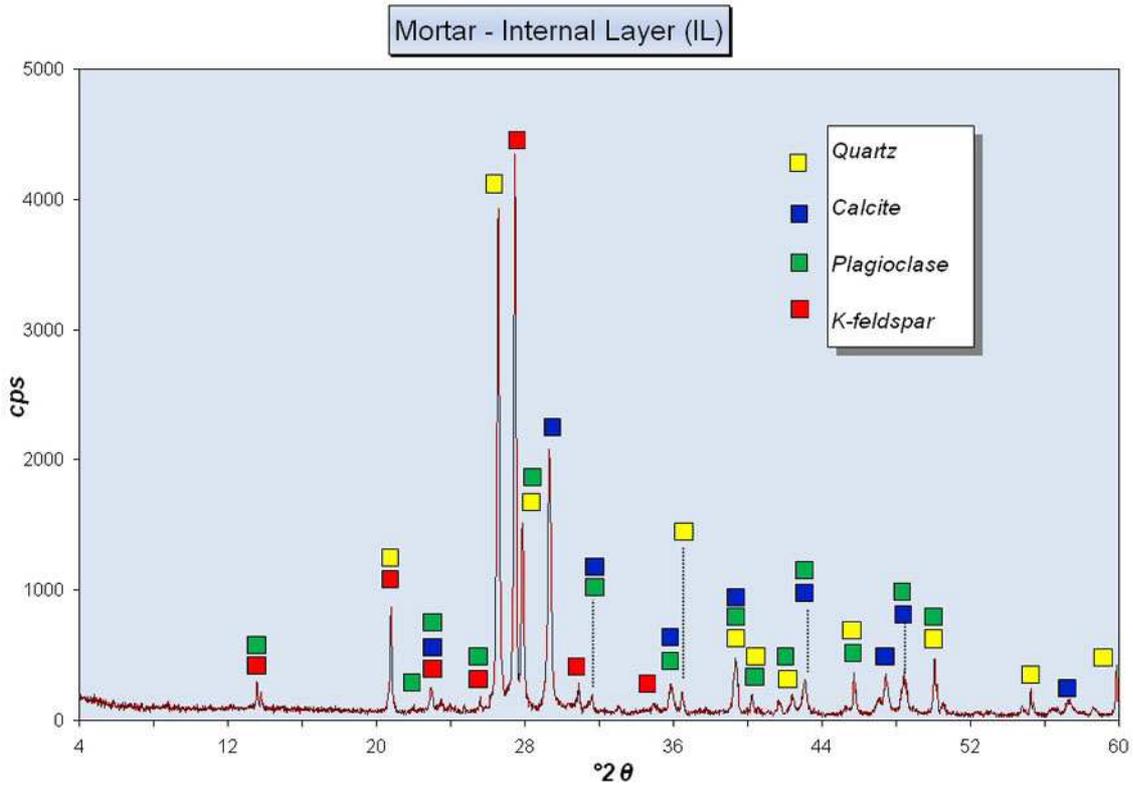


Fig. 7 – Representative XRD spectra of investigated building materials: Mortar – Internal Layer.

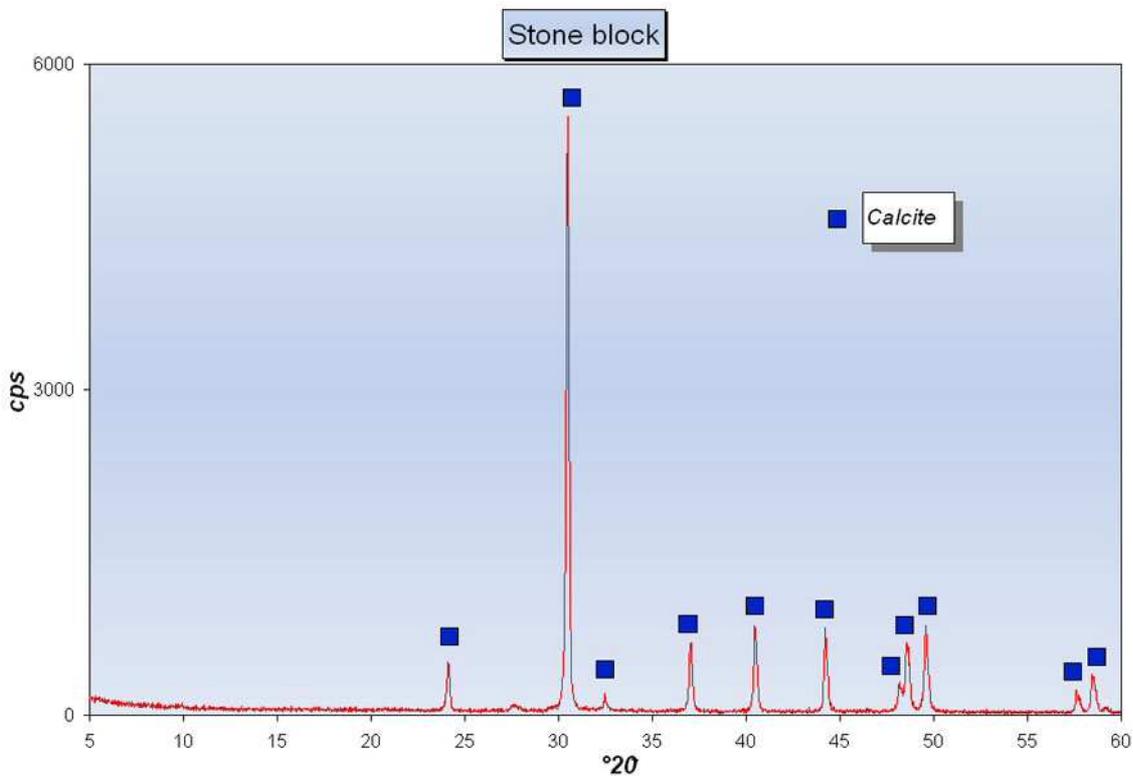


Fig. 8 – Representative XRD spectra of investigated building materials: Limestone.

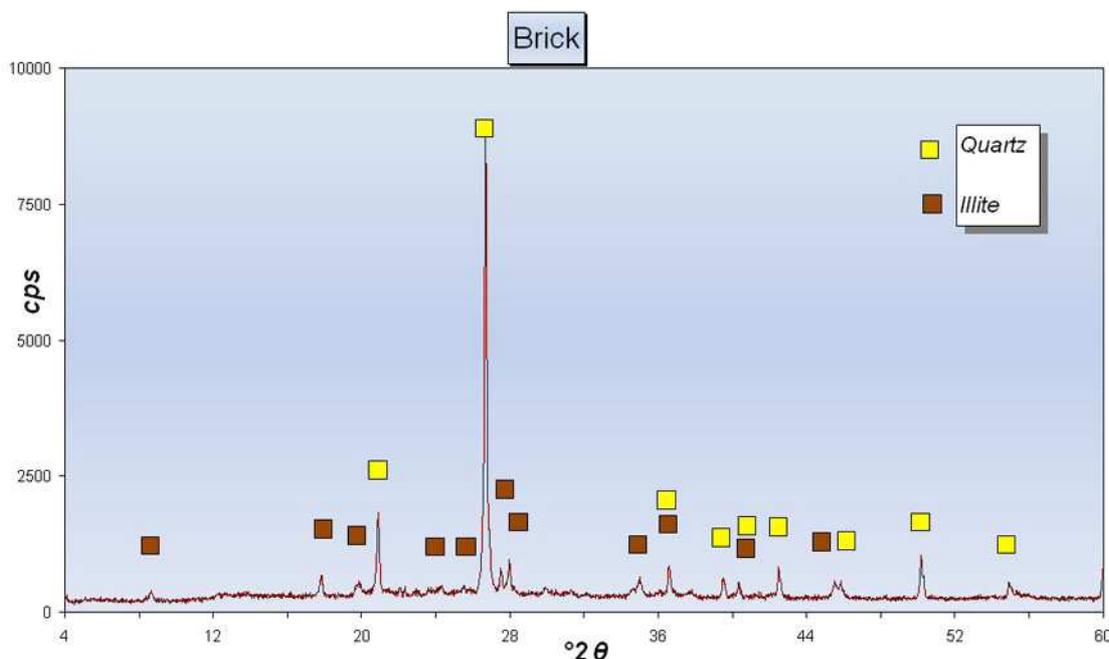


Fig. 9 – Representative XRD spectra of investigated building materials: Brick.

Conclusions

The integrated interpretation of the ultrasonic techniques and mineral studies, applied in the study of Palazzo Regio, revealed very effective in recovering quantitative information for planning the restoration actions and monitoring the conservation state of the building materials.

Ultrasonic techniques, using different data acquisition procedures, were very effective in detecting the shallow altered areas of the masonry. The refraction method allowed to define the thickness of the alteration. The analysis of the results obtained with ultrasonic techniques evidenced that the propagation velocity values of longitudinal pulses are representative of the elastic conditions of the building materials making up the masonry structures, and consequently of their state of integrity. It is important to emphasize that the ultrasonic velocity values obtained by the indirect modality must be interpreted as relative and not absolute values. Nevertheless, though the velocity values measured with the indirect modality cannot be interpreted in the absolute sense, the velocity variations detected in the building materials have all been accounted for by variation in the integrity state of the investigated materials. This was also confirmed by the mineral analyses. The application of the refraction method allows to determine the thickness of the shallow altered zones, and measure the absolute values of the velocity of the material under the altered layer.

The mineral data show that the most altered zones, independently from type of material, are characterized by the presence of minor amounts of gypsum and illite. The mortar and limestone blocks, where the lowest acoustic velocities were detected, are the most altered building materials. The alteration phenomena prevail at the contact surfaces between the three constituent layers of the mortar. These surfaces are in fact a preferential way for the circulation and stagnation of the meteoric waters, enhancing chemical-physical alteration processes. As consequence, several zones of the façade are affected by detachments. Since permeability is one of the main factors favouring the alteration, also limestone blocks show a mineral composition characterized by the presence of newly-formed minerals.

In conclusion, ND ultrasonic techniques, integrated with mineral investigations on a number of adequately located samples, can give an important contribution in acquiring quantitative information on the preservation state of building materials before planning a restoration project, and later, in monitoring the effectiveness of the restoration.

Acknowledgements

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Winner of the
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2010

The Historical Maps from Ingelheim as a Data Source for Archaeology

Matylda GIERSEWSKA / Piotr NOSZCZYŃSKI

Forschungsstelle Kaiserpfalz Ingelheim, University of Göttingen, Germany

Abstract: The Palatium in Ingelheim (Germany) is located in the eastern part of the current municipal area of this city, in the so-called Saalgebiet.

The first excavation in this palace was carried out at the beginning of the 20th century. After that, archaeological research was resumed twice, in 1960 and 1993.

The study area of this project includes, in addition to the Carolingian Palace, the expansion area from the Staufen-period with the surrounding remnants of the fortification.

The main objective of this work is a presentation and comparative analysis of the cartographical sources for this area. This includes old cadastral maps and two other maps from the 17th century, namely Engelhart's and the Marksburg plan.

The secondary aim of this project is to generate information which would be useful in the pre- and post-excavation phase.

The application of the Geographic Information System also plays a crucial role in this investigation.

The paper focuses on the different georeferencing methods of the input sources: digitising of the originals and transformation by 1st to 3rd order polynomials with best fit adjustment into a common land coordinate system. The discrepancies between these methods and a critical view at the results will also be discussed. Equally important is the accuracy of these processes. The distortion grids will also be illustrated as an additional method for a comparison of the old maps and the present sources.

The whole process is carried out using the program ArcGIS 9.2, Google Earth, Google SketchUp and AutoCAD 2008.

As the result of this work, a few examples of the georeference adaptation in the pre- and post-excavation phase will be demonstrated.

Keywords: GIS, Georeference, Cadastral map, Cartography.

Introduction: The site, its history and previous excavations

The city of Ingelheim is located in the south-western part of Germany in the Lower Rhineland-Palatinate, near the city of Mainz, on the Rhine's west bank. The Palatium of Ingelheim was founded in the middle terrace of the Rhine, which belongs to the above flood area, near the medieval settlement (SCHMITZ 1974) (Fig. 1).

The research area covers among others the Carolingians Palatium and the extended part in the 12th century in the eastern part of the current municipal area of this city, in the so-called Saalgebiet (Saal).

Historical sources date the beginning of the palatium at the end of the 8th century. The first visit of Charlemagne in Ingelheim occurred in year 787 and 788 (GREWE 1998). The primary residence was

confined to the northern part of the territory of Saal. Three centuries later it was extended by the Staufen dynasty. At this time the southern part with the surrounding walls was built and the residence took on a defensive character (GREWE 2010).

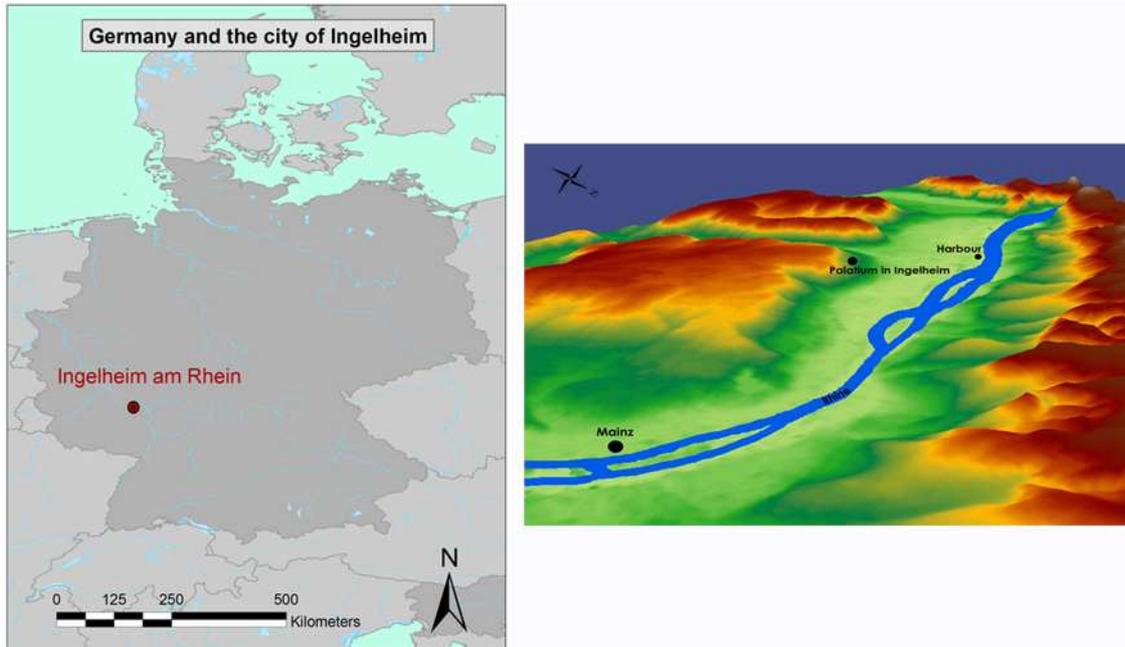


Fig. 1 – Map of Germany and location of the city of Ingelheim (Copyright: Forschungsstelle Kaiserpfalz Ingelheim, Jet Propulsion Laboratory – California Institute of Technology).

Archaeological excavations of the Palatium in Ingelheim were carried out from early 20th century until today. The investigations were executed in three phases (Fig. 2).

The first regular research began over one hundred years ago and it was conducted by the art historian Christian Rauch from 1909 to 1914. At that time, exploring of the palace was limited only to the main - northern part of the palace area. After that, archaeological research was resumed twice, in 1960 and 1993. The excavations are continued in the whole area of the residence, within the framework of the research program of the Forschungsstelle Kaiserpfalz Ingelheim. Actually, the area of the palatium is a part of urban environment. The excavations can be conducted in the selected part of the residence and only as small sections.

This paper focuses on the latest excavations, namely research carried out in 2009 and 2010. The pre- and post-excavation phase of the investigation will be also described. A prospection of the find-spot and an evaluation are the themes of this report.

Goals

The main goal of this paper is to present and provide a comparative analysis of cartographical sources for the research area. This includes old cadastral maps and two other maps from the 17th century, namely Engelhart's and the Marksburg plan.

The secondary aim of this project is to generate information from the discussed sources and its usefulness in the pre- and post-excavation phase.

Additionally, the application of the cartographical sources and their efficiency for the reconstruction of the buildings of the residence and the city of Ingelheim was an objective of this study.

The application of the Geographical Information System also plays a crucial role in this investigation.

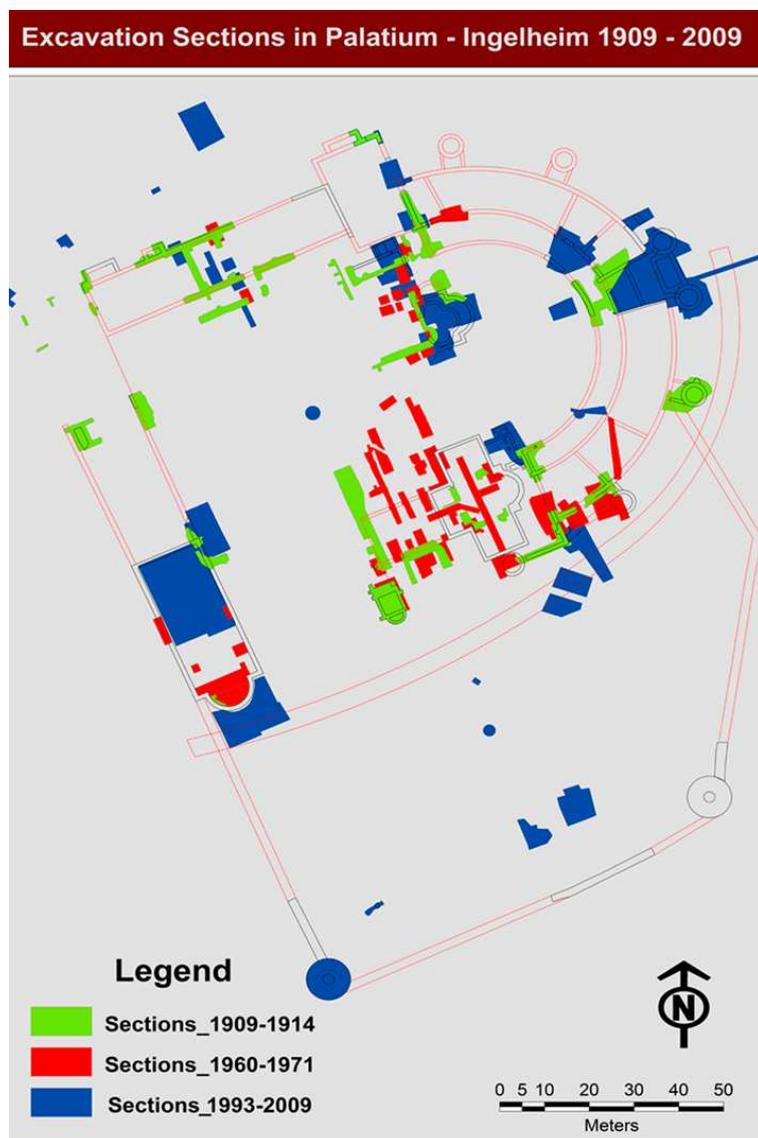


Fig. 2 – Location of the archaeological trenches in the Palatium in Ingelheim between 1909 and 2009 (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

Input Data

As the input data the following cartographical sources were used:

- Engelhart plan dating from 1621
- Marksburg Plan dating from 17th century
- Cadastral map dating from 1812
- Cadastral map dating from 1842–1844

The name of the plan Marksburg (Fig. 3) comes from the place where it was found, i.e. the archives of the Marksburg castle. It is not known exactly which century this map dates from – probably the 17th century.

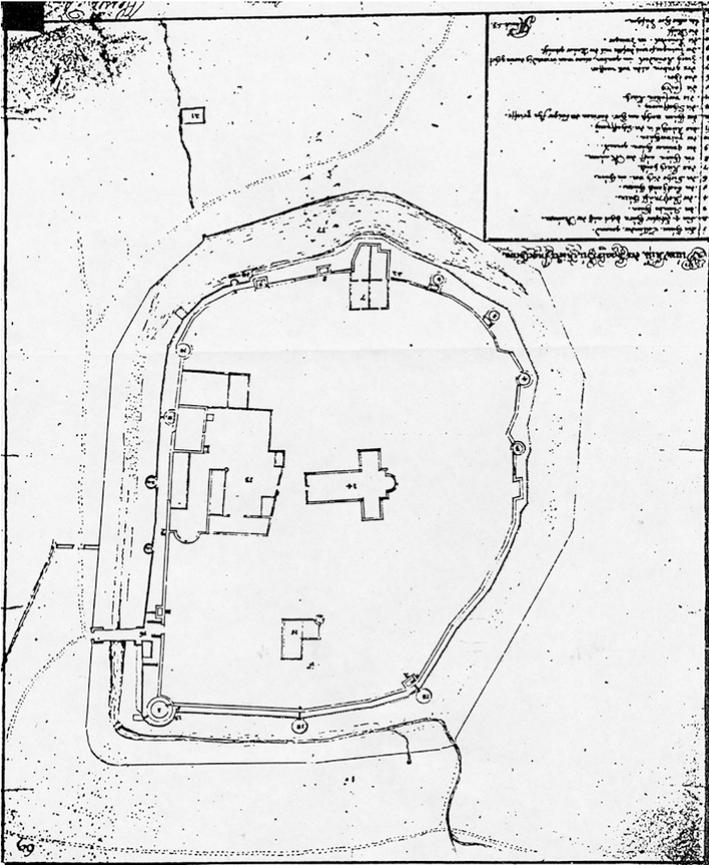


Fig. 3 – Marksburg plan for the city of Ingelheim from the 17th century (Copyright: Europäisches Burgeninstitut in Braubach).

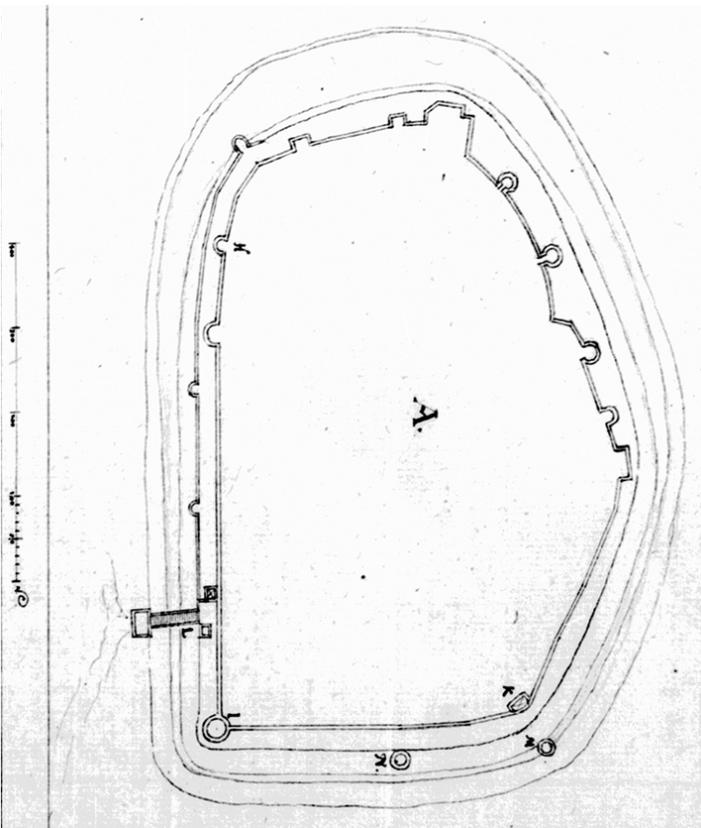


Fig. 4 – Engelhart plan (1621) (Copyright: Bayerische Staatsbibliothek).

Presumably the origin of this source could have been connected with the Thirty Years' War and the possible use of the palatium as a defensive fortress. This is known from other cartographic sources for this area – Engelhart plan (Fig. 4).

Both of the plans have great historical value but they are not comparable with the younger cadastral plans from 1842–44, they do not have any cartographic projection. The dimensions of the whole residence and the various elements of urban architecture are not proportionate and consistent with the real constructions, yet they do not deviate from them heavily. Such an element as a scale is present only in the Engelhart plan. The Marksburg plan is also oriented to the south.

The cadastral plan from 1812 (Fig. 5) is based on the French tax law from 1798, which should allow intensive and equitable taxation of the land. In 1799 the meter was introduced as a new unit. The plan of the Saal area in Ingelheim was a one of more sections that were prepared for this city (LETZNER 2001–2010).

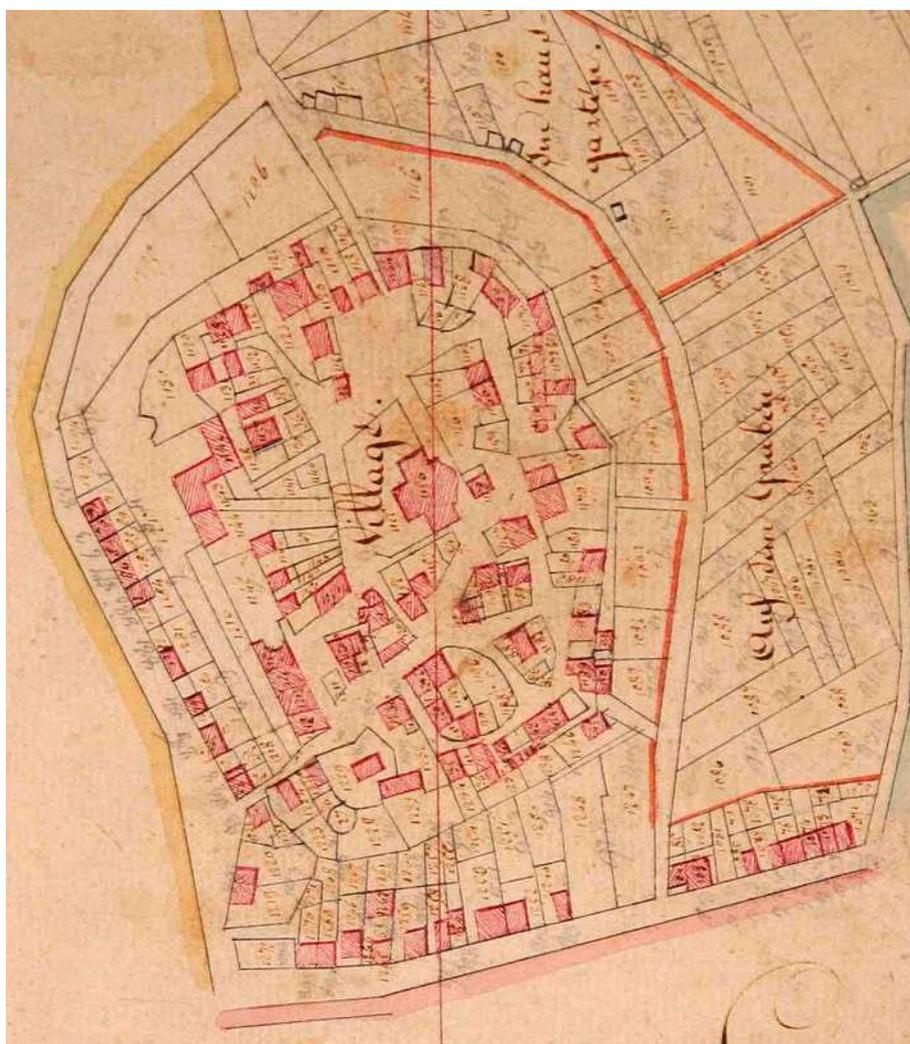


Fig. 5 – Cadastral map of city of Ingelheim (1812) (Copyright: Stadtarchiv Ingelheim).

The cadastral map from 1842–44 was used for identifying the geometrical position of all parcels, their boundaries, buildings. The individual parcel identifying numbers, residential or public buildings, outbuildings and boundaries of individual parcels are visible on this map (Fig. 6).

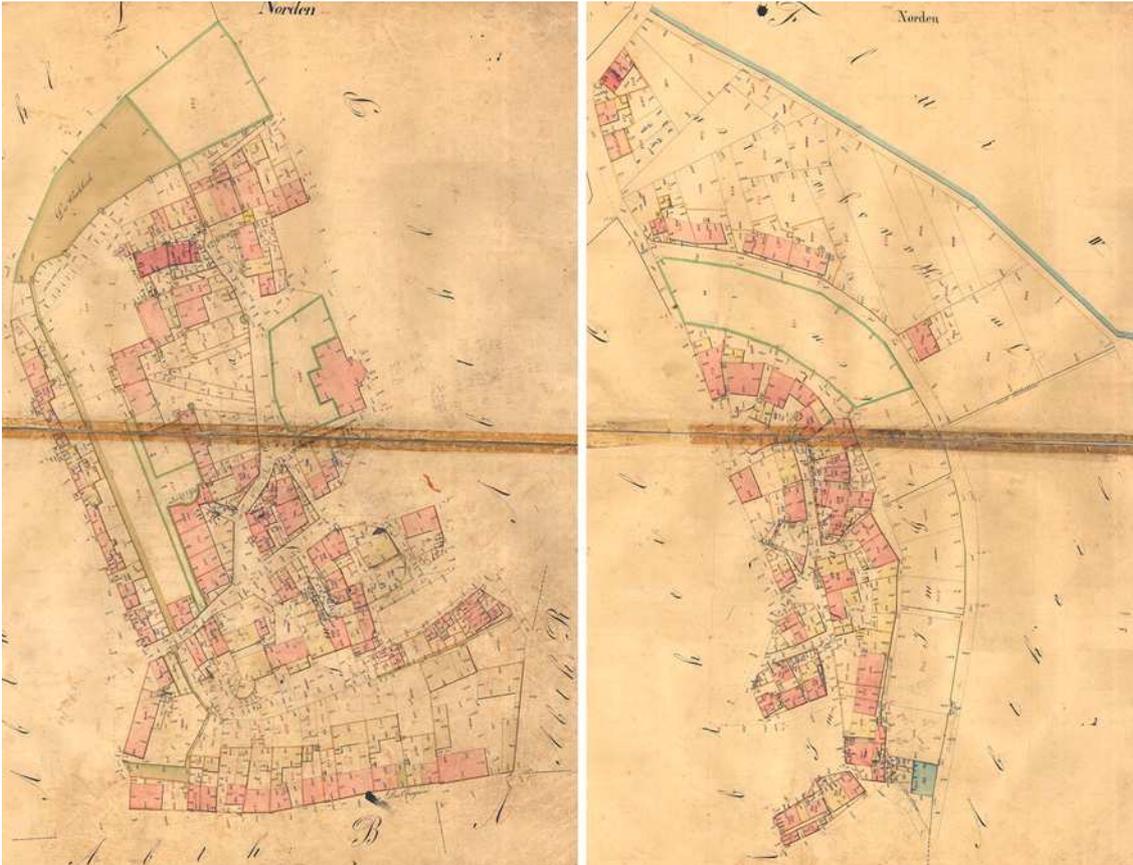


Fig. 6 – Cadastral maps of city of Ingelheim (1842–44) (Copyright: Vermessungs- und Katasteramt Bad Kreuznach).

The coordinate system of a modern and actual cadastral map of the city of Ingelheim was used to combine and link all the older maps together by means of homologous points. Also the recent documents of the still ongoing archaeological field work were included, everything added into the same ArcGIS database. Additional measurements were done with a total station Leica TCR 307.

Methodology

Firstly, the historical maps were scanned and transformed into the 'target'-coordinate system of the modern cadastral map. After this transformation all actual points of the historical maps have coordinates in the target coordinate system, i.e. the national land survey system, which is according to the geographical position of the site (longitude 8,07 and latitude 49,97) the Gauss Krüger Coordinate system DHDN Zone 3 (FLACKE 2007).

For the transformation of the Engelhart and Marksburg plan 18 homologous control points were identified each in the old (actual) maps as well as in the target cadastral map (i.e. corners of the buildings) as control-points between the two coordinate systems.

For better precision of these transformations, the control points have to be regularly distributed over the area to be transformed. The values of the point coordinates correspond to the Gauss-Krueger map projection and they were read from the cadastral map of Ingelheim and the vectorised reconstruction of the palatium. In ArcGIS these transformations need at first the input of the actual (historical) plan as a i.e. JPEG file. The

individual control points have to be marked so that the program can combine them with the target coordinates of the homologous points in the target coordinate system from the cadastral map. Finally the transformation formulas were determined and the transformation of all points by means of these formulas was executed. During this study different formulas have been tried, namely linear polynomials with 4 parameters for defining the spatial position, scale and rotation; affine transformation with six linear polynomial parameters; bilinear with 10 parameters and deforming nonlinear spline polynomials. The spline transformation optimises for local accuracy but not global accuracy. It is based on a spline function- a piecewise polynomial that maintains continuity and smoothness between adjacent polynomials. Spline transforms the control points of the source (map) exactly to target control points. The pixels that are away from the control points are not guaranteed to be accurate. This transformation should be used with carefulness; in case when the control points are very important and it is required that they be registered precisely (ArcGIS 2008).

Although the spline method affects the local accuracy of the source, the image after georeference fit better into the reconstruction of the palace (Fig. 7), than the result of the method of the first to the third polynomials (Fig. 8).



Fig. 7 – Comparison of transformations of two historical maps (Copyright: Forschungsstelle Kaiserpfalz Ingelheim, Europäisches Burgeninstitut in Braubach, Vermessungs- und Katasteramt Bad Kreuznach).

In contrast to these sources the cadastral maps of Ingelheim from 1812 and 1842–1844 were transformed and georeferenced with the third polynomial.

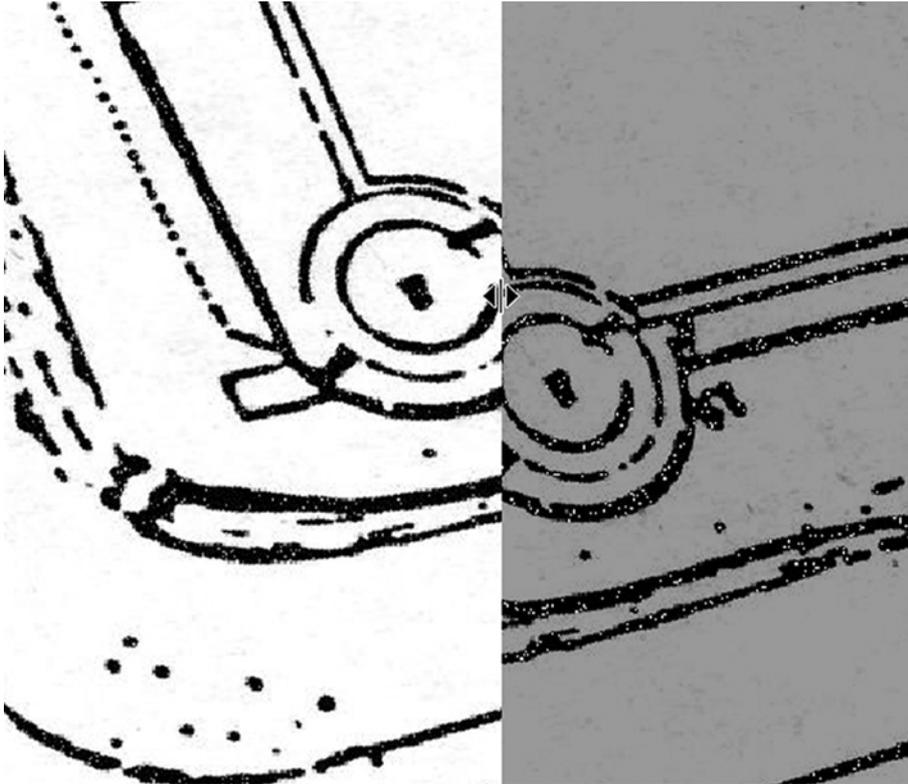


Fig. 8 – Comparison of transformations of the Marksburg plan (Polynomial vs. Spline) (Copyright: Forschungsstelle Kaiserpfalz Ingelheim, Europäisches Burgeninstitut in Braubach).

The results of the georeference and the accuracy of the output data have been tested in following ways:

- using the graphical method by analysing and comparing the differences between spatial position some of the building of the palatium and discovered archaeological features in the target map projection (modern cadastral map) and on the transformed map (output)
- using the graphical method of the distortion grid to present the accuracy (in-accuracy) of the historical map against the inversly transformed target grid (target grid in the actual coordinate system) (Example Fig. 9) (NIEŚCIORUK 2006, 2007; FORSTNER et al. 1998).
- using the RMSE (Root Mean Square Error) values in case of using of the polynomial algorithm.

The distortion grid was constructed in AutoCAD and exportet to the JPEG format. Then, both the original Marksburg plan and the image with the mesh-grid were loaded into ArcGIS 9.2. In this case, on the basis of the Marksburg plan and the previously mentioned control points (stable and instable), the image was georeferenced with the grid. The meshes in the grid represent a correct size of 10x10 m. The whole area is about 4 ha large. The size of the mesh was also defined with the approximate minimum distance of the control points. Creation of the distortion grid and its size are not explicitly referred to in the literature. This depends mainly on the size of the research area as well as the adapted method (FORSTNER et al. 1998, NIEŚCIORUK 2006).

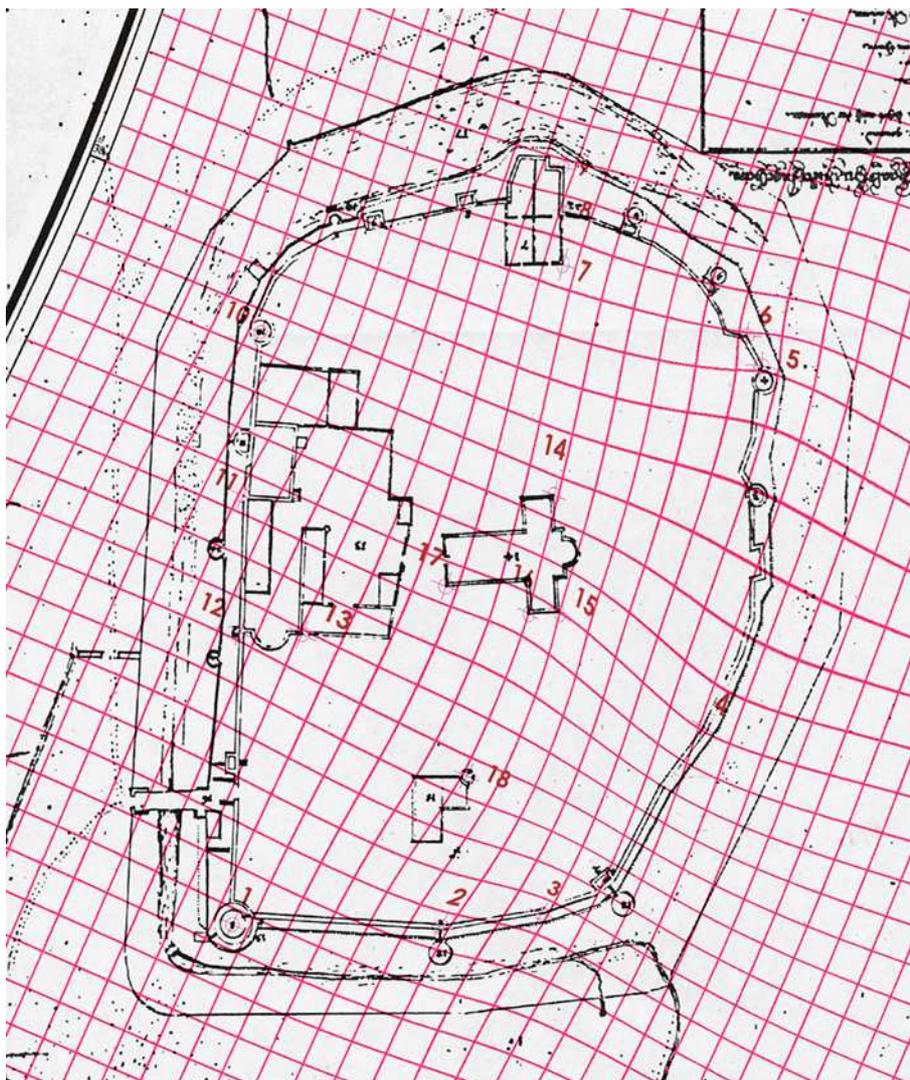


Fig. 9 – Distortion grid for the Marksburg plan (Copyright: Forschungsstelle Kaiserpfalz Ingelheim, Europäisches Burgeninstitut in Braubach).

The georeferenced historical maps were digitised and the attributes were stored in a created spatial database. All of the cartographical sources were digitised as a one Feature Dataset. Each map was a separate Feature Class. All of the features were saved as polygons. The feature types were added as attribute: among others buildings, streets, water wells and water. Among the buildings the following types were designated: public, defensive, sacral buildings. The simple digitising, called "heads-up" digitising, by applying Sketch Tool – Create New Feature tool from the editing toolbar was used. The transformed, georeferenced raster versions of the historical plans were used as background layers. The digitising and editing process consists of drawing the geometry in the map view and then entering its attributes. This was repeated for each feature and map. The vector data were used among other to compare and analyse the map information and for the reconstruction of the city structure (Fig. 10).

For the entire presented process the ArcGIS 9.2, Google Earth and Google SketchUp were used. Only the distortion grid was constructed in AutoCAD 2008.

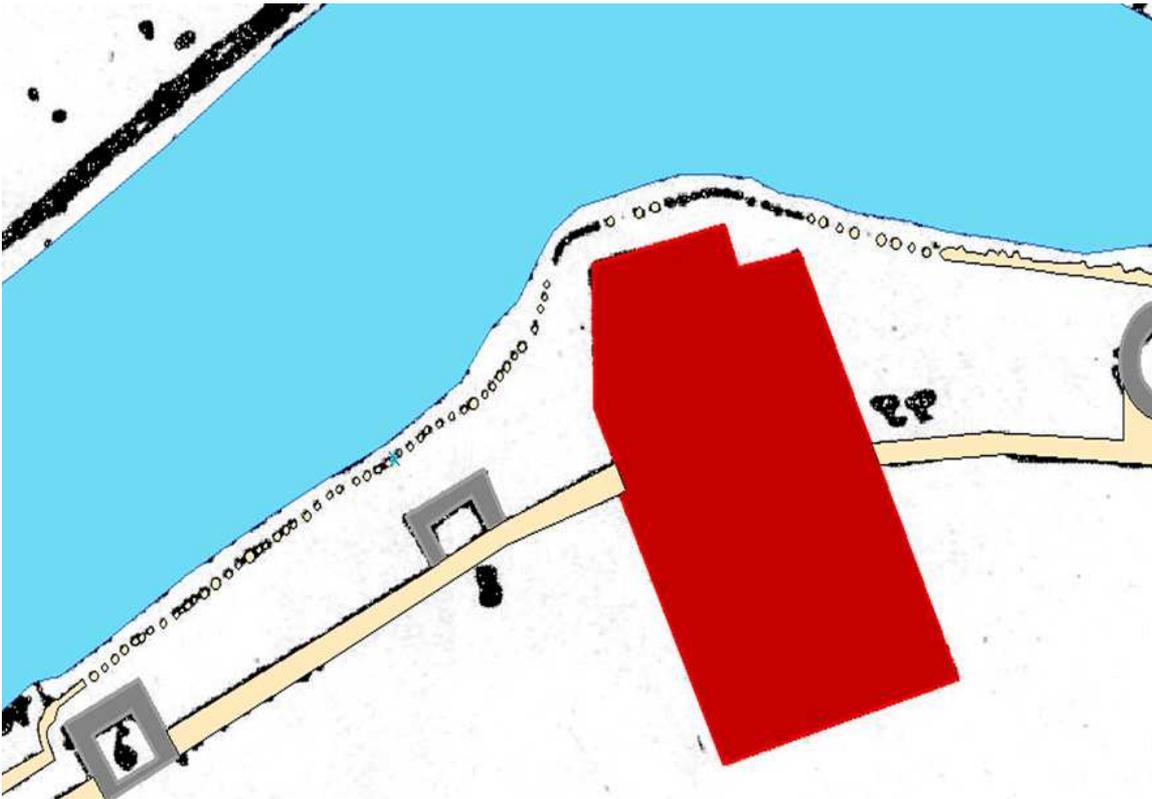


Fig. 10 – Palisade structure – discovered during digitisation (Copyright: Forschungsstelle Kaiserpfalz Ingelheim, Europäisches Burgeninstitut in Braubach).

Application

The geographic information system could be applied to archaeological research and historic preservation. Also the historical maps are very useful to locate of archaeological trenches or to evaluation and interpretation of the excavation results. One of the advantages of this approach is the examination and recognition of possible archaeological features, especially these which are not visible and accessible nowadays. Based on the cartographic sources one can learn more about underground building structures. The historical maps have not only a great scientific potential, but they give us an overview of the development of an area. The application of the cartographic historical maps and geographic information system open a number of new methodological possibilities of their interpretation.

Excavation

The most important issue of using GIS and cartographic sources in archaeology is the possibility of their effective application in all of the excavation phases.

For instance the identification process of the building remains, which were located within the archaeological trench in the Palatium area, was executed during the pre-excavation process. Thanks to this operation archaeological features found during the excavation in Ingelheim in 2010 were efficiently interpreted and dated (Fig. 11). The masonries from tree construction periods are shown in the figures 12.

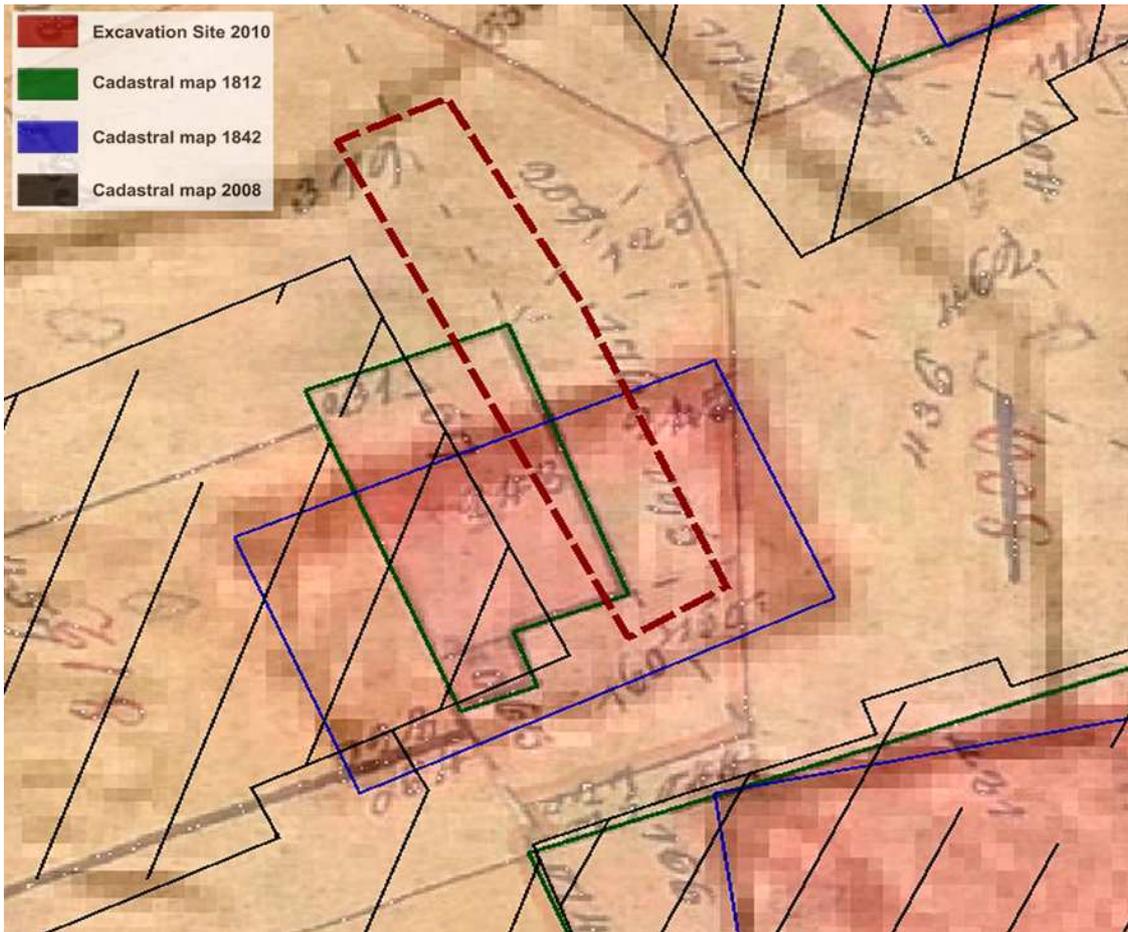


Fig. 11 – Comparison of three cadastral maps of Ingelheim and the archaeological trench (2010) (Copyright: Forschungsstelle Kaiserpfalz Ingelheim, Stadtarchiv Ingelheim, Vermessungs- und Katasteramt Bad Kreuznach).

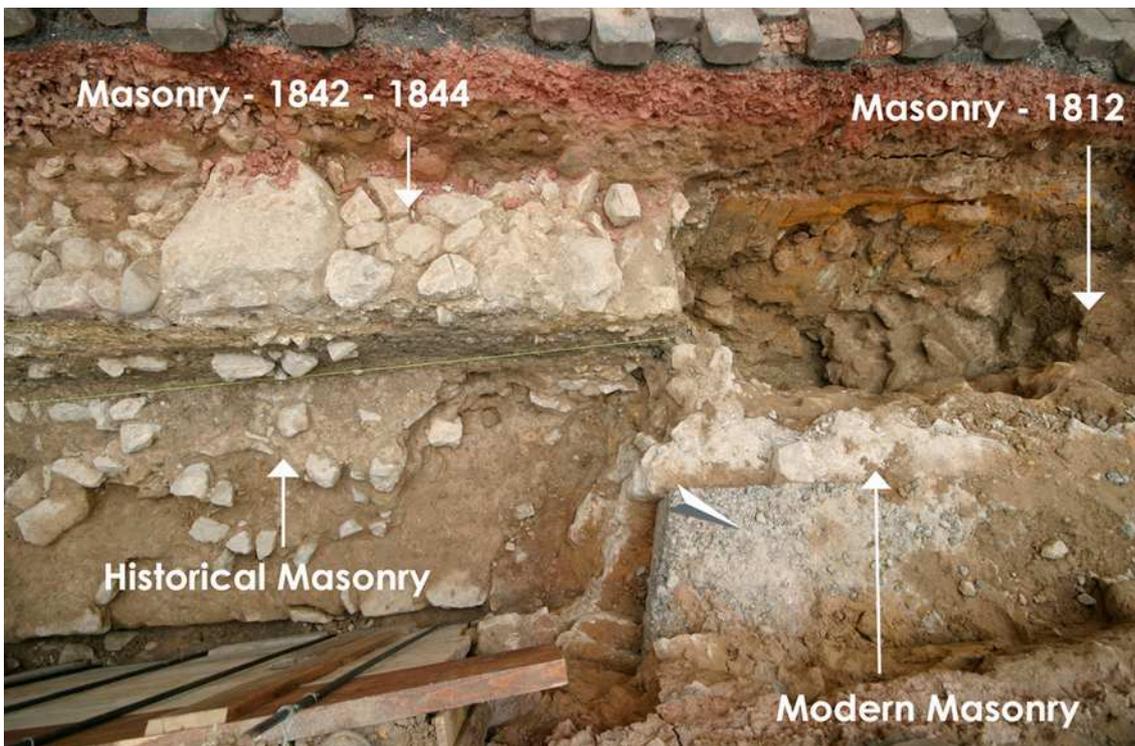


Fig. 12 – Discovered walls – Excavation in 2010 (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

The situation in the trench was compared with the cadastral maps from Ingelheim (1812, 1842–44). Two of the structures were correlated and recognized with the features on the map. The third one was determined as a prior construction.

GIS and the use of historical maps are also very useful during a rescue excavation, e.g. a historical well was found during a street renovation in 2009 (Fig. 13). This feature was surveyed and compared with the object in cartographical sources (Fig. 14).



Fig. 13 – The discovered water well (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

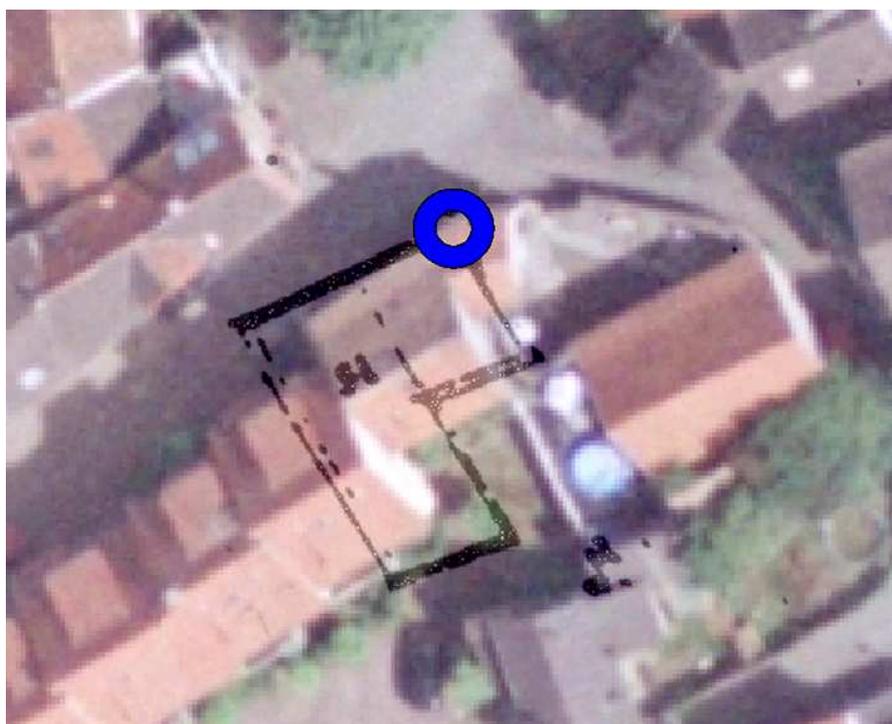


Fig. 14 – Location of the water well (Copyright: Forschungsstelle Kaiserpfalz Ingelheim, Google Earth).

The transformed and georeferenced Marksburg plan and an orthophoto of an aerial image from 2000 were correlated with the location of the archaeological feature on the research area. This process helped to interpret the discovered object as a well next to the Bailiff House (Farteibrunnen) (Fig. 15).



Fig. 15 – Exploration of the water well (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

Also by planning of the excavation this procedure could be very helpful. It is very important to know the exact location for an archaeological trench. If the position of some of the archaeological features is known, it is much better to prepare and carry on the research.

Reconstruction

The cartographical sources could be also used to reconstruct the past structure of the city. In the 14th century the palace was transferred into the hands of the Order of Augustine by Charles IV. Also, at this time administration of the city of Ingelheim acquired all the authorities of the region of the Electoral Palatinate [in German: *Kurpfalz*] (GEIßLER 2010). During the Thirty Years' War the buildings of the palatium were substantially damaged and the palace fell into ruin. In the modern period the area of the Saal was intensively extended and in a slightly modified form has not been changed until today.

The 3D building reconstructions in various level of detail (LOD 1 - LOD 3) were created for a better understanding of the historical data obtained from the cartographical sources and presented in Google Earth (Fig. 16).

Not all of the buildings, which are presented on the maps, exist until today. It is important to mention that not all of the architectural objects were also inserted to these sources.



Fig. 16 – 3D building models in Google Earth (LOD 2) (Copyright: Forschungsstelle Kaiserpfalz Ingelheim, Google Earth).

Conclusion

The geographic information system is a very effective tool for the city's history and archaeological research. Using this technology not only individual historical maps can be analysed, but also a complex information system could be build, that a series of historical plans of a region or a city can be investigated like in Ingelheim.

The data quality and the method, especially for the georeferencing of the historical maps, play a crucial role in this process. The quality of the analysis depends on quality of the input data.

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SITAR Web-GIS: A Tool for Managing Archeological Data in the Cultural Heritage Conservation and Town Planning

Petra GRINGMUTH / Stefania PICCIOLA / Simone RUGGERI

Soprintendenza Speciale per i Beni Archeologici, Rome, Italy

Abstract: The SITAR geospatial databank is a project of the *Soprintendenza Speciale per i Beni Archeologici di Roma* that draws on the talents of a team consisting of archaeologists, topographers, and computer experts. SITAR uses RDBMS architecture to record the archeological data that enter the data base directly, analytically and without interpretation. The logic of the system is designed to organize, within one single databank, data deriving from bibliographic and archival research, as well as data from the entirety of the various territorial investigations (including remote sensing, boreholes, geophysical surveys, preventive excavations, etc.). The system is structured on three logical levels of detail which enable data deriving from a given number of corresponding conceptual categories to be archived and also allow very heterogeneous types of data sets to be organized.

The cognitive and analytical path works either bottom-up or top-down, and has as its primary goal the description of any given archaeological context. In order to acquire and use the geo-topographical information, an optimal procedure for the digitization of archive materials has been developed.

This consists of successive steps of rasterizing, georeferencing within the cartographic system shared by the other offices that deal with town planning, vectorizing and entry into the databank. This procedure produces an archaeological GeoDatabase that can be used both internally by the Soprintendenza and externally through sharing and exchange with other offices and universities.

Keywords: SITAR; webGis; Urban Archaeology and city planning.

SITAR Web-GIS: A Tool for Managing Archeological Data in the Cultural Heritage Conservation and Town Planning

The SITAR (*Sistema Informativo Territoriale Archeologico di Roma*) geospatial database is a project of the *Soprintendenza Speciale per i Beni Archeologici di Roma* that draws on the talents of a joint team of archaeologists, topographers and computer experts. SITAR operates on geo-RDBMS architecture to record the archaeological data, which enter the database directly, analytically and without interpretation.

A key commitment undertaken in developing the referral system is to enable a continuous mapping between the Sitar data model and the data provided by the ICCD¹.

The SITAR project aims to establish, maintain and develop a real spatial data infrastructure, in line with the guidelines provided by the Directive INSPIRE², by *Commissioni Ministeriali* for the creation of the SITAN³ (*Sistema Informativo Territoriale Archeologico Nazionale*) and for the Preventive Archaeology⁴.

¹ ICCD Institute for Catalogue and Documentation, responsible for process standardization.

² The E.C. in c.d. Directive INSPIRE "Infrastructure for SPatial InfoRmation in Europe", issued by the European Parliament in 2007.

The archaeological GeoDatabase that can be used both internally by the *Soprintendenza*, and externally through sharing and exchange with other offices and universities.

The logic of the system is designed to organize data from different sources, within a single database in few and very flexible geo-spatial features classes.

These can originate from field work (excavations of various kinds - from underground utilities trenches to planned excavations -, geophysical surveys, core sampling and restoration) and case studies (bibliographical records, scientific publications, historical and epigraphic sources, historical maps) (Fig. 1).

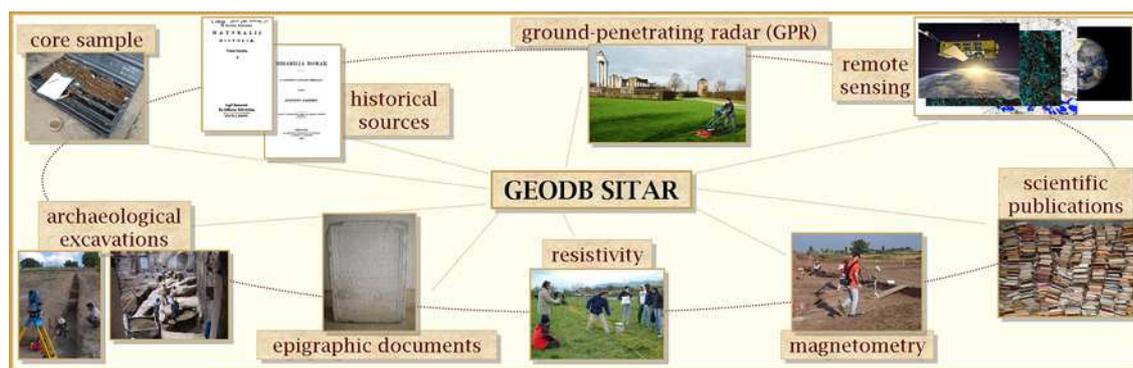


Fig. 1 – Geo-spatial features classes (Copyright: MIBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

The system is based on three logical levels of detail which makes it possible to archive data associated with the equivalent conceptual categories and to systematize extremely heterogeneous types of information.

The *Origine dell'Informazione (O.I.)* represents each intervention of archaeological and geognostic research implemented methods, purposes and at different times, both in the field and in archives.

It also takes into account interventions that have generated negative data (absence) or non significant data (not evidence).

The *O.I.* record collects the administrative and statistical information.

The *Partizione Archeologica (P.A.)* includes every knowledge element derived from each research intervention (*O.I.*) to which it's permanently associated.

The *P.A.* record analyzes and describes the archaeological finds on the basis of chronological and functional criteria.

The *Unità Archeologica (U.A.)* identifies each historical and architectural context uniquely identified through chronological and functional criteria, based on the processing of all the knowledge elements acquired at the lower logical hierarchy level (*P.A.*).

The *U.A.* record may be utilized for the synthesis and interpretation of each archaeological context.

There can be multiple *P.A.* records for each *O.I.* record (Fig. 2).

³ *Commissione Paritetica* for the creation of the Archaeological Information System of the Italian cities and their territories, established in 2009.

⁴ *Commissione Paritetica* for the Preventive Archaeology, established by the Director General of Antiquities in 2008.

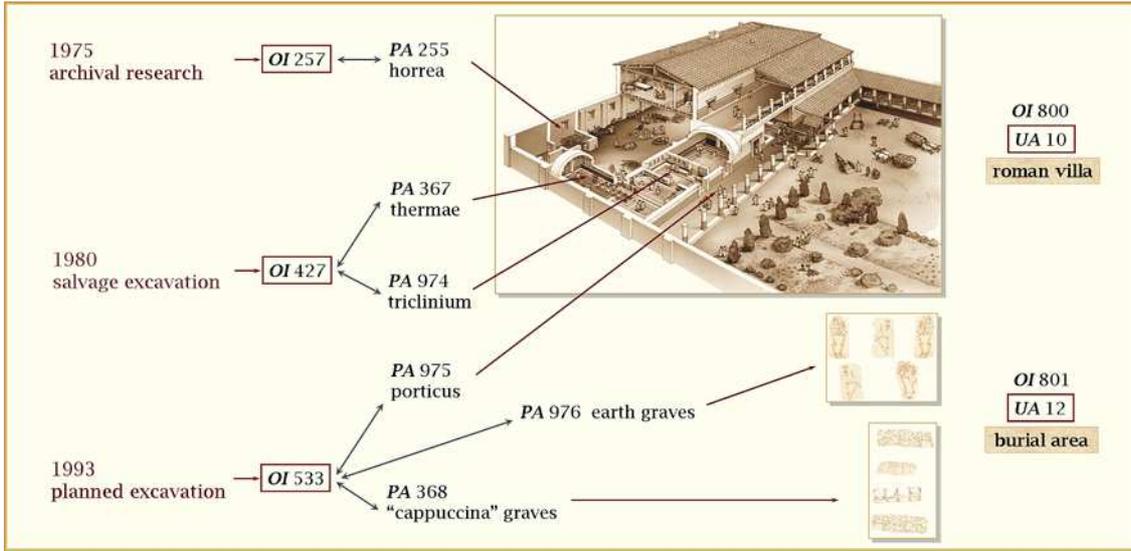


Fig. 2 – The logical levels (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

Equally, there can be only one *O.I.* record for each *U.A.*, referring to the specific study, and multiple *P.A.* records referring to the individual component elements (Fig. 3).

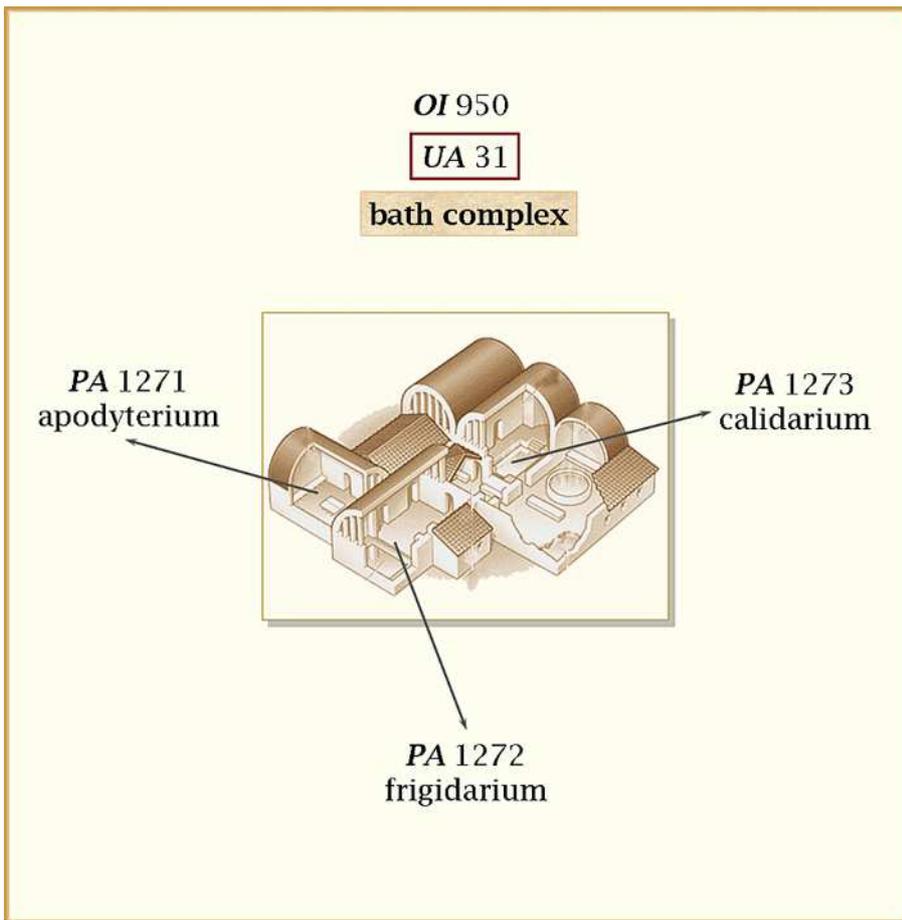


Fig. 3 – The logical levels (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

The cognitive and analytical path works either bottom-up or top-down, and has the primary goal of describing each archaeological context in a progressively more detailed manner (Fig. 4).

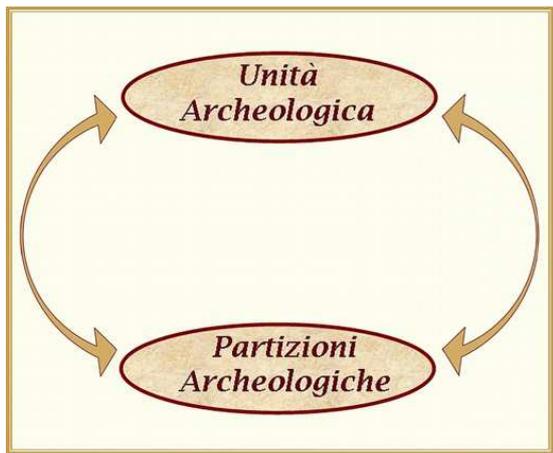


Fig. 4 – Bottom-up or top-down (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

In order to acquire and use the scientific data, an optimal procedure for the digitization of archive materials has been developed. Research starts from the archives, selecting all the documents that permit the identification of an *O.I.*, and of the *P.A.* derived from it, exhaustively describing each survey carried out. These are administrative documents, scientific documents (archaeological, geological, non-invasive investigations, bibliographic research, etc.) and cartographic documents (topographic locations on different maps, detailed plans, sections and front elevations).

This consists of successive steps of rasterizing, geo-referencing within the cartographic system shared by the other organizations that deal with urban planning, vectorizing and entry into the database (Figs. 5–7).

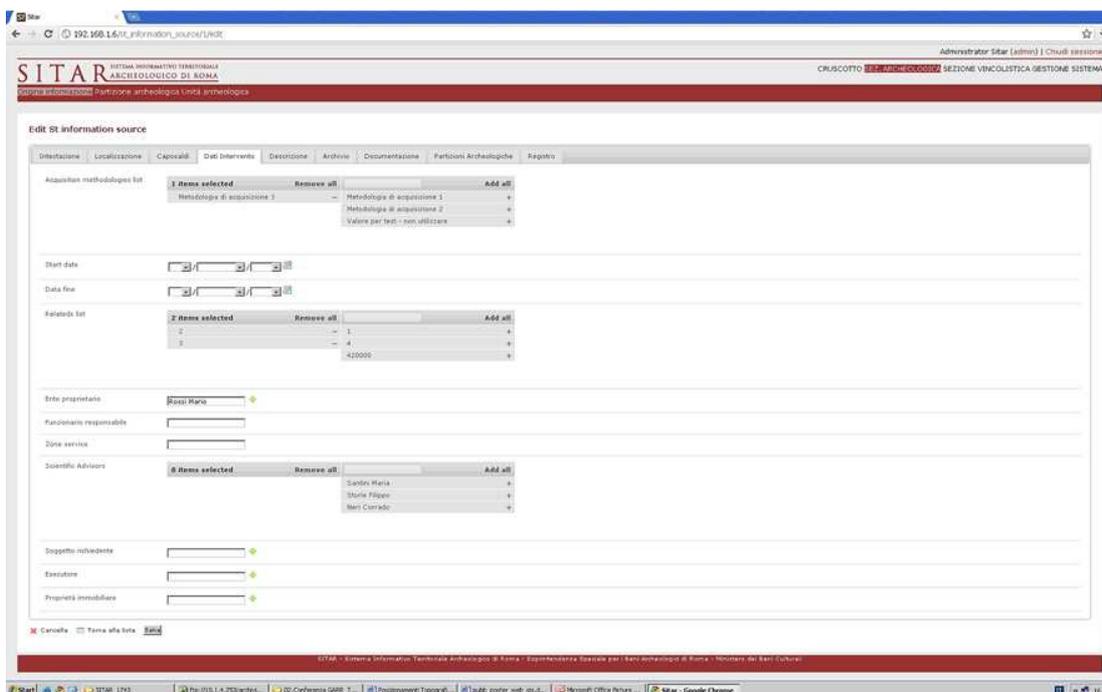


Fig. 5 – The *O.I.* record (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

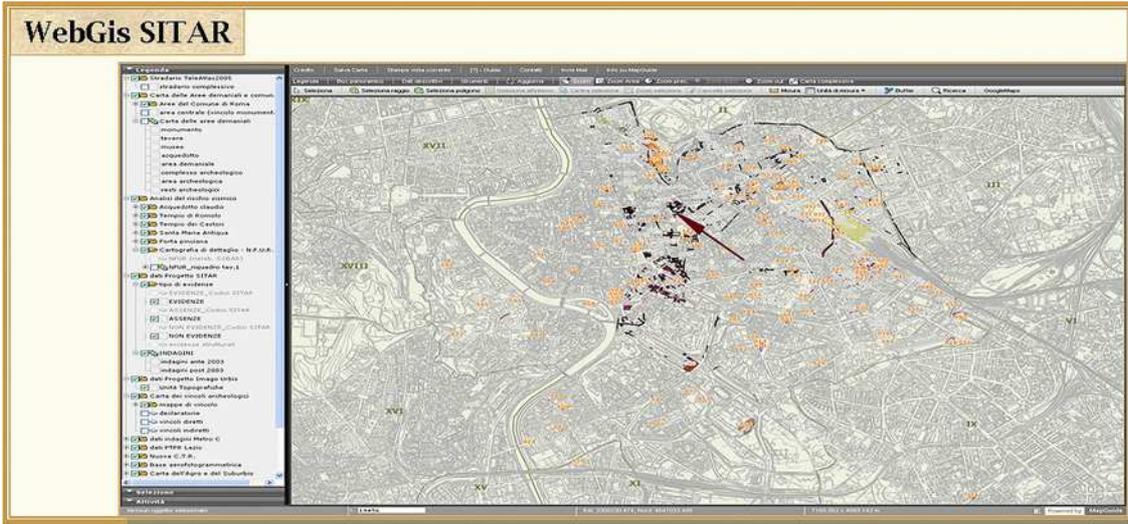


Fig. 8 – WebGIS SITAR (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).



Fig. 9 – WebGIS SITAR (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).



Fig. 10 – WebGIS SITAR, the P.A. geo-referencing and vectorizing (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

Quest for Medieval Masons and the Building Techniques They Applied

Tanja RATILAINEN

PhD student at the Department of Archaeology, University of Turku, Finland

Abstract: The aim of the ongoing research is to study the brick building techniques of the Holy Cross Church at Hattula. Questions asked are: How did the bricklayers proceed in their work? Is it possible to identify masons? Was it a single project concluded in a relatively short period of time? In this article I will briefly present the digital surveying methods applied with the focus being on a selection of results concerning the building techniques.

Building archaeological surveying methods such as stratigraphic analysis of the walls and photogrammetry (PhoToPlan, iWitness) and laser scanning were applied in co-operation with Muuritutkimus Ltd and the Institute of Photogrammetry and Remote Sensing of the Aalto University and the Geodetic Institute. Studying the building archaeological record showed that bricks were probably assorted after firing and in some cases the colour of the brick revealed where the masons proceeded horizontally. The brick measurements suggest that there was a change in the brick producing process and therefore possibly a break or a delay in the building project. However, analyzing the bonding technique it seems that the same group of masons built the whole church. Studying of the putlog holes showed that the masons working on both sides of the walls proceeded at a slightly different pace that the planks of the putlog scaffolding were probably taken down as the works progressed and that several types of scaffolding were applied during the building project.

Keywords: Brick, building techniques, church archaeology, digital surveying methods, Middle Ages.

Introduction

The Holy Cross Church of Hattula in Häme (Sw.: 'Tavastland'), which is located circa 100 kilometres north of Helsinki (Sw.: 'Helsingfors') is the only preserved medieval (1150–1523) parish church in Finland that was originally and completely made of brick (e.g. DRAKE 1967: 223; EDGRÉN and HIEKKANEN 1987: 87; HIEKKANEN 1996b: 47, note 1. On the time frames see e.g. TÖRNBLOM 1998: 273; HIEKKANEN 2003b: 73). In addition to its building material, the church is famous for its colourful and rich paintings completed in 1510s (on their dating e.g. PETTERSSON 1982: 215–216).

The building of Finnish stone (including brick) churches began at the end of 13th century and continued until circa 1560 (e.g. HIEKKANEN 1996a: 79–87; 1997: 149–157; 2003b: 75–76; 2007: 8–50). The Holy Cross church is estimated to have been built at the end of 15th century, probably sometime between 1472–1490, when Knut Posse was in charge of the nearby Häme Castle, built of brick as well (See e.g. DRAKE 2001a: 216–217; 2001b: 126–127; 2003: 11–14; RATILAINEN 2003: 157; 2006: 278; HIEKKANEN 2003a: 168; 2007: 285. On the earlier datings, see HIEKKANEN 1994: 220; KNAPAS 1997: 17–20). However, the only direct dating evidence available is a dendrochronological dating result suggesting that the church was not built before 1388 (ZETTERBERG 1995; KNAPAS 1997: 18).

The church is situated on a slope of a hill by the lake Vanaja in the village of Hurttala. The plan is cruciform: the porch and the sacristy are on the opposite sides of the rectangular nave. There is an exterior buttress in every corner of the church and in the middle of the western part of the nave. The gables are decorated with brick ornamentation. The nave is three-aisled and the vaults, both of the nave and the sacristy, form a simple cross. (Fig. 1)

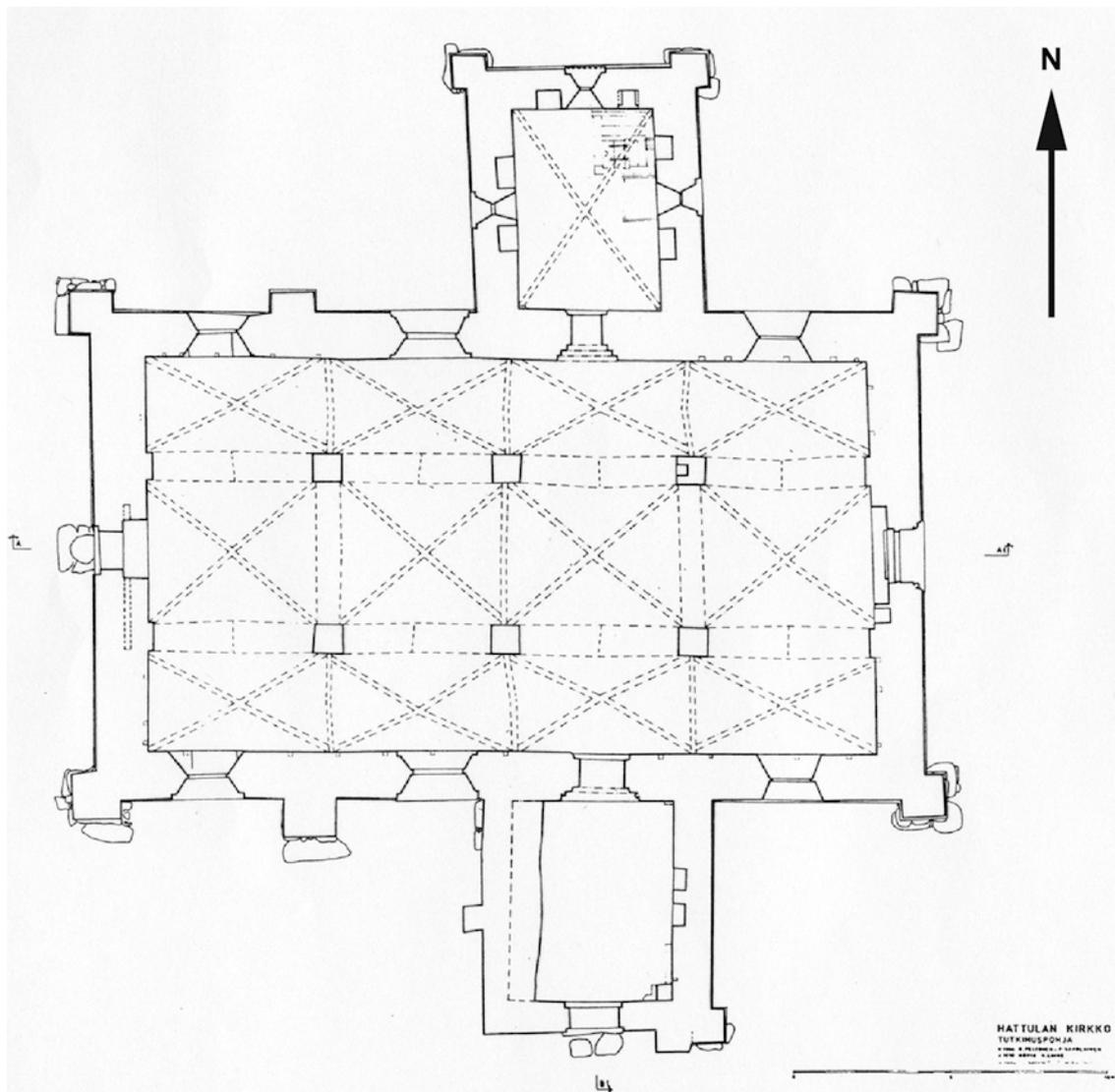


Fig. 1 – The plan of the church (original 1:300), scale bar 10 meters. Drawing by PELTONEN and SAVOLAINEN 1966, later completed by HIRVONEN 1994. Department of Monuments and Sites, National Board of Antiquities.

The nave and the sacristy are fairly well preserved in their medieval appearance. The southwest buttress and the western part of the south nave wall, including the buttress in the middle, were rebuilt later, and two new windows were opened on the north wall while the old ones were enlarged (DRAKE 1967: 220; 1970: 16; KNAPAS 1997: 11–13; MÄNTYLÄ 1979: 747; HIEKKANEN 2007: 283). Only the southeast buttress and the east wall of the medieval brick porch were saved, the rest was torn down and rebuilt in stone, probably at the end of the 18th century (AILIO 1913: 13; EDGRÉN and HIEKKANEN 1987: 87–97; HIEKKANEN 1994: 198; 1996b: 57–59; 2007: 283; KNAPAS 1997: 13–17, 117–118) (See Fig. 2).

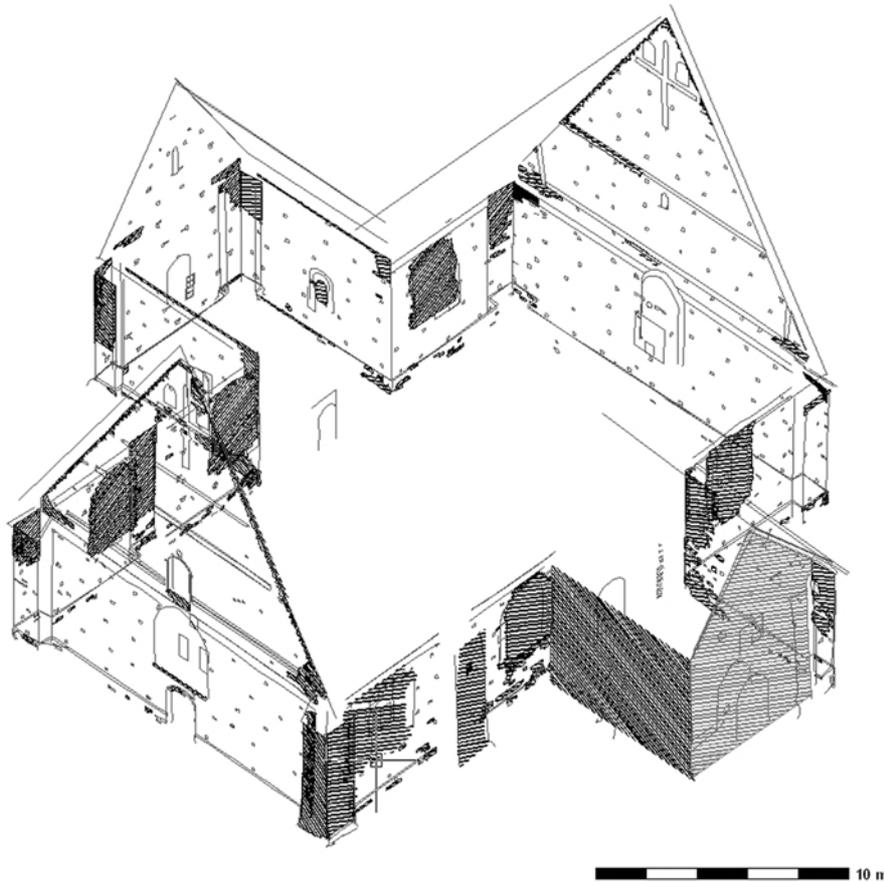


Fig. 2 – Wireframe model acquired with total station measurements. Hatched areas mark the later repairs. Scale bar 10 meters. Isometric view: south-west. Image by Tanja Ratilainen.

The church was studied for the first time at the end of 19th century when the paintings were revealed and recorded (e.g. NERVANDER 1886). The building archaeological survey mostly concentrated on the porch and the construction works mentioned in the written sources (RINNE JA MEINANDER 1912: 6; AILIO 1913: 1, 4; MELANDER 1913: 92–95; AILIO 1914: 11–15; KARTANO 1948: 79–82; KARTANO 1949: 94–98). Later it was established that the entire porch was originally made of brick (e.g. EDGRÉN and HIEKKANEN 1987: 87). The first person to really put emphasis on building archaeological survey was Knut Drake (1967: 217–231; 1970: 12–29) who studied the building phases of the church. He suggested the nave with the gables was built first (firstly the eastern gable, then the western gable secondly), then the walls of the sacristy and the vaults, and finally the porch. However, he underlined that some of these phases could have been executed at the same time or immediately after one another, or that a considerable amount of time could have passed between them (DRAKE 1967: 220–222; 1970: 20). The general conception prevailing at the time was that the building of a stone church was a heavy economic burden for parishes and thus, stone churches were built little by little, for decades or even longer (e.g. KRONQVIST 1948).

In Markus Hiekkänen's dissertation *The Stone Churches of the Medieval Diocese of Turku, A Systematic Classification and Chronology* (1994) Finnish medieval stone churches were studied as a whole for the first time. Applying the methods of art history, archaeology and absolute dating, mainly dendrochronology, he was able to divide the churches into three groups (A, B, C) with regional distribution and give time frames for their building. He deduced from the evidence that stone churches were mainly designed and built, being

completed from the foundations to the wall paintings in a relatively short period of time and in some regions considerably later than previously imagined. This applied to the Holy Cross Church as well (HIEKKANEN 1994: 220–221; also HIEKKANEN 1996b: 47–76). Since then, the results of the dissertation have been compiled and sharpened, for instance concerning the dating, but the basic conclusions on the stone church building still stand (see e.g. HIEKKANEN 1996a; 1997; 2003b; 2007). Later, in an issue of the Suomen Kirkot -series (Sw.: 'Finlands kyrkor'), the paintings, the liturgical artefacts and the building history of the church were treated as a whole by various writers (KNAPAS (ed.) 1997).

I first studied the church for my MA thesis (2001), discovering new information on its building techniques and concluding that the church was built as a single building project. However, I suspected then that the masons perhaps changed the bonding technique according to their needs and not simply applied the technique they once learnt. Many questions posed including the latter were left open then because of the challenges in the documentation of the survey (see RATILAINEN 2003: 155–164). In 2007, I returned to the subject as I started to work on my PhD.

The aim of the ongoing research is to study the brick building techniques of the Holy Cross Church. Questions asked are: How did the bricklayers proceed in their work? Is it possible to recognize individual masons? Was a single project concluded in a relatively short period of time? In this article I will shortly present the digital surveying methods applied and a selection of the results concerning the building techniques used on the church.

Surveying Methods and Acquired Data

Rectified photographs – foundation of the documentation

One of the popular and simple applications of photogrammetry applied for recording of flat surfaces like walls is producing rectified photographs (e.g. ANDREWS et al. 2003: 10; ANDREWS et al. 2005: 2; BITELLI et al. 2006: 324). In this method, recording of a wall is executed with one photograph in which the errors in perspective are corrected or "rectified" (See e.g. ANDREWS et al. 2003 for a more thorough discussion on the method).

In co-operation with Muuritutkimus Ltd and my supervisor, docent Kari Uotila, rectified photographs were produced with PhoToPlan, a plug-in software for AutoCad. Digital photographs and control points of the walls were acquired for the rectification process. The upper walls were photographed with a camera mounted on a helium filled Zeppelin. Reflectorless total station was applied to measure the control points (See RATILAINEN 2009; in print a; in print b for a more thorough discussion on the procedure).

All the facades were rectified and put in the same coordinate system. In this way a simple 3D model of the exterior church walls was created (Fig. 3). To increase the accuracy of the record, more than one photo per façade was usually applied. In addition, the buttresses that extend out of the wall were each rectified individually; therefore they are located in the correct position in the coordinate system (RATILAINEN 2009; in print a; in print b).

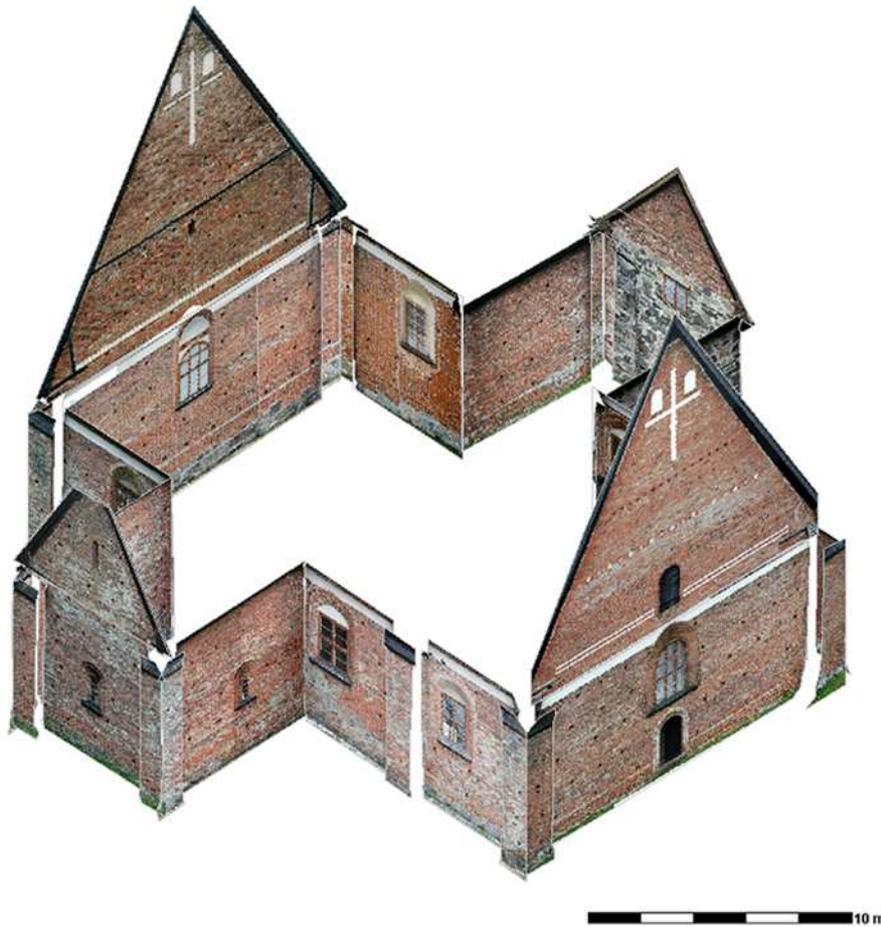


Fig. 3 – All the facades were rectified and put into the same coordinate system. In this way, a perhaps not so beautiful, but usable 3D model was created. See also the whitewashed band-like niche located on the upper part of the nave. Scale bar 10 meters. Isometric View: north-west. Image by Tanja Ratilainen.

Measuring the putlog holes

Most of the putlog holes in the exterior walls were measured while acquiring the control points for the rectification process. In addition, total station measurements were also made inside the church where the first two levels of putlog holes are visible, while the rest of them are probably covered with paintings and whitewash. Furthermore, the putlog holes situated in the attic, on the gables of the church, were recorded in co-operation with the Institute of Photogrammetry and Remote Sensing of Aalto University by using stereo-photogrammetry (See RATILAINEN in print a and in print b for a more thorough discussion on the co-operation, procedure and problems concerning the measurements).

Making use of point cloud acquired by laser scanning

In Finnish building archaeological research, laser scanners have been applied mainly on an experimental level (HEISKA 2008: 37; 2009: 91; UOTILA 2007: 12–20), as in Hattula. A point cloud was acquired both of the exterior and interior walls of the church with Faro LS 880 by the team consisting of researchers of the Institute of Photogrammetry and Remote Sensing of the Aalto University and the Finnish Geodetic Institute. Using the point cloud, of which accuracy was 2 cm, researcher Nina Heiska produced projections showing the shape of the wall. Thus, the slight curves visible on the masonry could be studied (See RATILAINEN 2009; in print a; in print b).

Building archaeological data

All the data gathered during the building archaeological research was transferred to the simple digital 3D model created with photo-rectification. As the textured walls work as traditional line drawings by themselves, I chose to draw all the anomalies in the brickwork. In that way, the changes and irregularities in the monk bond could be pointed out and studied. Features such as bats and other than two stretchers between headers were drawn on separate layers in AutoCad. Thus, it was possible to study a certain feature or a certain combination of features at a time per wall or for the whole church. The measurements acquired with stereo-photogrammetry and reflectorless total station were combined in the same coordinate system with the rectified photos. Thus, all the data gathered for example on the putlog holes was in the same environment (See RATILAINEN in print a; in print b).

Results

Colour zones of bricks

The colour of the bricks in the masonry varies from light red to black. This is due to the heat and bricks' location in the kiln while firing (e.g. BERGSTRÖM 1936: 14). In addition, the gases created in the kiln affect the colour as the oxidized conditions turn bricks red and un-oxidized grey or black (e.g. ANDERSSON and HILDEBRAND 2002: 52).

Occasionally bricks of the same colour tone form horizontal zones of four or more courses in the masonry. These zones were drawn onto an AutoCad record, and compared with vertical and horizontal joints indicating brakes in the building project. The lichen and moss growing on the walls created a problem in defining the colour zones, therefore certainly not all areas were found. However, when the zones were clearly definable, in most cases they matched with the joints relating to brakes in the building project. Thus, in some cases bricks were probably sorted according to their colour and a clear change in brick colour zone would indicate a brake in masons work; when the works were recommenced bearers would have delivered bricks from another pile. These colour zones relate also to the bricklayers' way of working in horizontal courses (Ratilainen in print a) (See Fig. 4).



Fig. 4 – The colour zones visible on the east wall of the nave. Photo by Tanja Ratilainen.

Brick measurements

In theory, the size of brick is defined according to the bonding technique applied. In an ideal case applying monk bond the length of the brick should be two times the width including the joint in between (SUNDNÉR 1982: 70; MALM 1992: 235. See also BERGSTRÖM 1936: 10 and RINNE 1941: 66). In practice, the factors influencing the brick size are varied. A lot was dependant on the skills of the brick maker: did he know how the clay, sand and water should be baked together; was he aware of the characteristics of his material concerning the shrinking and how he handled the firing process (e.g. ROSBORN 1973: 44–45; LINDGRÉN and MOESCHLIN 1985; MOORE 1991: 220–223; ANDERSSON and HILBE BRAND 2002: 51–52). However, considering all this, variation in brick size can be used to study building phases and within the building phase, size can be used to study brick production (See e.g. ROSBORN 1973: 44–45; SUNDNÉR 1982: 53–63; BROGILOLO 1988: 27; UOTILA 1998: 43–55).

The analyses of firing temperatures, the ingredients or the density could widen the picture on the brick production (See e.g. DAHLBÄCK 1982: 142–144; LUOTO 1982: 128; WAHLBERG 2000: 123–130; HULTHÉN 2001). Furthermore, the marks on the surfaces of the bricks could provide information about the handling of the bricks during the production process (e.g. SMITH 2004: 259). In addition, the brick makers' signature marks could be used to study the organisation of brick making (See e.g. DEBONNE 2009: 459–464). In this case, brick size and signature marks were selected for closer study.

A sample of in situ bricks was measured from the eastern wall and the gable with 0,5 cm of accuracy (See their location Fig. 5.). A total of 260 bricks were measured from the eastern gable, 245 bricks form the northern part of the eastern nave wall and 237 on the southern side.



Fig. 5 – Three samples of bricks measured on the eastern gable and on the east wall of the nave marked with red. On the right is the northern sample, on the left the southern. The samples were 1 meter wide. Each brick was measured with 0,5 cm accuracy. Image by Tanja Ratilainen.

These locations were chosen because they were assumed to present three stages in the building process. Bats were excluded from the analyses. The distribution of the length measurements (Fig. 6a) shows that the brick size used on the eastern gable is consistently smaller than on the eastern wall, but there is no difference between the samples of the nave. The same applies to the width measurements, but not to the thickness (Fig. 6b & 6c). However, this could be explained by the fact that shrinking affects thickness in a smaller proportion (e.g. SUNDNÉR 1982: 58). Following the tracks of Sven Rosborn (1973) we may deduce from the evidence that the brick maker of the eastern gable was probably aiming at a length of 27 cm and

the one making the remainder aimed at 28 cm. Thus, it is possible that at least two different brick makers using different mould sizes produced bricks for Hattula.

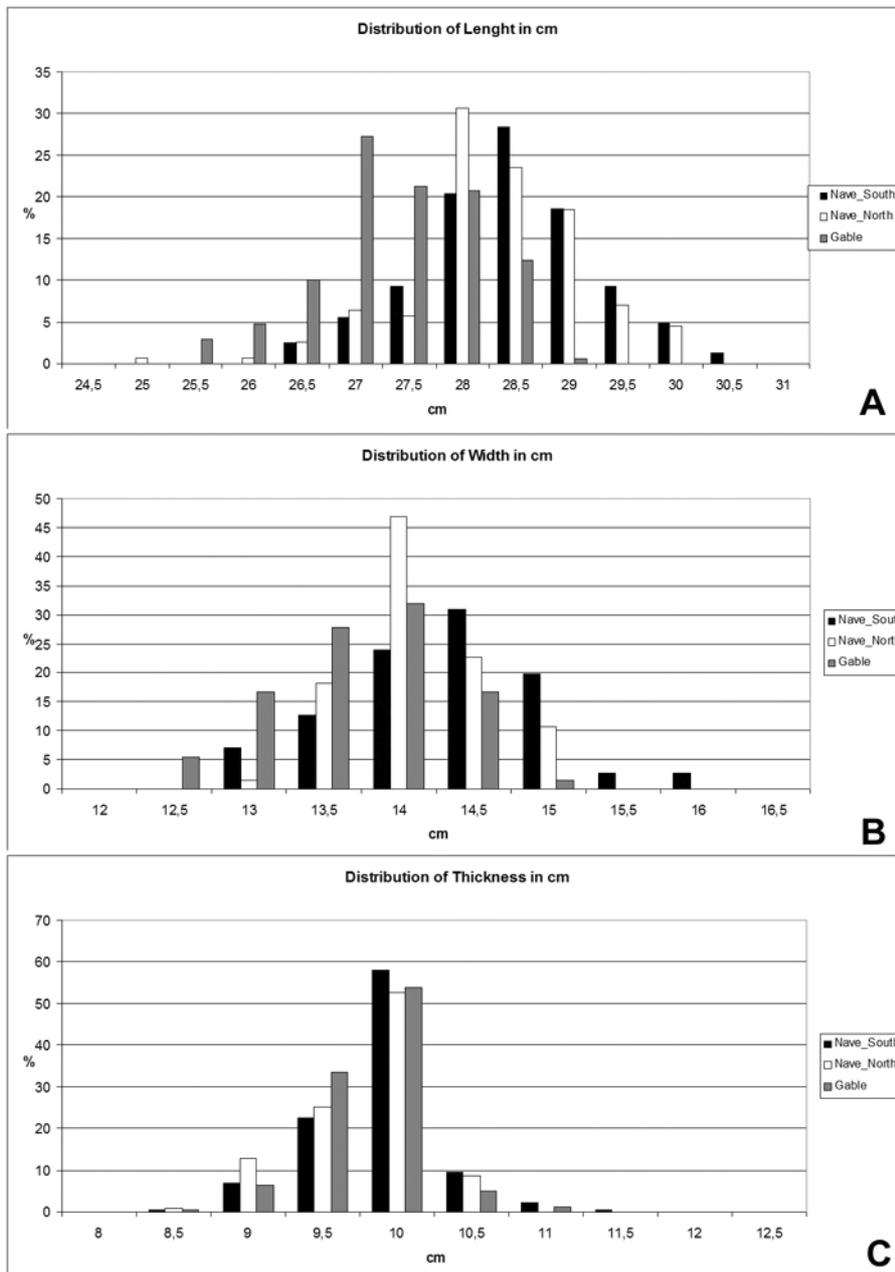


Fig. 6a–c – Distribution of length, width and thickness in cm. Chart by Tanja Ratilainen.

On the walls there are no marks that could be interpreted as brick makers marks as in Turku Cathedral (RINNE 1941: 309; RATILAINEN, in print c). It is difficult to imagine that in Hattula all the marks would have been hidden in the masonry. Does the lack of brick makers marks mean that producers did not need to mark them, i.e. they were all produced on the same site? But then why use different dimensions in the mould? It seems more likely that there was change in the brick production, which could indicate an interruption or delay in the building project. This could have happened after finishing the nave with roof trusses and probably vaults as well.

Bonding technique

In medieval Sweden, to which most of modern day Finland belonged, two bonding techniques were in use; monk bond i.e. Flemish double stretcher bond and Wendish bond. In the regular monk bond one header is followed by two stretchers and headers create either a zigzag or diagonal pattern between the courses. In Wendish bond, there is only one stretcher between the headers. Monk bond was commonly used through the Middle Ages while the Wendish bond was rarer (See e.g. GARDBERG 1957: 33, 63; LINDGRÉN and MOESCHLIN 1985: 57–58; MALM 2000: 205; ANDERSSON and HILDEBRAND 2002: 55–56). The use of monk bond is estimated to have come to an end in Finland at the beginning of 16th century, (e.g. GARDBERG 1957: 33, 63) but this is not certain (HIEKKANEN 1994: 215). Wendish bond became the prevailing bonding technique in the 16th century (GARDBERG 1957: 33; HIEKKANEN 1994: 215). In general, the use of regular bond is considered to improve the firmness or strength of the wall. Wendish bond, with its denser use of headers compared to monk bond, is usually connected to a desire to make the wall stronger (See e.g. GARDBERG 1957: 32; MALM 1992; 2000: 206; ANDERSSON and HILDEBRAND 2002: 56). However, based on the notion that Wendish bond and two types of monk bond may exist in the same wall, Malm (1992; 2000: 206) suggested they all would have an equal function. Each mason would have used the bonding technique he had learnt, provided no technical or architectural (decorative) cause affected the work. This was also the conclusion of Sundnér (1982: 71–72, 80–81) who also analyzed building technique. For instance, when the walls that shared the same function and bearing capacity were studied, the building of windows and portals would not have affected the number of stretchers used, but was rather due to the tradition the mason had learnt. In addition, saving bricks would have affected the technique (SUNDNÉR 1982: 71).

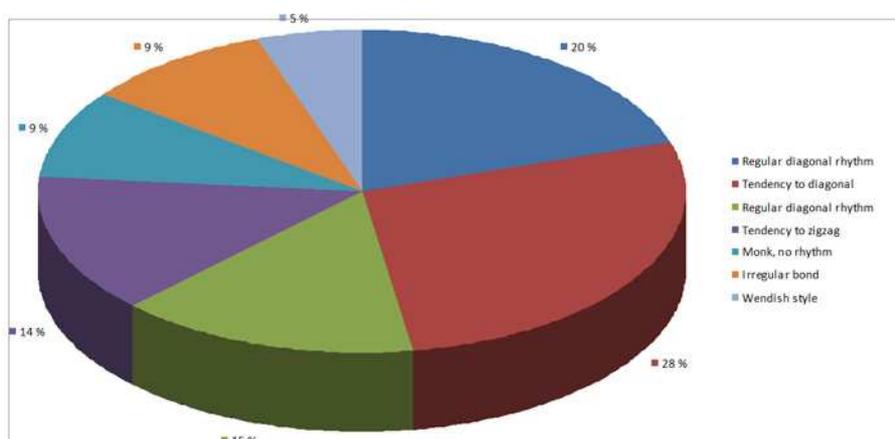


Fig. 7 – A total of seven different bonding rhythms were defined. Chart by Tanja Ratilainen.

Monk bond was studied by analyzing the rhythm of the headers i.e. how headers alternate in the bond and by counting the number of stretchers between the headers. A total of seven different types of bonding rhythms were defined in Hattula (Fig. 7). The four most commonly used rhythms were: 1) regular diagonal pattern, where headers ran diagonally, either regularly or nearly regularly; 2) tendency to regular diagonal pattern, where headers sometimes ran diagonally, but with many exceptions; 3) regular zigzag pattern, where headers of every third course are under each other regularly or nearly regularly; and 4) tendency to

regular zigzag pattern, where headers sometimes form the pattern, but with many exceptions. The three least applied rhythms were: 5) monk bond without a rhythm, where there are two stretchers, but no headers form any pattern; 6) totally irregular rhythm, where headers create no pattern and there is an irregular number of stretchers in between them; and 7) Wendish style rhythm, where there is one stretcher between headers (On the earlier analyses see RATILAINEN 2003: 160). The percentages are based on the number of the defined areas, but it also appears to apply on the size of the areas. Contrary to Sundnér's notion, according to which bonding rhythm maybe regular even if the number of stretchers is other than two, this does not seem to apply at Hattula; the more irregular the bonding rhythm, the more irregular is the number of stretchers in between.

Following Barbro Sundnér (1982) and Gunilla Malm (1992; 2000) I first tried to find reasons other than masons' tradition to explain the variety and changes in the bonding technique. Firstly, aesthetic reasons were considered. It seems likely that the exterior walls were not covered with whitewash. This is based on the use of special building material, brick, which I do not think the builder would have wanted to be hidden. In addition, in places where the masonry is not meant to be seen, the quality of the brickwork is not as refined, for instance in the north wall of the porch, though this has to be studied more thoroughly in the future. Furthermore, the whitewashed decorative details, for instance the band-like niche running on the upper part of the nave (See Figs. 3 and 8), even with paintings, would have been less visible if all the walls were whitewashed. Thus, the masonry needed to be made according to the fact that it was meant to be seen, so in that respect aesthetics influenced the masons work, but it did not affect the order in which headers and stretchers were laid as for example no black headers were used to make decorative patterns. Secondly, the number of stretchers applied and thus saving of bricks was studied. Comparing the number of more than two stretchers between equal sized walls showed that a lot of stretchers were used on the eastern gable and on the sacristy gable. There saving bricks probably had an affect on bonding technique, but it did not seem to affect the masonry elsewhere. Thirdly, technical factors such as building the buttresses and windows were studied. It is clear that bats and irregular numbers of stretchers and irregularities in the bonding rhythm appear in the masonry when structural details were built and thus, they cause irregularities in the bonding rhythm. In addition, the putlog holes affect the bonding technique. As Malm (2000: 208) already noted the tendency, placing the holes for the scaffolding in many cases causes irregularities including breaks in the bonding technique. In Hattula this applies to 146/305 original putlog holes. However, this does not explain why also the bonding rhythm changes around the putlog levels.

To see if one mason could change from one bonding rhythm to another according to the space available, for example if there was little space he would have used zigzag and with large surfaces he would have used diagonal rhythm, the location of the bonding types where analyzed (See also RATILAINEN 2003: 160). Wendish rhythm was mainly used on the upper part of the long walls of the nave, which could suggest a technical reason relating either to building up windows or the vaults (See RATILAINEN in print b). In addition, the areas where Wendish rhythm was applied are so small that it is hard to imagine they could correspond to one mason's contribution to the building works. However, all the other defined rhythms occurred in both lower and upper as well as on the middle of the wall, not depending on the space available. Furthermore, the colour zones discussed above were compared with the changes in the bonding rhythm and their boundaries mostly matched. As the change of the colour zone apparently relates to an interruption in the masons work,

this could hint that another mason using another bonding rhythm continued the work. In conclusion, the remaining explanation for most of the variations of bonding rhythm is the tradition masons learnt to use. Thus, the mason would have applied the bonding rhythm he knew best when no structural, technical or economical reason required otherwise.

Considering the above it is possible to recognize a mason or rather group of masons that applied the same kind of bonding tradition. This means that it is possible to estimate if the same group of masons build the whole church, like Sundnér (1982) did. The four most commonly applied bonding rhythms can be found on nearly all of the walls of the church. Considering the main building stages: the nave and the sacristy, and the porch and each of the gables, all types of rhythms can be found on each stage. Furthermore, except for the Wendish style, the least applied rhythms can also be found on each stage or, logically, on the first and the third stages. Thus, this would suggest that same masons built the church from the foundations to the top of the gables.

Scaffolding

In the medieval period the masons usually worked on both sides of the wall, therefore they needed scaffolding on both sides (SUNDNÉR 1982: 77; RODWELL 1989: 123). At least three types of scaffolding were used: 1) flying scaffolding i.e. planks with only horizontal logs through the wall; 2) putlog scaffolding i.e. planks with horizontal logs not through the wall, but supported also by vertical poles on the ground; 3) self-standing or trestle scaffolding i.e. not attached to the wall. When the first two were applied, the putlog holes were created on the wall; the third one left no marks (See e.g. ANDREWS 1976: 69–70; SVANBERG 1983: 63–64; RODWELL 1989: 123; EKROLL 1997: 79; BINDING 2004: 16). Putlog scaffolding was particularly applied to brickwork according to Binding (2004: 16).

Putlog holes with fairly regular intervals cover the exterior walls of the church. Only the western gable, part of the buttresses and the lower part of north nave wall lack them (see Fig. 3). In the church, one can find putlog holes in one or two levels, the rest were probably covered when the paintings were made. Above the vaults, there are no putlog holes in the sacristy gable, but they are present on both of the nave gables. On the eastern gable wall, putlog holes are distributed throughout the wall in seven levels. On the western gable wall, there are three levels under the area of brick ornamentation and three levels above it (See Fig. 8). Comparing the location of the putlog hole levels on the exterior and interior walls, it was interesting to notice that they do not coincide. The interior putlog holes are located 1–4 courses higher than the exterior ones. The fact that horizontal logs did not go through the walls was expected, since the brick in the back of the hole was mostly laid in a way that it could not have been put there afterwards. However, now it is clear that bricklayers working on both sides raised the walls slightly at a different pace using mostly putlog scaffoldings and were not completely dependent on each other.

Between the putlog levels there are usually 10 to 12 courses. In centimetres the height between the levels varies from 110 to 140 cm. It has been suggested that masons working horizontally raised the walls about 80 cm or slightly more at a time. This could be seen as slight horizontal curves or waves in the masonry (PIETARILA 1999: 41, note 3). Having analysed the projections showing the shape of the wall it seems unlikely that curves relate to the amount of brickwork masons were able to build at a time, but some exceptions off the plumb could be related to the building technique of the windows, stages in the building

process and later repairs (See RATILAINEN in print a, RATILAINEN in print b for a more thorough discussion). The heights between the putlog levels suggest that the planks were mostly taken away while other scaffolding structures remained. Examples of this kind can be found among the medieval illustrations (See e.g. BINDING 2004).



Fig. 8 – Putlog scaffolding was applied on the western exterior nave wall, but not on the gable. However, on the interior gable wall there are putlog holes in six levels, only the area marked with white lacks them. See also the whitewashed band-like niche above the window and the decorative elements on the gable. Photo by Tanja Ratilainen.

It was proposed that the lack of putlog holes on the exterior western gable was perhaps due to another group of masons having finished the church later, after an interruption in the building works (DRAKE 1967: 220; 1970: 20). I do not think this is necessarily the case since it is likely that different kinds of scaffolding were used during a building project. An example of this may be found in a manuscript depicting the construction works of a tower where masons use three kinds of scaffoldings at the same time: simple flying and presumably a safer option of flying scaffolding supported by diagonal logs attached to the lower level and, partly hidden behind the tower; a self-standing scaffolding supported only by vertical poles (See BINDING 2004: 145, ill. 453). Naturally, one must be careful interpreting medieval illustrations, but building archaeological evidence at Hattula also points at the use of many scaffolding types. The lack of putlog holes

on the lower parts of the north nave wall and on some of the buttresses indicate that besides putlog scaffolding, trestle scaffolding had been used as well. Furthermore, the western interior gable with its putlog holes on the upper and lower part, shows that there masons applied scaffolding attached to the wall, but they had to use some other technique too, since there are no holes in the middle of the gable (Fig. 8). It is possible that building of the roof trusses affected the works in a way that scaffolding not attached to the walls was used or the roof trusses themselves were applied in the structures of the scaffolding and no holes were needed. In addition, there are no holes in the interior gable of the sacristy even if one can find them on the exterior; therefore two kinds of scaffoldings had to be used there, too. Since scaffolding both attached and not attached to the wall was applied even within a single building stage, like a gable, it seems likely that the same masons could have used different kinds of scaffoldings during a building project. It is possible that the masons building the western gable used the putlog scaffolding of the western nave wall as the base for scaffolding not attached to the wall, otherwise the structure would have been too unstable (See also HIEKKANEN 1989; RATILAINEN 2003: 160–161). The reason for using scaffolding not attached to the walls could have been the brick ornamentation of the gable, which the masons did not want to break with putlog holes. On the eastern gable there are not as many decorative elements as on the western (see Figs. 5 and 8).

Conclusions

Analyzing the digital building archaeological record created by applying photogrammetry, total station measurements and laser scanning showed that bricks were probably assorted after firing and in some cases the colour of the brick revealed where the masons proceeded horizontally. The brick measurements suggest that there was a change in the brick producing process and therefore, possibly a break or a delay in the building project, but upon analyzing the bonding technique it seems that the same group of masons built the whole church. Studying of the putlog holes showed that the masons working on both sides of the walls proceeded at a slightly different pace that the planks of the putlog scaffolding were probably taken down as the works went on and that more than one type of scaffolding was applied during the building project.

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Preliminary Results of Semantic 3D Modeling of Seddülbahir Fortress Using Laser Scanning Data

Esra TEKDAL-EMNIYETI^{1,2} / Karl-Heinz HAEFELE² / Joerg ISELE²

¹ Istanbul Technical University, Civil Engineering Faculty / ² Karlsruhe Institute of Technology, Institute for Applied Computer Science

Abstract: In this poster, the laser scanning task carried out for the documentation and restoration of the Seddülbahir Fortress which is located at the Gallipoli peninsula of Turkey will be explained. The Seddülbahir Fortress project started as a research project in 1997, in 2004 the project evolved from being a research project into a restoration project. As a part of the Seddülbahir Fortress Site Documentation and Restoration Project the entire site was scanned with a point spacing of 5 mm using a Leica HDS 3000 laser scanner accompanied with a Leica TCR407 Power reflectorless Total Station. With the 360° horizontal and 270° vertical field-of-view of the Leica HDS 3000 laser scanner the survey was concluded with satisfactory results at a site comprising nearly 24.000 m² and a building mass of 4200 m². The scans were then processed and the point clouds were registered using the Cyclone Register program and after the registration the noises are eliminated from the data. Then the evaluation of the point cloud data is carried out.

The aim of the work is to create a semantic 3D model for parts of the fortress from the laser scanning data. As possible models the international standart for building information models IFC (BuildingSMART) and the international standart for 3D city models CityGML (Open Geospatial Consortium) will be evaluated.

The final semantic 3D model will be used by different groups of interest (architects, archeologists, structural engineers, etc.) within multiple applications not only for visualization but also:

- Examining the structural condition
- As built documentation for restoration and renovation projects
- As base data for 4D model.

Keywords: Laser scanning, cultural heritage, 3D model, CityGML.

Introduction

The fortress of Seddülbahir, the "Dam of the Sea", was built in the mid 17th century at the entrance to the Dardanelles, on the European side by Hadice Turhan Sultan, the mother of the Ottoman Sultan, Mehmet IV. The fortress was constructed as a part of the Ottoman defense against Venetian naval incursions into the Dardanelles during the long war over Crete and the eastern Aegean. Since that time Seddülbahir has protected the Ottoman, and later Turkish lands, against threats to the Dardanelles, the strategic waterway which leads to the capital of Istanbul on the Bosphorus (Fig. 1).

The documentation project of Seddülbahir Fortress is carried by a team including architects, geomatic engineers, civil engineers and archeologists, employing different surveying techniques like laser scanning as well as traditional measurement like total station, which makes this project interdisciplinary.



Fig. 1 – The location of the Seddülbahir Fortress.

Objectives

In this paper the steps that should be followed to create a semantic 3D model for parts of the Seddülbahir Fortress from laser scanning data using CityGML will be explained.

CityGML is a standardized information model that focuses on semantics, topology, and appearance, in addition to objects geometry. Semantic data tells the geometric entities what they are and relates them to the real world objects (Fig. 2.).

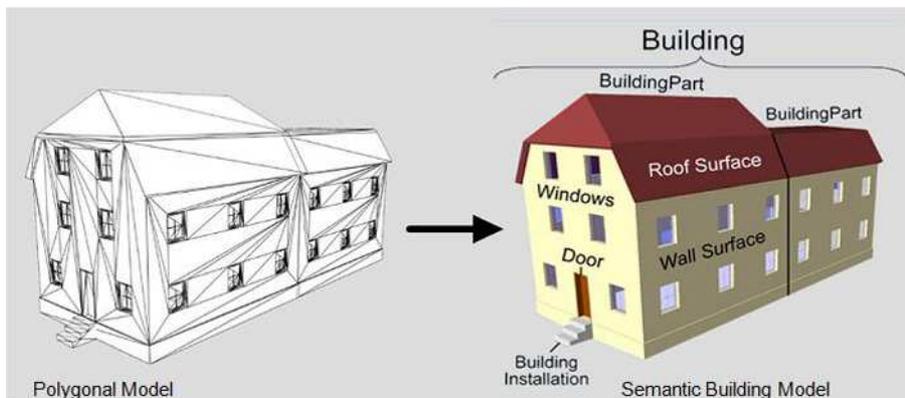


Fig. 2 – The semantic of a building (NAGEL et al. 2009).

Methodology

The North Tower which is a part of the Seddülbahir Fortress is a masonry building, made of stones and mortar. An octagonal structure is formed by the outer walls and hemispherical structure by the inner walls (Fig. 3). The input data for the 3D semantic model are the point clouds. As the fortress is settled on a large area, several scans have been made to scan the whole tower.

In order to use the point clouds as input data for CityGML, several processing steps have been carried out (Fig. 4).

The first step is the registration process that is carried out to unify the different scans (point clouds) in one common coordinate system the Leica Cyclone Register program has been used for this purpose.

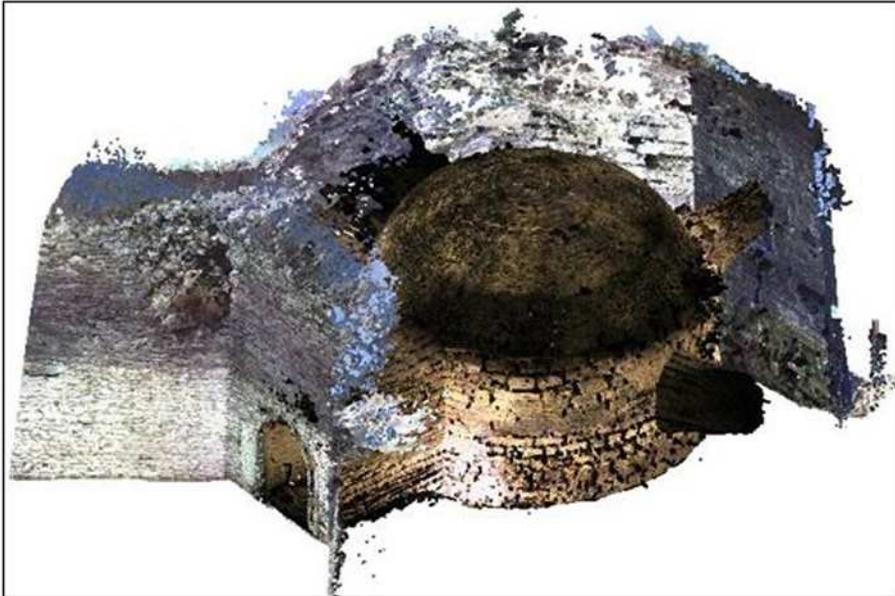


Fig. 3 – Point cloud of the North Tower.

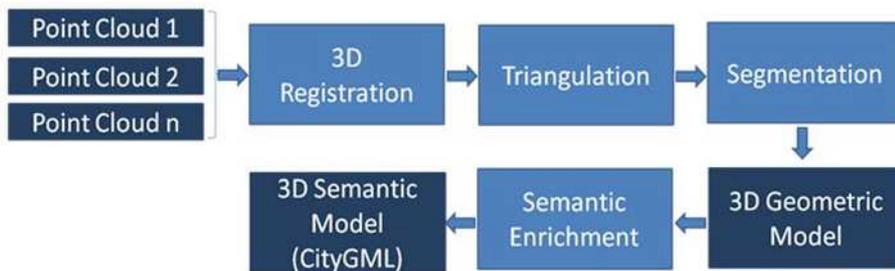


Fig. 4 – The work flow of the evaluation procedure.

The segmentation part is concentrated on detecting the stones in the point cloud using software that can answer the needs of the users. And after the segmentation procedure of the stones, in order to make the stones ready for 3D modeling they need to be triangulated using a suitable algorithm or software.

Semantic Enrichment is the step carried out according to the purpose of the model. The semantic 3D model can be used for multiple applications that may require different semantics for analysis. In our case the semantic inputs can be the results of material analysis and/or findings from archeological excavations.

The figure 5a shows a wall from the North Tower, it does not contain any semantic information, just consists of polylines and surfaces detected from the point cloud. In figure 5b the segmented stones are not only geometric objects but they also contain semantic attribute data (geometric entities are stones belonging to North Tower’s wall).

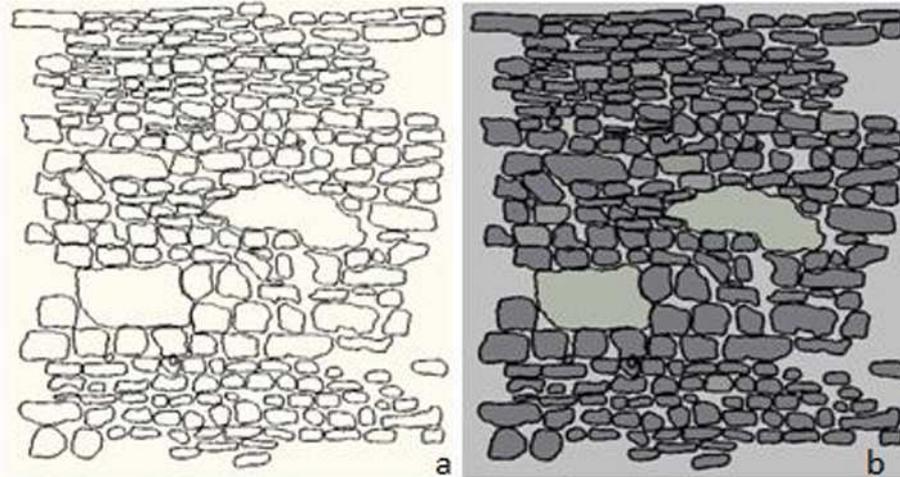


Fig. 5 – (a) 3D Geometric model consisting of surfaces (b) 3D semantic model showing a wall consisting of stones.

Conclusions

This paper is mainly concentrated on a new technology CityGML, for the documentation of cultural heritage using laser scanning data. The preliminary results of that work showed that

- Cost of laser scanning is high compared to other data collection techniques, but it reduces data collection time.
- The final 3D CityGML model will allow different user groups to reach and edit the data easily by saving time and without facing difficulties.
- The Seddülbahir Fortress is in need of immediate conservation and restoration. The 3D model can be used by different disciplines for restoration (i.e. architects, archeologists and structural engineers).

Future work will concentrate on detecting stones from point clouds using automatic or semi-automatic methods.

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