SESSIONS

Urban Archaeology – Session Dedicated to Samuel Paley

In Memoriam Professor Samuel Michael Paley

A short personal obituary, based on many e-mails!

Willem BEEX

Introduction

I can't actually recollect my first encounter with Sam Paley at the Vienna conference anymore. But as usual for him, it must have been intriguing. In any case, it made him a figure to remember.

It is however still crystal clear to me that we had one encounter a year later which showed us that we were kindred spirits on the subject of "Publishing Old Excavations with New Technologies". And while Sam was focusing on the written legacy of those projects, I was focusing on their graphical heritage. Add the fact that we both possessed a same kind of (at times rather cynical) humor, spiced with a bit of sarcasm and enough optimism: The only option that remained to us was to have a workshop with this theme.

This all happened in 2006 and immediately after in 2007 this was a reality. I guess, this was a blueprint for some of Sam's ideas. Somehow, he always could sense people with the same kind of interests and ideas. And once those interests and ideas merged, he was persuasive enough to make them happen!

During that period and later on, I also learned a lot about him personally. Gradually, he told me more and more about his own youth, his education, and his family. Of course, this is not enough to be able to be his biographer, but I do have the impression that it is enough to commemorate him in this publication. This, as I also believe, that he rather would have me to analyze an ancient site, as opposed to wasting my time with too much attention to his own history …

Sam's background

In his own typical way Sam never told me directly that he himself was born in a rather privileged environment in the USA. But from his many e-mails I can tell that he knew that he was fortunate, as he always made this clear in many a small reference between the lines, regarding his own youth.

This is important to know, as his family came to the USA at the beginning of the twentieth century as refugees. So he always knew that his well-being was founded on hard work, rather than pedigree.

SAM came from 14 generations of Rabbis … The family was exiled from Spain in the 15th century and went to France, where they worked for the Palace (d’paley … hence Paley). Later they were beckoned to Poland in the 18th/19th century, when the King wanted to build a middle class.

Sam's family

Samuel Paley was the son of Joseph and Roxy (Stahl) Paley. He met Yael Lazar as a grad student at Columbia and they married in 1967. Together they lived for many years in Buffalo where they raised their 3 daughters. At the moment of his death, Sam also had 3 grandchildren (Amelia, Sofie, Gabriel) and 2 more were on the way.

Sadly, Sam and Yael divorced 1980s. But the next stage of Sam's life began when he met Barbara Koz at a party in Hoboken 1993. She set him up with donors and funders. He seduced her by translating Assyrian reliefs at the Metropolitan. They married in 1995 and he promised never to wear polyester again.

Sam's early years

Actually, it took me quite a while to find out his day of birth. He never made a secret about the fact that he was born in 1941, but once he was gone, I realized that he never ever mentioned his birthday. This was as we never met during one of those occasions. Thanks to his wife, Barbara, I finally solved this enigma. Sam was born on the 15th of October 1941.

He grew up during WWII in Rye Beach, New Hampshire. This must have been interesting for a small kid, as it was near the US Portsmouth Naval Base. His father was a civil engineer in the army, who built airports and other military installations. It did refrain him from visiting the coast, as this part was littered with tar and unexploded ordinance from German U-boats, but it got him on a helicopter before most people in the world even knew those machines existed.

His talent for languages was also triggered during those days. We may partly thank his nanny for this, who came from the French speaking part of Canada. With her, he listened to the French Canadian radio broadcasts and learned French in the mean time.

When he grew older, Sam went to the prestigious Boston Latin School. And being both Jewish and a swift learner, he also studied at the Hebrew High School Brookline, Massachusetts in the afternoon. Not only impressive, but it also shows us something about his future "passion" and his "perpetual energy". I guess his father told him and made it possible to attend both schools at the same time, but in the end it was Sam who completed both of them.

Vietnam?

For a person like Sam, including his family background during WWII, the US armed forces were of course very keen enlist him and to put him in a group for encryption training after his education. Sam's birthday group however, had over 300 boys in it and they stopped at about 180. Sam's number was 242. He himself told me: "Lucky me!.” So he was not immediately drafted.

The US forces did not come back for him for this secret training since by then he was a graduate student at Columbia University. During his years as a student there were riots against Vietnam at Columbia. After that, anyone from Columbia was deemed a security risk. In short, Sam was very lucky.

His cultural life

Locally, Sam was a vibrant presence in the Jewish community of Western New York. He was religious director of Temple Emanuel in Batavia (USA). His dedicated cultivation of the study of Judaism in all its facets, culminated in the recent establishment if UB's Institute for Jewish Thought, Heritage and Culture.

During his life Sam became proficient in 16 languages, modern and ancient. Although he confessed to me in one of e-mails: "I mix them up (language interference), a problem I have had since childhood ..." However I do have the feeling that this was a bit of modesty from his part.

His early scientific career

During his early scientific years, Sam studied at Columbia University. He got his MA at Columbia University, in Art History and Archaeology in 1965. In 1969, he got his M. Phil at Columbia University, in Middle Eastern Languages and Literatures. In 1974, he got his Ph.D., also at Columbia University, in Middle Eastern Languages and Literatures.

In this period Sam conducted excavations in Cyprus and in Israel. Later he became curator at the Brooklyn Museum.

SUNY

The most important part of his scientific career was at the Department of Classics, State University of New York at Buffalo. He started there in 1977 as Adjunct Associate Professor, later becoming Associate Professor and Director and finally Professor and Director of the Judaic Studies Program.

Important archaeological excavations were the Emeq Hefer Project in Israel (from 1979 onwards), Phlamoudhi-Vounari (1970-1973) and the Alishar Hoyuk Excavations in Turkey (from 1993 to present.)

Sam at the Vienna Conference

During the past seven years Sam was a regular visitor of the Vienna Conference on Cultural Heritage and New Technologies. With his enthusiasm and great scholarship, he swiftly became a member of the Scientific Committee. In this function, he was able to focus on two important subjects: The publication of old excavations with new technologies, and a workshop for "newbies". Both subjects clearly reflect his scientific ideals: The need for high standards in archaeological publications and the education and integration of new generations of students in the scientific community.

In December 2008, Sam was diagnosed with brain cancer. A very sad thing to happen to a man with his extraordinary knowledge. In November 2009, he visited the Vienna Conference one final time. He passed away peacefully, surrounded by his wife and family, on the 31st of March 2010.

Sam will be truly missed …

Fig. 1 – Sam in Phlamoudi in Cyprus in 1972.

Fig. 2 – Sam in Israel during the late eighties.

Fig. 3 – Sam in Istanbul.

Fig. 4 – Sam at his latest project in Turkey.

Fig. 5 – Sam at the Vienna conference in 2008.

Fig. 6 – We will miss Sam Michael Paley.

What is Urban Archaeology?

Some short notes from a practitioner

David BIBBY

The point of view in this paper is consciously European and north of the Alps, mainly but not exclusively illustrated by examples from Baden-Württemberg, South West Germany and neighbouring Switzerland, relying heavily on the development of the archaeology in the city of Constance of the German-Swiss border. Whilst this talk is not really about “new technology”, archaeology in the urban environment has always been a strong motor, driving developments in archaeological techniques and thinking, in both practiced and theory. As first speaker at this conference I have set myself the task of answering the question: “what is urban archaeology?” A question which can be approached in various ways. In trying to identify what distinguishes urban archaeology from other types of archaeology – or indeed whether urban archaeology is clearly distinguishable at all – I will approach the question from the point of view of an archaeologist who has worked every day for many years in that environment. Whilst preparing this talk I soon realised how ambitious the task I have set myself is – especially in the time available. Maybe I can provide a few answers and some thoughts. I hope at least to provide an initial platform at the outset of the conference and look forward to many more answers during the next few days!

A simple “naive” definition is that urban archaeology takes place in an urban environment, which in turn results in the name. But is really that simple? In modern German usage urban archaeology is generally called „Stadtarchäologie” town archaeology but sometimes also “Stadtkernarchäologie” – town centre archaeology. This might just be a function of the German language’s propensity to categorize. But maybe what we imagine to be „urban archaeology“ is, in the German sense, more specific and does appertain to „city centre“ or at least “urban conglomerate”. On the other hand: must an excavation be situated in the centre of a, most likely, medieval town to qualify as “real“ urban archaeology? Some years ago the well known German archaeologist Dieter Planck, spoke of *Medieval archaeology* concentrating on excavations in the *medieval* city centres (of the cities in Baden-Württemberg) (PLANCK 1986: 6). Consciously or unconsciously he thereby defined urban archaeology as a subsection of medieval archaeology. Is that misleading? Archaeology in an urban environment has a long tradition:

> *“Archaeological-historical urban research can look back on a long tradition in the previously Roman areas of southern and western Germany and Switzerland. Systematic excavation some of them as early as the 19th century resulted in Trier, Cologne and Mainz, in Bonn, Xanten, Rottweil and Rottenburg, in Basel, Geneva and Avanches – to name only a few examples – in outstanding new knowledge on the form, structure and development of the Roman towns”* (OEXLE and SCHNEIDER 1992: 14)

Even if at first the medieval layers in these early urban excavations where largely ignored, their presence could not be denied and slowly an awareness for their value grew (as we will see I the example from Constance, below), affording the recognition of the *medieval* as an aspect of the *archaeology* rather than just the architectural history of historical towns.

Günther Fehring, another famous German archaeologist also saw part of the origin of modern urban archaeology in Germany in the growth of interest in “previous Roman towns and their survival into the early middle ages” (FEHRING 2000: 150). Some of his examples can be recognized from the previous reference: Cologne, Bonn, Mainz and Trier as well as Augsburg, Regensburg and Xanten as examples. Xanten however, seems to me to me to be a curious example for a centre of urban archaeology. Apart from sporadic excavations in the cathedral and the occasional discovery of roman graves in the medieval town, most interest was invested in the Roman town of Colonia Ulpia Trajana lying, as it does completely outside the medieval town.

The South West German and Swiss perialpine lakes might not seem to be a promising area of research when trying to investigate the essential nature of urban archaeology. But they show a further aspect. The example shown in Fig. 1 may be illustrative. Both photographs show wetland archaeology on the Neolithic pile dwellings of the perialpine lakes – two almost identical sites. But the top one, 25 years ago in the eminently rural and idyllic setting of the German shore of western Lake Constance, the bottom one late 2010 in the centre of Switzerland’s largest city – Zürich – The „Opera“ excavation campaign. What makes the Zürich site „Urban“? it‘s certainly not the type of archaeology itself – standard every winter on the shore of any one of the prealpine lakes. The only difference in this case, it seems, is the immediate environment in which the excavation takes place. It is certainly not the type of archaeology itself. In fact the archaeology itself is if anything archetypical of a special rural environment. Even so, we now have at least three different epochs represented in archaeology within the Urban environment: Neolithic/wetland, Roman and Medieval – and there are many more, as we will see.

Fig. 1 – Neolithic pile Dwellings excavations. Left, rural South West Germany. Right, urban Zürich (Landesamt für Denkmalpflege Baden-Württemberg/Stadt Zürich, Hochbaudepartement, Stadtarchäologie).

In Constance too, the author’s archaeological *heimat* from 1985–2005, in the very South West of Germany on the Swiss border, erudite scholars originally out to discover the Romans, where already uncovering the wider meaning of “urban archaeology”. Led by the apothecary Ludwig Leiner, born 1830 (Fig. 2) and already by the middle of the 19th century „modern“ in the sense that he treated the Roman and the post Roman layers as equals. Even though his starting point was clearly the search for “Roman Constance“– he did not simply dig through the later layers, he analyzed their finds and categorized them accordingly. He was also an early “rescue archaeologist” on the building sites in late 19th century Constance he took notes and – as he wrote himself – collected the finds “like a crow picking up the seeds“ (OEXLE and SCHNEIDER 1992: 14).

With the nearby example and, most probably, inspiration of “Antiquarische Gesellschaft” – the “Antiquities Society” in Zürich, a bigger city, but with much in common with Constance, both topographically and archaeo-historically, Leiner’s observations, and his many finds became the basis for the Rosgarten Museum, which he founded in 1870 (pre-empting the foundation of the Swiss National Museum in Zürich by almost 30years) and provides us with an early example of a display showing urban archaeology as a “history supplier” not in a general sense, but specifically for the town in which the archaeology took place. The Rosgarten museum is now a sort of “museum in a museum”, especially the Leiner Collection itself. Fig. 3 was taken in 1925 and hardly differs from today’s appearance.

Fig. 2 – Ludwig Leiner, Constance around 1900, photo Eugen Wolf (Stadtarchiv Konstanz, Sammlung Wolf).

Fig. 3 – Rosgartenmuseum, Leinersaal 1925, photo Eugen Wolf (Stadtarchiv Konstanz, Sammlung Wolf).

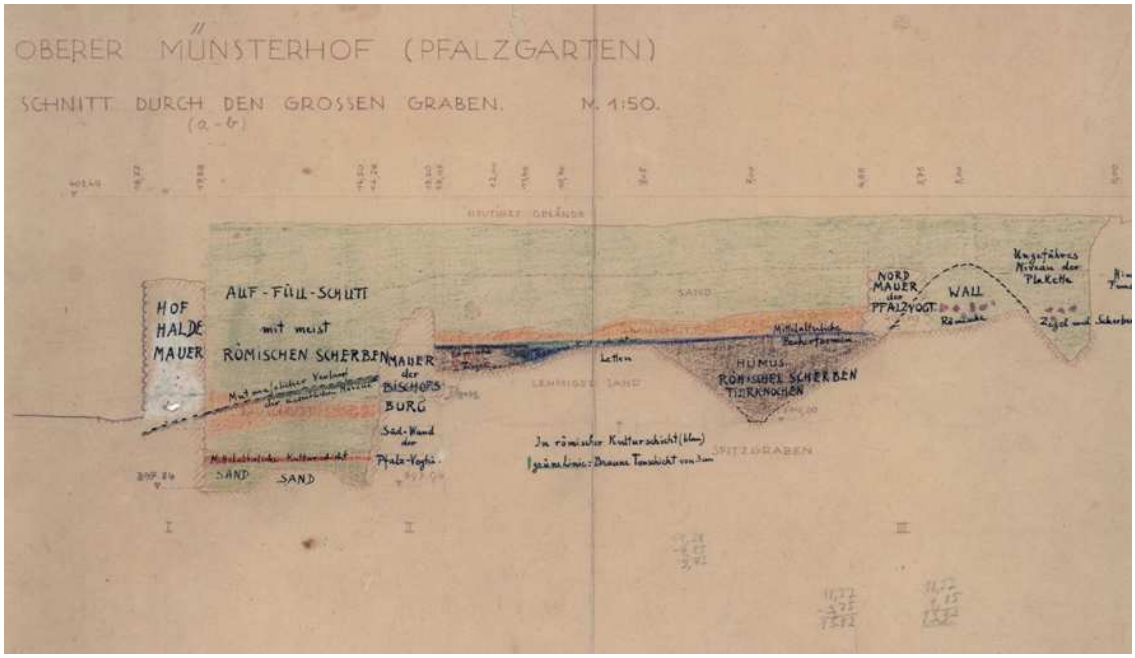

Fig. 4 – Original excavation section Pfalzgarten Constance, early 20th Century (Landesamt für Denkmalpflege Baden-Württemberg, archive Konstanz).

The field notes and drawings of Leiner and his assistants, who later continued his work, show not just Roman, but also medieval features, which are clearly identified and where considered worthy of recording. The excavation section illustrated in Fig. 4 shows the Roman layers still to be the main point of interest, but it also shows how awakening of curiosity in the archaeology of the medieval or, more generally, the post Roman town, was promoted – at first as a by-product of the interest in the Roman origins but with increasing

autonomy. The outcome of which is however not the simple equation: “urban archaeology = medieval archaeology”.

In Constance in the year 1995 a late medieval house was demolished during redevelopment on the Münsterplatz in the city centre. Immediately below the floor level of the house complicated medieval layers in many fine strata were uncovered (Fig. 5) above Roman layers, exemplified by an early Roman defensive ditch (Fig. 6). And below the Roman levels? Features dating to the late LaTène period (Fig. 7). Maybe this example is of help in recognizing some of the defining criteria of urban archaeology: urban archaeology is not just Medieval or Roman or even industrial archaeology, it can be all of those in any combination – and it can also reach back into prehistory – with or without a Roman intermezzo.

Fig. 5 – Medieval floor levels Münsterplatz 1, Constance 1993 (Landesamt für Denkmalpflege Baden-Württemberg/Bibby).

Fig. 6 – Roman ditch, Münsterplatz 1, Constance 1994 (Landesamt für Denkmalpflege Baden-Württemberg/Bibby).

Fig. 7 – Iron Age Pit, Münsterplatz 1, Constance 1994 (Landesamt für Denkmalpflege Baden-Württemberg/Bibby).

Complex stratigraphic situations feature strongly in urban excavation. And it is no accident that one of the greatest revolutions in stratigraphic analysis and thinking, The Harris Matrix originated in an attempt to grapple with the deep and complicated stratification of Medieval Winchester, England in the early 1970s. The Harris Matrix as we all know is not a Matrix in the mathematical sense, but a “half ordered set“ and as such has awakened the interest of Mathematicians set theorists and computer programmers, who have developed computer programs to ease the building and phasing of such diagrams. So here we have urban archaeology in a completely different roll, as a cradle of innovations which have come to benefit all types of archaeology. Sometimes the similarity between urban archaeology and settlement archaeology is strong. On an excavation in “epicenter” of Constance in the *Pfalzgarten*, the palace garden, adjacent to the cathedral, remains dating to Medieval period were almost completely absent. Those present consisted of little more than a dust layer with a few medieval sherds. The strongest feature was a 60 cm Roman horizon (Fig. 8).

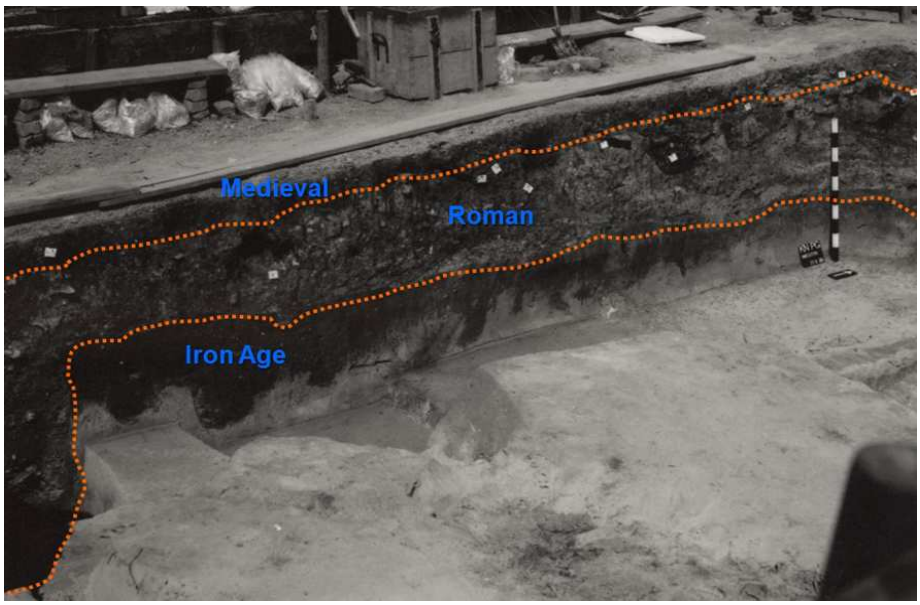

Fig. 8 – (Landesamt für Denkmalpflege Baden-Württemberg/Bibby).

Fig. 9 – (Landesamt für Denkmalpflege Baden-Württemberg/Bibby).

Fig. 10 – (Landesamt für Denkmalpflege Baden-Württemberg/Bibby).

The La Tène horizon was not a surprise, but the richness of features was: stake walled wooden buildings (Fig. 9) reminiscent of the buildings from rural iron age settlements as well as clear traces of prehistoric plowing less than a meter under the present surface of the palace garden (Fig. 10): the first archaeologically ascertainable traces of human activity being therefore rural and agricultural at the central point of the medieval and modern city!

The question appropriate to this example is not *what* is "urban archaeology"? But *is* this urban archaeology? Is this example that what appears in the mind's eye when one hears the term "urban archaeology"? Should we not be surprised to find such a site in the city centre? It would certainly be less unusual in a rural setting. No one would be surprised and say that the site would fit better into a city centre situation. The excavation on the *Pfalzgarten*, with its tendency to untypical findings, provides us with another partial answer to the question of definition: the ratio *to* each other of *findings* on the one hand and geographical situation within the urban environment on the other, the weighting varying from case to case. The findings on the *Pfalzgarten* make a case against an "urban archaeology-definition". The unique geographic position in the town centre adds weight to the case for defining the excavation as urban. Whilst digging on the on the *Pfalzgarten* site all those years ago a colleague from the countryside visited the excavation and suggested that this particular dig was a "pleasant change" for me. At that time, I agreed with him, without thinking about it. On reflection, today, I ask myself "change from what"? What he was referring to were the clean sandy layers, the light colors , the simple stratigraphy, and that everything was airily open, clean and dry. Might it be that real urban archaeology should be dirty and occasionally waterlogged, or even completely flooded or perhaps extremely smelly to qualify as authentic? (Fig. 11).

In the urban environment we are constantly reminded that we are operating in the real world and not in some ideal archaeological research situation. We are involved with and in urban development and our own interests have to fit in with this development. We must, as a matter of course, become involved in the planning from the outset – not just on the legal side, citing the heritage protection laws – but also in with the real world processes – to avoid building delays where possible. Cooperation breeds good will and brings advantages with it in the long run. This process often leads to unpleasant compromises and working conditions for the archaeologists. Construction firms do not like or maybe are not even able to start building in the winter period. So then the archaeologists have to dig then.

In the majority of cases, city centre excavations are associated with construction sites – other excavations in other contexts too. The same scenario is not unusual for rural excavations. But urban construction sites start as demolition sites. There isn't much virgin development land available in the city centre! And we, the urban archaeologists are the sandwich filling between the first slice of demolition and a second slice of development. Perhaps the arc stretching from demolition to rebuilding is another definition criterion.

I have spent nearly every day of my working life trying to do archaeology on urban sites. I have been a practician looking out onto the world of urban archaeology from the inside, rather than looking at it and analyzing it from the outside. Whether my approach or my views are right or wrong or find general acceptance or not is secondary. For me it is sufficient to maintain the momentum of a discussion on the traits that specifically characterize urban archaeology. Is such a discussion necessary? *yes*, I think it still is. It is well and good and formally correct when Professor Fehring writes: "Important knowledge about administrative topography have been made in cases where central buildings of profane or sacral life … could

be discovered or reappraised. Or “To understand parcels of land and their building structure in a representative manner, large multi plot area excavation are necessary” (FEHRING 2000: 166). They, however, are statements on excavation strategy to particular ends. But what do they mean for those who have to carry out the excavation itself?

Fig. 11 – (Landesamt für Denkmalpflege Baden-Württemberg).

Perhaps it is the diversity of that which awaits the archaeologist in the city that is most characteristic: diversity as the most useful and most homogenous attribute of urban archaeology. And the sheer amount of finds of all types and epochs, which must all be recognized and handled and analyzed in the appropriate manner. And the huge spectrum of features – walls of churches, houses, and other buildings, Complete house plans, wells cemeteries, water pipes, prehistoric, Roman or Medieval street surfaces and of course

the ubiquitous latrine. All these features, usually interwoven into each other in a deep and complex stratification. It is the task of the urban archaeologist to successfully excavate and interpret this diverse spectrum against a backdrop of incessant loud noise and exhaust fumes from heavy plant and traffic, constantly flowing domestic secrets from private bathrooms in trickling sewers, and the comments of passers by and developers who are not always positively inclined toward the work in hand – amongst other things because – especially in the city, “time is money”. New technological developments are continuing to give us better and more efficient tool and method to deal with all of this. Never the less, excavation in the city remains a complex and challenging activity. Perhaps *the* most challenging?

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A Scribe in his city

Reconstructing a day in a scribe's life in the Early Dynastic period*

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Abstract: This short paper is dedicated to the memory of Sam Paley who made such important contributions to the world of „virtual archaeology“. Based on written sources and on pictorial representations, an attempt is made here to re-create the atmosphere and some of the major events structuring the daily life of a Sumerian master scribe. Often, historiography restricts itself to major cultural features and to the chronologies of major (public) events. This glimpse into the daily life is, of course, in many respects speculative. However, there are enough sources available for a plausible reconstruction.[1]

Keywords: Mesopotamia, historiography, daily life, scribes.

Our scribe named a-ba-sá, a nice name, to be translated as “who equals him”,[2] was recently promoted to the position of the “exalted scribe of (the city god) Ningirsu-k”[3] in his home city of Lagash-Girsu in southern Babylonia, in the modern province of Nasiriyah. He used to work in the temple’s registry where the supervision of roughly a dozen of scribes was among his duties, and where he was responsible to the chief-administrator DU.DU, a scribe himself.[4]

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* The abbreviations of source materials follow the usual practice in Ancient Near Eastern Studies, cp., for instance, the list provided in the *Archiv für Orientforschung* vol. 40/41 (1993–1994) 343–369; for other material cp. the bibliography. I wish to thank N. Linder for correcting my English.

[1] The following remarks were inspired by the seminar “Daily Life in Mesopotamia,” held together with M. Jursa and Nicla De Zorzi in summer 2010 at the Oriental Institute, Vienna University. My thanks go to my colleagues as well as to our students. As a starting point we choose an article by EDZARD 1993. There are a few attempts to reconstruct the daily life from archaeological record, cp. POLLOCK 2010.

[2] A scribe of this name is well-attested in the Presargonic sources from Lagaš-Girsu, e.g. DP 257 5:4, 545 2:5, Nik I 30 7:3 et passim. The referent of this name is actually a deity, not the name-bearer. The name-type is very common in Near Eastern sources; cf. the name Michael “Who is like El/God“.

[3] This title is attested in DP 132 2:3, 226 2:1, and VS 14, 2:3.

[4] The statue of a scribe DU.DU from Lagaš-Girsu (see ill. 1) may be connected with the famous temple administrator DU.DU, a very influential person under the ruler En-me:te-na(k). A discussion of the responsibilities of this high-ranking official is provided by BAUER 1998: 471–472.

Fig. 1 – Late Early Dynastic statue of the scribe DU.DU from Girsu (STROMMENGER and HIRMER 1962: 87).

These days he usually would be working on drafting official inscriptions, including official legal documents.[5] Today, he had to set up a contract concerning the purchase of a cult-singer who had lived with the indebted[6] sailor Lugal-á-gur-ra.[7] The Queen herself[8] paid the ransom to his creditors, and the witnesses of the transaction had been recorded; the town-crier Lala made this contract public.[9]

[5] For the training of early Mesopotamian scribes and their curriculum see VELDHUIS 1997.

[6] The origins of such debts is not entirely clear; we have little information concerning the economic status of seamen; the so-called 'reforms' of Uru-KA-gina' indicate, however, that they must have had close ties to the „temple"; although in our case it is likely that these debts originated in the 'private' business of Lugal-agura; cp. SELZ 1999/2000: 18–20.

[7] The text Nik I 17 (cp. the edition of EDZARD 1968: Nr. 44, pp. 93–94) reads as follows: "Lugaledene, a cult singer – he is a young adult man: 13 mina minus 2 Šeqel of silver as his purchasing price, that is 12 1/3 Šeqel of refined silver – has Luagal-agura, the sailor taken away; 4 Šeqel silver has Ganki, the wife of LAK648-si, the leatherworker taken away; 1 ½ Šeqel silver has Utu-luĝu, the child of

In the past years, several accused had been submitted to the river ordeal in order to prove the correctness of their statements in court. Up to now he had 17 notes about such ordeals collected and assembled in a summary document. – Luckily all of them survived the test, no one was devoured by the river.
Thus, at the end of the day, he was tired now, and he returned to his house rather sleepily, wondering what would wait for him for dinner. He was quite sure that his wife with her maiden would have prepared just the usual soup and bread. Hopefully she had added enough *garum* to make the soup tasty, something which he liked very much, albeit his wife detested the *garum's* smell of rotten fish. At home, after sunset, when the heat of the day slowly ceded, he rather hastily poured out some water and lighted an incense stick in the living room's corner, where, behind a curtain, small figurines of his ancestors were kept.
He then sat down in the courtyard having his first mug of beer.[10] When afterwards they all climbed onto the roof of the house[11] to lay out their mattresses, he and his wife murmured to each other about the impending festival days.

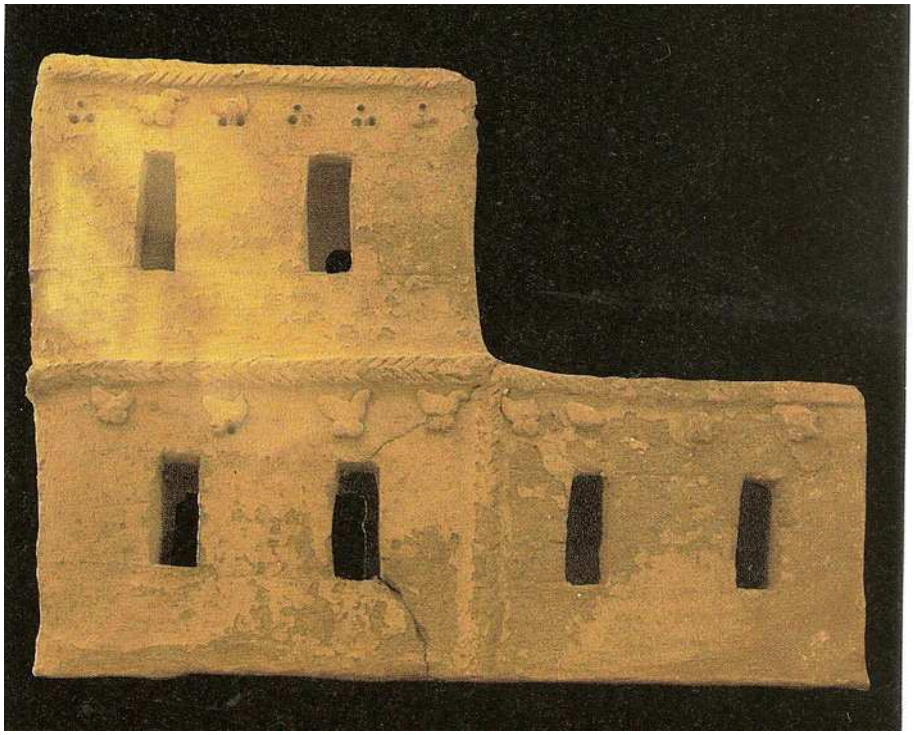

Fig. 2 – Model of a house (from Salamiya, near Hama) (HROUDA 1991:196).

E-meam-su, the merchant, taken away: These are the creditors (of Lugal-agura). Baranamtara, the wife of Lugal-anda, the ruler of Lagaš, has compensated them. Lala, the town-crier, En-iggal, the administrator, Ur-Emuš, the chief merchant of the ‘woman's house’, En-lu, the cup-bearer, Luagalra-mugi, the policeman, Lala, the town crier were the witnesses. 3. (year in the reign of Lugalanda).“

[8] She is the buyer of this cult singer; apparently she acted on behalf of a ‘temple’, as the gala were generally attached to the temples of various deities.

[9] Publishing, that is announcing legal matters to the ‘public’ was an integral part of Mesopotamian legal customs from the earliest times.

[10] Beer was, besides barley, among the most popular foodstuffs distributed on various occasions from the temple administration.

[11] Models of houses provide some ideas about their structures; cp. for a collection of Mesopotamian architectural drawings in BAGG 2011.

It was a full moon tomorrow[12], and there would be the major procession of the deities to the different temples. The procession would be lead by the ruler and his wife and family,[13] and also the high officials to which Abasa now belonged.

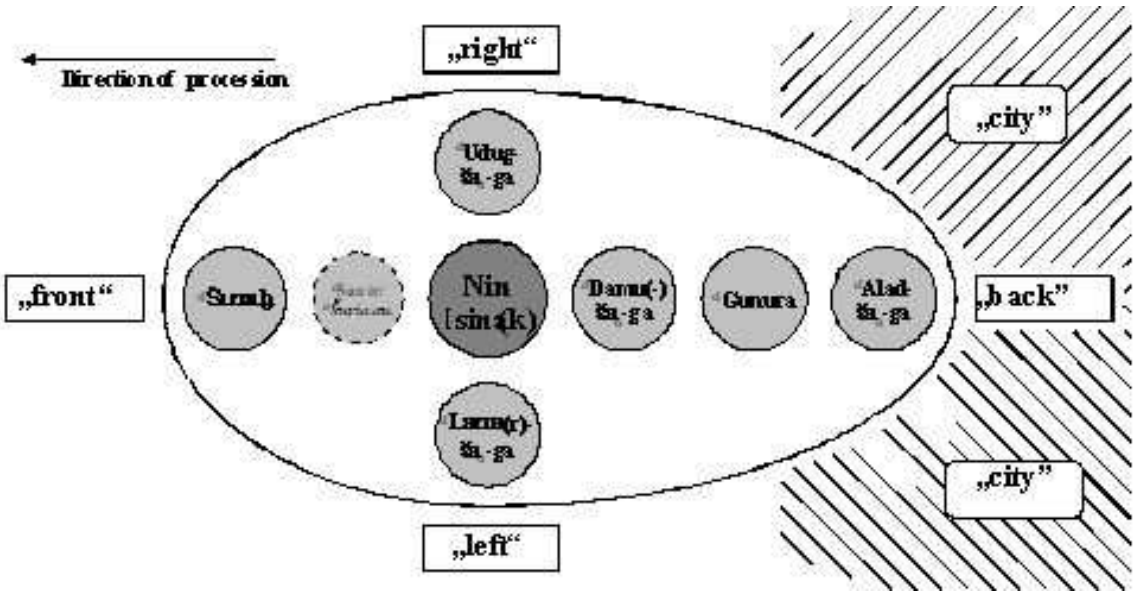

Fig. 3 – Reconstruction of a procession (early Old Babylonian); based on a reconstruction of “Nin-Insina-(k)s Journey to Nippur” (WAGENSONNER 2008: 279).

At midday, in the main temple of the state god, the head of the local pantheon, the state's élite would receive priests and nobles from other towns and minor sanctuaries, and they would sit together to have an opulent meal and beer to drink.

Fig. 4 – Detail from the “Standard of Ur”: the banquet of the noblemen (STROMMENGER and HIRMER 1962: X).

[12] The moon festivals, e.g. New Moon, Full Moon and Half Moon provided the basic structures of the Mesopotamian (lunar) calendar; cp. BELD 2002: 117–142, SALLABERGER 1993: 37–96, and further COHEN 1993: 6–8 and *passim*.

[13] This can be deduced from the numerous Presargonic offering lists; cp. the references in SELZ 1995: 376; the arrangement of such a procession in the Early Old Babylonian period was reconstructed by K. Wagensonner; cp. here ill. 3.

Besides the ritual eating of malt and the drinking of milk of the officials – which functioned as a reminder of the foundations of the country’s subsistence[14] –, there would also be meat available, as well as a lot of fish. Later on, the procession would set out on the river for a visit of temples of the other major cities of the state;[15] this procession would last altogether some 7 days.

Fig. 5 – Early Dynastic Votive Plaque (unprovenanced): Banquet, (offering) animals, and procession on a boat (Photo courtesy K. Wagensonner).

A couple of months ago the sheep had been plucked, and this time, during the festival, wool was distributed, especially to those officials who had earned recognition for their work during the past months. Indeed, Abasa was looking forward to receive a higher ratio of wool than usual, and he really needed that. The father of the apprentice silversmith amar-bàd-šà-ga, namely the renowned jeweller ur-^{d}nin-tu, had approached him asking for the hand of his daughter. He was satisfied; his daughter would marry well, and the bride prize agreed on was fine. However, his daughter’s dowry was not yet very large, and besides the box of silver rings, some furniture and clothes, it was really not yet very substantial. So some wool would make a nice addition, especially since the daughter would later on live in a different quarter.

[14] Such an event is recorded in a number of Presargonic documents s. SELZ 1995: 77–78, BELD 2002: 128–140.

[15] In Lagaš-Girsu the main procession lead from the governmental city Girsu, over Lagaš to NINA/Niğin, primarily by ship following the water course which connected these cities over a distance of roughly 50 km. The first stop was made in city Lagaš at the state god’s temple Bagara, which the texts describe as the “dining hall of the gods“.

However, she would not need a part of his house which he would otherwise have to give to the young couple.

Therefore, he was now more optimistic than the better part of the last year. Although he was quite successful in his career, and after his promotion to the position of the “Exalted scribe” he had even bought an additional room adjoining his house from a neighbour. The new room, however, was not yet fully refurbished. He also had many worries with his only son, who was trained as an apprentice scribe by xxx with whom Abasa had a long and difficult relationship.

He was once his fellow student, but later on much competition and envy arose between them. And further, there was no way denying that his son was neither gifted nor diligent. He had yet to finish his primary education, although he was past 12 years old. He repeatedly approached his father to make presents to his teacher. Indeed his son’s teacher was a rich and very influential man; one of his responsibilities was to investigate pending law suits, his speciality being the search and the questioning of possible witnesses. He was well-known for being corrupt, however, as long as the ruler sets his trust into him, such bribes could not been avoided.

Next morning Abasa rose and took his breakfast which the family's female servant had prepared. It was a thin soup with some vegetables from their orchard – and bread again.

He and the entire family prepared themselves for the procession, Abasa and his wife, proudly dressed in their linen garments, oiled their hair and sprinkled a few drops of Amber perfume over their body. Setting off from their home they took different ways; Abasa went to the main Temple of Ningirsu-k, whereas his wife joined the female entourage of Ningirsu-k’s divine spouse Baba.

During the night, the temple's personnel had made all sort of preparations: The statues were invested with their newly washed garments, the censers were filled, and numerous flowers and strips of coloured wool were heaped upon the holy chariots on which the deities and the ruling couple would ride. The singers had assembled, and the murmuring of incantations filled temple and courtyard. When the procession moved, a bulk of people singing and shouting joyfully followed the procession chariots. On their way a stop was made at a small chapel, where a protective goddess, revered and addressed by the common people for all sorts of help, received some barley, grapes, dates and a bundle of fish. These offering were, of course, also accompanied by prayers for the protection of the people, the city and the land.

When they arrived at the temple of the goddess Baba, a solemn meal was arranged in the main hall of the temple where the cooks had been busily preparing all sort of delicious foodstuff and drinks. Lower ranking personnel in the courtyard, among them numerous commoners and slaves, also received their share of beer and bread; music was played, various songs were performed, and the noise of the masses became overwhelming. Especially popular were the ensuing wrestling events performed at the entrance to the temple complex. Everyone knew of course that wrestlers impersonalized the two basic cosmic dimensions, the “light” and the “dark”, the “inner” and the “outer”, “this world” and “the otherworld”, that these were all the spheres in which the famous Sumerian heroes performed their deeds.[16]

[16] Festivals were also accompanied by music and athletics cp. Gilgameš’s Dream and Death where we read in ll. N_1 v 6 - N_1 v 10 cp. CAVIGNEAUX and AL RAWI 2000: 61: “When in future days (humankind’s(?)) (funerary) statues are fashioned / The youth and the young men alike, (at) the observation of the New Moon / Did indeed perform the *threshold ritual*, / When they in public conducted

Fig. 6 – Musicians at a festival: Detail from a vessel fragment (STROMMENGER and HIRMER 1962: 128b).

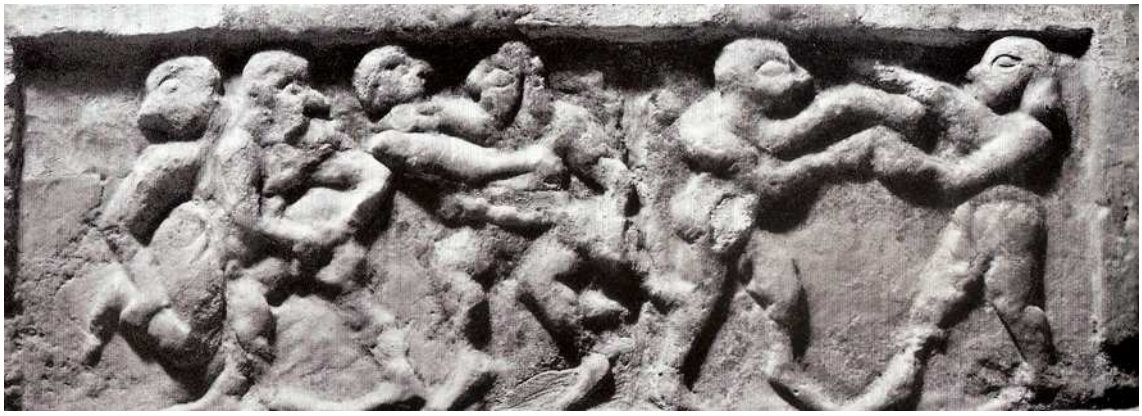

Fig. 7 – Wrestling games during festivals: Early Dynastic votive plaque from Khafadji (detail) (STROMMENGER and HIRMER 1962: 46a).

When the sun-god began to descend from his culminating point and the stomachs had been filled, after a while, the entire procession returned to the main temples, and the crowd slowly dispersed.

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wrestling and athletics, / In the month of Ab, at the festival of the spirits, / It would not be possible to make light without him (=Gilgameš).”

Not so our Abasa, for although he nearly fell asleep having had just a little too much of the sweet emmer beer, he still had to attend the evening rituals in the temple. This was indeed not such a harsh fate, because he certainly would be given a huge chunk of mutton to bring home to his house. However, arriving there he found his daughter weeping because his steward had collected her with some girl friends in the region close to the harbour. Yes, she had ignored the strict advice of her mother. Abasa sighed; it was really time to get her married.

Fleeing this domestic trouble, he himself withdrew to the harbour's tavern, where, as rumours had it, the now debtless sailor Luag-á-gur$_8$-ra was treating his friends and acquaintances. Perhaps he would also buy him a pint of the "princely quality beer"?

And Sam being there, would certainly join him.

Fig. 8 – Beer drinking buddies: Old Babylonian terracotta plaque from Mari (Photo courtesy K. Wagensonner).

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SESSIONS

Urban Archaeology and New Technologies

Urban Economics

Urban Development, Land Use and the Real Estate Market in Early Modern Amsterdam

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Abstract: The Landscape Department of the Dutch Cultural Heritage Agency (Rijksdienst voor het Cultureel Erfgoed) has been working on a GIS-cartography project, focusing on a large set of historical data that has come down to us from seventeenth-century Amsterdam, a large part of which was recently included in UNESCO’s World Heritage List. Jaap Evert Abrahamse, researcher of the history of urbanism, and Menne Kosian, researcher of spatial analysis, were involved in the project, together with Erik Schmitz, researcher of topography at the Amsterdam City Archives (Stadsarchief Amsterdam). This article presents the first results. It contains a short introduction to urbanism in the Dutch Golden Age, the growth of Amsterdam and the way land in the city’s extensions was auctioned by the city administration. The GIS project is explained and a transect of the city is highlighted. First observations show that GIS research of financial and ownership data can contribute to our knowledge of economic and urban history, of the functioning of the early modern town and its social stratification. These new perspectives on the history of urbanism on the micro-scale of parcellation might also be of use in the present-day practice of urbanism and project development.

Keywords: Amsterdam, Dutch Republic, Economy, History of Urbanism, City Extensions, GIS Cartography.

Recently, the Landscape Department of the Dutch Cultural Heritage Agency (Rijksdienst voor het Cultureel Erfgoed) and Amsterdam’s City Archives (Stadsarchief Amsterdam) have been working on a GIS-cartography project, focusing on a large set of historical data that has come down to us from seventeenth-century Amsterdam. Jaap Evert Abrahamse, researcher of the history of urbanism, and Menne Kosian, researcher of spatial analysis, were involved in the project, together with Erik Schmitz, researcher of topography at the City Archives (Stadsarchief Amsterdam). Master student Anouk Wiegman of the Art History Department of Amsterdam University (Universiteit van Amsterdam) has been working on the GIS system as an intern with the Landscape Department. In this article, the first preliminary results of the project will be presented, together with an introduction to urbanism in the Dutch Golden Age and the growth of Amsterdam.

During its Golden Age, that lasted from ca. 1585 to 1672, Amsterdam grew from a small town on the banks of the river Amstel to one of the biggest cities in Europe (Fig. 1). In the process, a huge amount of grounds have been expropriated, parcelled out and sold. The administrative reflections of these transactions have come down to us in the form of auction books and a large number of maps by the city’s successive surveyors. These data have been collected in a GIS database. This article describes the intentions, set-up and first results of this on-going research.

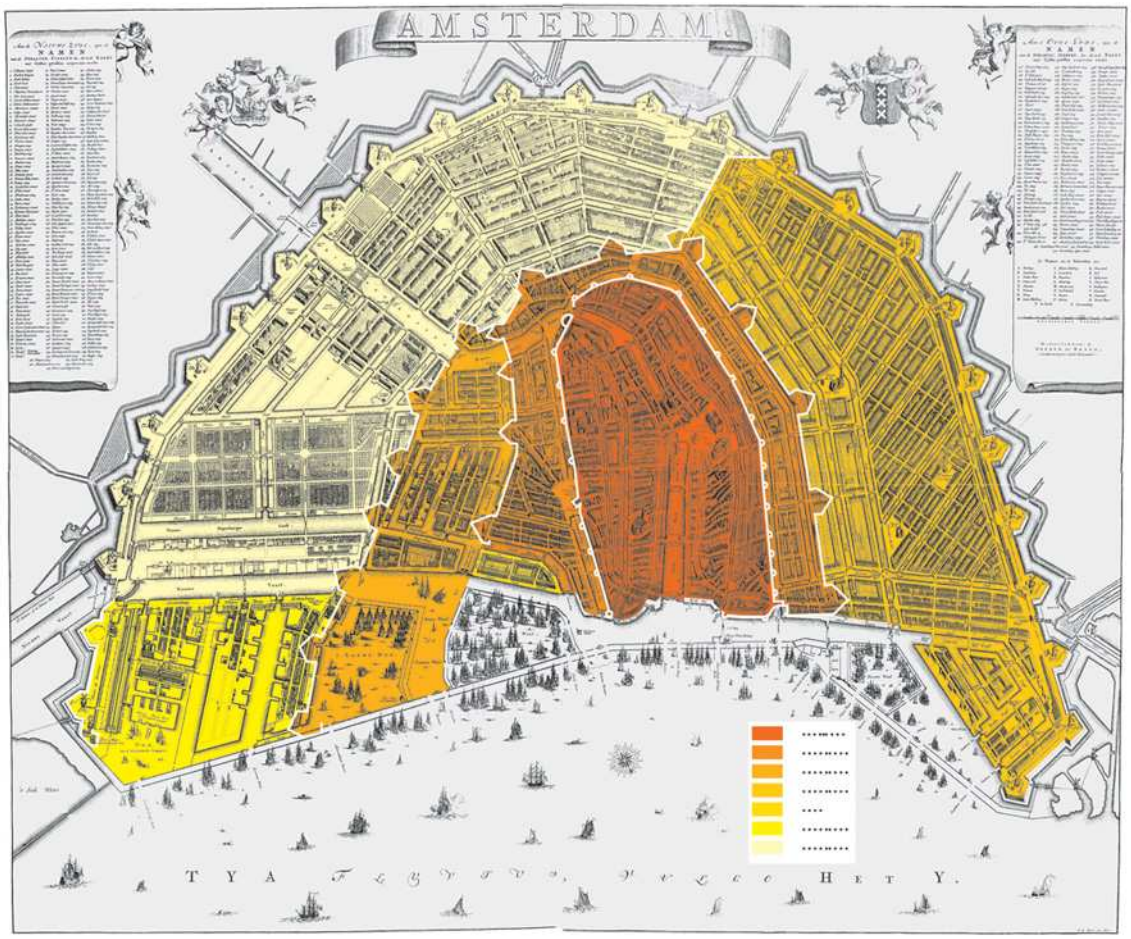

Fig. 1 – Urban extensions of Amsterdam, 1585–1663 (Copyright: Jaap Evert Abrahamse/Menne Kosian/RCE).

The Urban Development of Early Modern Amsterdam

During Amsterdam's Golden Age, the city's built-up area increased by more than fivefold (ABRAHAMSE 2011). Amsterdam's rapid growth captured the attention of historians and city planners. They have analysed Amsterdam's development from a variety of angles. Two aspects have attracted most of the attention: the large scale of the city's expansions and their methodical planning. This second aspect has, since the nineteenth century, been looked upon mainly from the point of view of *townscape*. Amsterdam was presented as a large-scale, scenographic composition, a *Versailles of the North*, and as a consequence, the work of a single genius. This, of course, fitted in perfectly in nineteenth-century history historiography, in which heroic personalities occupied centre stage. Later on, researchers began to study the city's ground plan. Amsterdam's development has often been described as an elaboration of the *città ideale*, the apex of urban planning.

The city's ground plan, however, was the result of a complex process in which different, sometimes incompatible, interests had to be balanced. A city design is not an isolated work of art, but a solution (or an attempted solution) for a broad range of problems within a specific situation. The city's government was responsible for Amsterdam's defence, for building and maintaining functioning traffic and water infrastructures, for the provision of sufficient numbers of building plots to private citizens and companies and for the management of various other urban services. Therefore, any design for a city extension must be

considered in relation to the circumstances in which urban development took place during: soil conditions, water management, traffic, a shortage of space for housing, harbour activities, trade and industry, spontaneous urbanisation, private landownership, and the entire network of infrastructures in which the city was entangled. But the city’s ground plan was not just the result of physical factors. Indeed, the social reality was also a prominent factor in the constitution of Amsterdam’s ground plan. The field of urbanism was a game of interests, of interactions and sometimes confrontations between the forces of urbanisation and city design. Each of these factors had its influence on the planning processes and their outcomes. Furthermore, there were also the various instruments of urbanism: the methodology behind fortification plans, city design and the apportioning of parcels, as well as the legislative options.

The *Third Extension* of Amsterdam

Amsterdam was confronted with an unprecedented increase in population in the years following the fall of Antwerp in 1585 (for general historical information in English, see VAN GELDER and KISTEMAKER 1983). This period saw a spectacular spurt of urban sprawl outside the city’s walls. Shortly thereafter, the first large-scale city expansion was initiated. This is called the *third extension* (Fig. 2).

Fig. 2 – Amsterdam in 1620–1622, with on the right (west) side the third extension. The canal belt with its large building blocks contrasts with the Jordaan quarter, next to it on the right side (Copyright: Stadsarchief Amsterdam).

In 1609, Amsterdam obtained permission from the States of Holland, the provincial authorities, to extend its surface area and territorial jurisdiction. A year later, work commenced with the layout for a new harbour area. The first plans called for an expansion on all sides of the city, but these were revised to include just the west side. In 1613, new fortifications were constructed. The completion of the fortifications was followed by the

construction of buildings and the necessary infrastructure behind the newly expanded fortifications. Large parts of the suburbs had been built illegally but were absorbed behind the city's new fortifications in order to not antagonise the inhabitants. The city's government was well aware of the potential for disturbances of the public order. Thus the *Jordaan* district was not a newly designed area of town, but an incorporation of illegally built suburbs. Even after streets and canals were laid out, the basic landscape structure of the medieval peat reclamations was preserved (Fig. 3). The process of preserving this area led to a dispersal of the extension into a number of different neighbourhoods. The most important innovation of this expansion plan was the introduction of an exclusive residential area, the now famous canal belt. This meant that most industrial activities were halted in this area. The realisation of the belt of canals created a new neighbourhood where luxurious homes were built according to strict rules. The canal belt was the most successful part of Amsterdam's extension, not only aesthetically, but functionally and financially as well.

Fig. 3 – Amsterdam in 1560, at the west side the structure of the mediaeval peat reclamations is visible.

However, Amsterdam’s city council was unable to manage the planning, design and construction process properly. The expansion of Amsterdam occurred in the context of unbridled urban expansion, which was marked by the regents’ growing anxiety regarding public order, the limited financial resources, a lack of expertise and a political constellation that only provoked severe conflicts regarding the rampant land speculation by some of the more influential members of the city government. The results were that the grandiose expansion plan, that already was reduced to the west side of the city, fell apart into a number of smaller elements, that formed separate city parts: the harbour, the quarter around Haarlemmerdijk, the canal belt and the Jordaan quarter. This caused fragmentation of the urban structure. It also meant that the belt of grand canals attracted all of the attention and became the standard for subsequent expansions.

The Fourth Extension

Despite this large-scale extension, a new shortage of building lots arose shortly thereafter. As a result, parts of the city were developed and new streets and quarters were created by filling in small sections of the Amstel River and the IJ. But despite these efforts, haphazard urbanisation again took over. New fortification and extension plans were drawn up after stadholder William II’s failed *attack on Amsterdam* in 1650. In 1652, an extension and fortification plan was approved by the city council.

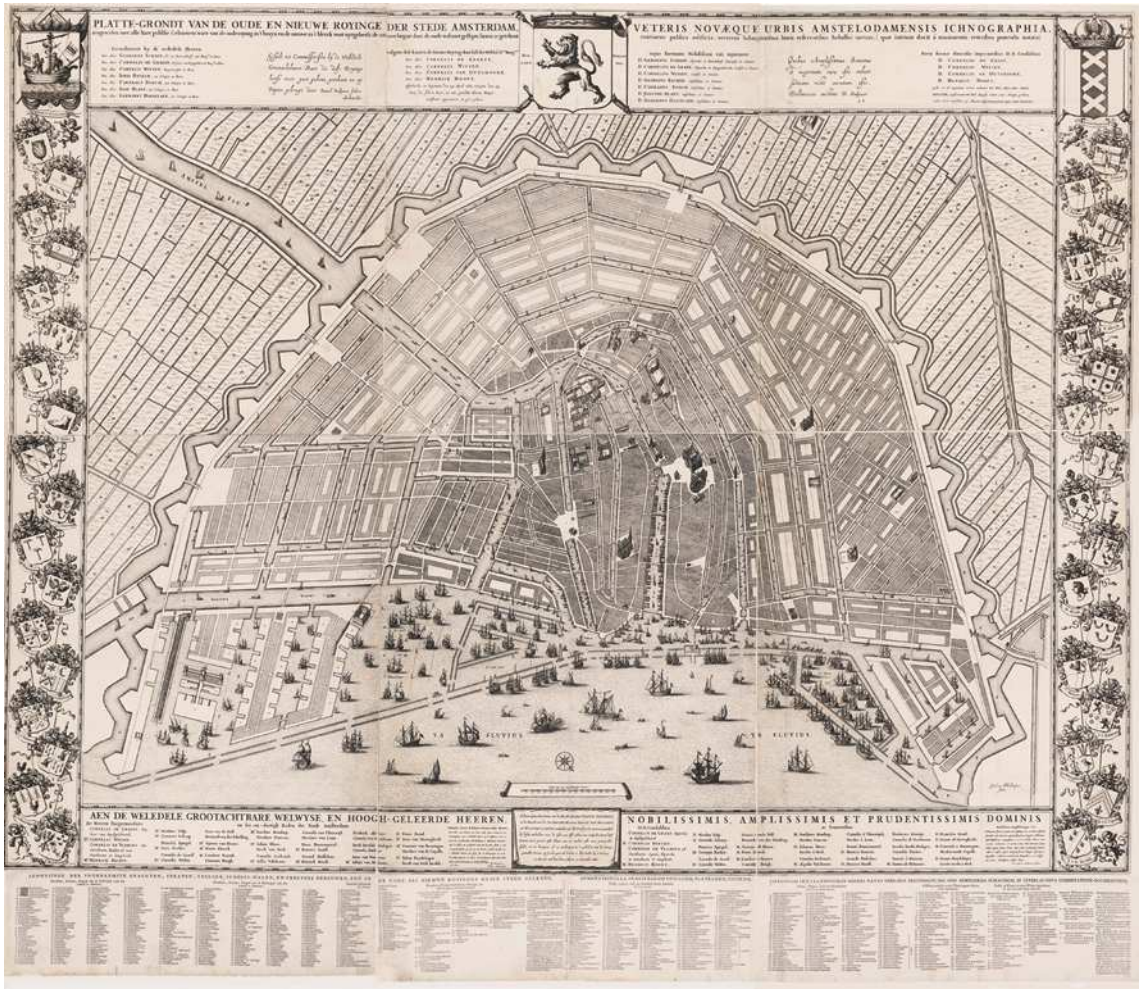

Fig. 4 – Extension plan, as decreed in 1662 (Copyright: Stadsarchief Amsterdam).

That same year, the First Anglo-Dutch War led to a period of economic stagnation that adversely affected the city's development. The 1652 plan wasn't realized. Shortly after the end of the war, a new harbour area was laid out along the eastern border of the city. This was a direct result of the war, during which hundreds of Dutch merchant ships and warships were destroyed. Again, harbour development ran ahead of city extension efforts.

In 1662, a new extension plan was approved for the area between the Leidsegracht and the Nieuwe Vaart (Fig. 4). Previous experiences were brought to the new plans, which led to a well-considered, coherent scheme in which all urban problems were to be solved. These plans were developed by a commission of well-trained, professional planners and educated city administrators. The plans were rooted in the further elaboration of the canal belt concept. To facilitate the execution of this scheme, all of the necessary land was expropriated and all of the suburbs were levelled. The *fourth extension*, as it was called, was the result of the development of a new methodology in urbanism, in which functionality and aesthetics came together. Again, the city government waited with the realisation of the extension until the point when land sales were expected to raise sufficient revenues. In contrast with the third extension, this time all of the suburbs were demolished and all ground were expropriated. These integrated land policies ensured the success of the fourth expansion.

However, the *Disaster Year* of 1672 saw the demand for building land collapse. Real estate development came to a sudden halt. Thereafter, progress was slow in the portion of the fourth extension east of the Amstel River while the area west of the river managed to develop quite dynamically. The city council gave extensive parcels of land to various charitable organisations that erected grand buildings in return. This allowed the city to prevent the Amstel, which was meant to become the central axis of the extension, from becoming the border that separated the canal belt from a large vacant tract of land. The area even further east of the Amstel was developed into a large private allotment garden complex, which was rented out to anyone who wanted a garden for pleasure or for growing vegetables. This area was called the *Plantage* or plantation. However, it would not be until 1850 that urban development recovered its pace. The Plantage area once again was partitioned and sold for the development of housing, thus fulfilling the function as the urbanists who had originally drawn up the plans in the 1660s had imagined it.

In the course of the seventeenth century, Amsterdam became the third largest city in Europe. The city's expansions were many times larger than its old centre. Amsterdam became a new and modern city. The fourth expansion, with its elaborate traffic arteries, functional zoning system and its well-outfitted public spaces gave it a cosmopolitan feel. The city was designed based on rapidly evolving insights into urbanism and the management of urban space. Amsterdam was the centre of innovative urbanism in the seventeenth century, just as Paris two centuries later, under the guidance of Haussmann and Alphand.

Amsterdam became a city of contrasts, which were observable in its population densities, as well as its prestige and the scale of its architecture, the city's layout and the upkeep of urban public space. The magnificent canal belt felt new and rich, wide and green, which was in sharp contrast to the cramped centre with its narrow, crooked alleys and quays. The planting of trees along the canals in the early seventeenth century further raised its profile (Fig. 5). In July, 2010, Amsterdam's canal ring has been included in UNESCO's World Heritage List (Fig. 6).

Fig. 5 – Herengracht in 1682 (Copyright: Stadsarchief Amsterdam).

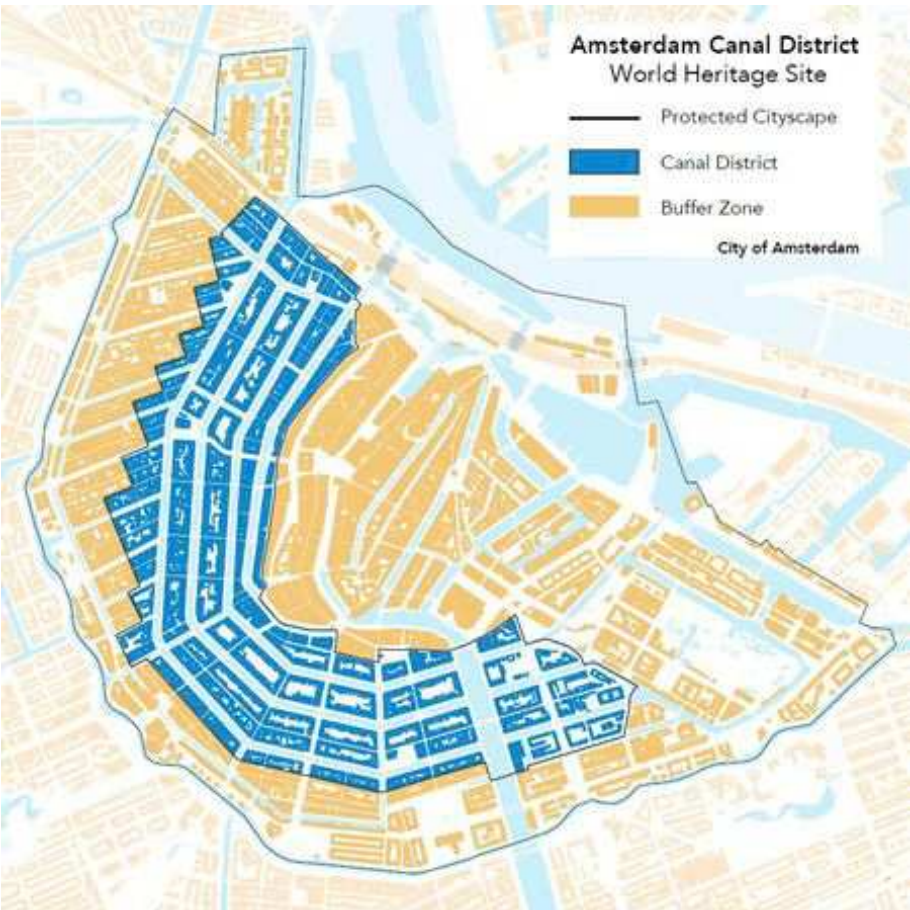

Fig. 6 – Boundary of UNESCO World Heritage site and buffer zone (Copyright: City of Amsterdam).

City Government, City Extensions and Ground Sales

In the seventeenth century, Amsterdam was governed by a city council of 36 men, who were appointed by co-option. Members of the council came from the merchant elite and were installed for life. They had to leave the council only in exceptional cases, such as bankruptcy or insanity. Four burgomasters and two treasurers were chosen from this council, for a period of one year. They formed the executive committee of the city. The two treasurers were responsible for public works. The city government was comparable to a modern multinational's board of directors, in other words, an old boys' network for whom profit was the main goal, and who were used to make decisions without interference from outside parties.

City development in the early modern period, and therefore the urbanism of that time, must be seen as the result of the city's economic ambitions. The city itself was a development project, with a goal of generating revenue. Every new expansion was a risky affair. The city financed parts of its development with borrowed money. Revenues from the sales of land and tax revenues rose as the city attracted more and more new inhabitants and companies.

Amsterdam acquired a new functional profile in the seventeenth century, when its numerous urban functions were meticulously allocated. The strictly residential areas created a new phenomenon. They provided luxury housing in an urban environment without the usual inconveniences such as pollution, noise and congestion. The canal belt served as an upscale residential area, which was clearly distinguished from the busy, largely medieval centre and the more industrial areas beyond Prinsengracht. The plots along Herengracht were the most desirable in the city. Anyone who could afford it, could live in luxury there, at the wide, tree-laned canal, in a city house with a huge garden, within walking distance to the economic and administrative centre located in the Dam Square area. Although Keizersgracht was further away from the centre and had less stature, it was, like Herengracht, an exclusively residential area. In the fourth expansion, Kerkstraat was the borderline between the canal belt and the outlying industrial areas. Beyond Kerkstraat, many sorts of industrial development were tolerated. The worst pollution was banned to beyond the city's borders. Industries deemed detrimental to the urban atmosphere because of their size, nature, or specific requirements, such as sawmills and textile mills, were relocated beyond the city's walls. The urban periphery was also designated as an area for the development of dangerous industries, such as the manufacture of gunpowder or health care institutions for patients suffering from the plague and other infectious diseases. Public space essentially reflected the functional profile of the city, which is represented not only by its architecture, but also by the design and condition of the road surfaces, the bridges and quays, which were all different in the old city centre, the canal belt, and the areas beyond Prinsengracht.

The costs of city extensions were extremely high. Even before a city extension could start, many expenses had to be made, to acquire the necessary grounds and buildings in the urban periphery. Building was illegal within the field of fire of the city's fortifications, but many exceptions were made and many other buildings acquired a semi-legal status over time. All owners were paid to leave their buildings and grounds.

During the first stage of realization, new fortifications had to be built, at high cost. A ring of bastions, with stone city gates and a wide defensive moat were laid out in a short period of time, usually no more than two years. After that, the old fortifications could be demolished and streets were laid out and canals were dug, according to the extension plan. Therefore it was needed to stake out the building blocks in the new part of the city. Streets and building plots were raised to a certain level to prepare them for building. This ground

level was obviously connected to the water levels in the canals. Earthworks were the major concerns in the early phase of an extension. They were costly, not just because of high labour costs, but also because of the high price of sand, which had to be imported from the coastal area or the sandy areas at the east of Holland. Earthworks therefore had to be realised as efficiently as possible. A system calls for tenders had to keep down the lid on expenses. After that, streets and quays were laid out, and had to be paved.

A large part of the city’s yearly budget was spent on public works. During city extensions, especially during the early phase when the large ground works were executed, there was a peak in expenses on public works. In some years, up to half of the total budget was spent on the “stadsfabriek”.

At the same time, budgets were tight. Tax rates were low in the seventeenth century and the city government didn’t have much financial scope. For a large part, city extensions were realized with borrowed money. To recover some of the costs, the city had to make as much money out of the extensions as possible. On the longer term, the city could count on higher tax and excise revenues, because of the higher number of inhabitants and companies. But the main source of income from a city extension came from the selling of building land.

There were two ways of raising the revenues out of ground sales. At first, the number of marketable parcels within the city’s extensions was to be maximised. This, of course, was a design problem. In order to create the highest possible number of building plots, the most important characteristic of every urban design is regularity on every scale. Every extension was composed of regular building blocks, as far as possible. Every block was divided up in parcels in a regular way. This way, as many parcels as possible could be laid out in Amsterdam’s extensions.

The second way of raising revenues was the ground price. Therefore, as much ground as possible was put up for auction. This also accounts for the uniformity of the auctioned building plots. To raise prizes, lots at the auction had to be comparable to each other (ABRAHAMSE 2011). Apart from that, the timing of auctions was a point of concern. Usually, auctions would be held during the “twelve nights”, i.e. the period between Christmas and the feast of the Epiphany. At this time of year, trade was slow. Most of the wealthy Amsterdam merchants would be in their hometown, and thus had the opportunity to be present at the auctions, which of course increased auction revenues.

Archival Data: Auction Books and Ground Issue Maps

Amsterdam’s archives contain a rich assortment of city council, burgomasters’ and treasurers’ resolutions, which detail a great many public works from the seventeenth century. From these archives, the city’s development can be reconstructed. But apart from these governmental archives, there are two types of administrative archival sources that contain data about the sale of building grounds: *ground issue maps* (*gronduitgiftekaarten*) and auction books. The great majority of both types of sources date from the period from 1586 to 1769 (HAMELEERS and SCHMITZ 1996).

Before an auction, the individual parcels were staked out by the city’s surveyor, who had a crew of assistants at his disposal for this job. During the fourth extension, this crew would count some twenty men. At the same time, the surveyor drew up a map of the area to be auctioned: the ground issue map. A copy of this map would be deposited for inspection at the location of an auction, usually an inn.

Many archives were destroyed over time, in the period when their value for history was not yet a consideration for preservation, especially when Amsterdam City Hall was converted into the Royal Palace after the enthronement of Louis Napoleon, the first king of Holland (1806–1810). The ground issue maps, on the other hand, had an administrative value even after auctions had taken place: most plots were partly paid in cash, and the rest of the purchase price was mortgaged, with the ground as a collateral security. Rent and principal payments to the city were registered in the auction books. This way, the city kept track of all owners who did not pay in cash. Apart from that, conflicts might raise over ground properties, during which this pre-cadastral ownership register might be of convenience.

Most of the ground issue maps were created during the seventeenth-century city extensions. From the sixteenth-century extensions, which were much smaller, not many maps have come down to us. In the seventeenth century extensions, the Jordaan area is hardly represented on ground issue maps, because of the above-mentioned character of an incorporated *faubourg* district. Most of the grounds there remained in the hands of private owners, so that no ground issue maps were made. Some of the owners might have divided up their grounds and put the newly created plots up for auction, but unfortunately no archival data have remained from any possible private auctions.

Not all of the ground issue maps are connected to city extensions. In some cases, maps remain from existing parts of the city, for instance, when new building land was created by filling in parts of water, or when large terrains were redeveloped. Thus, maps were drawn up when the large shooting-ranges of the citizen's militia, secularized convent complexes or the terrains of the city's public works department were divided up and auctioned (HAMELEERS and SCHMITZ 1996).

Most of the ground issue maps that are known to us, are in the City's Archives. Within the Archives' collections, most are in the former Atlas. Some have remained in the auction books, where they have been since the seventeenth century. A few can be found in other archive collections, such as the *Treasurers' Map Books* (*Kaartboeken van de Thesaurieren*) C and E. Apart from the City's Archives, collections of ground issue maps from Amsterdam are in the Amsterdam Atlas collection of the Royal Dutch Antiquarian Society (*Koninklijk Oudheidkundig Genootschap*) at the Rijksmuseum, and in the Bodel Nijenhuis map collection at the University Library in Leiden. An extensive catalogue of maps in the diverse map collections (also the collections outside the City's Archives) has been made up by Erik Schmitz and is available at the reading room of the City's Archives. Not all maps that we assume must have existed, have come down to us. Lost maps will be reconstructed on the basis of the data in the auction books in the process of making the GIS system.

There are two main types of ground issue maps: manuscript maps and prints. Every ground issue map of the third extension is a manuscript, sometimes very simple, sometimes decorated and in colour. Later on, the maps were printed and sold before the auction. Most of the printed maps (44) were printed and sold exclusively by Johannes Brandlight, who had his bookshop in Binnen-Bantammerstraat. Many of these printed maps have been annotated (Fig. 7). The information written on the maps usually gives the auction prices and sometimes the names of the buyers of plots. It may be assumed that auction visitors kept notes of lot prices. There is one example of a printed map, with the prices printed as well. This must have been a form of advertising for the auctions, since it depicts the block in the fourth extension that was auctioned first.

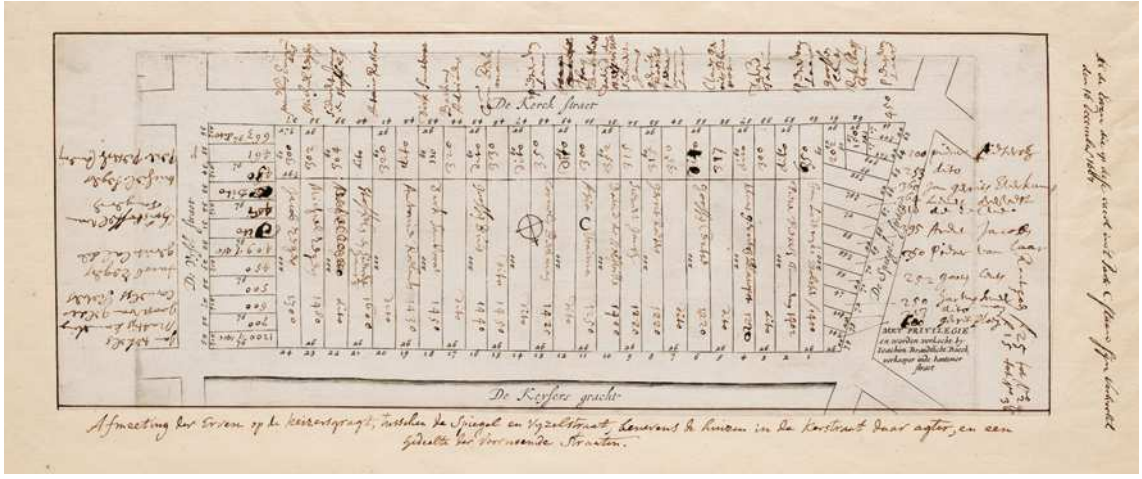

Fig. 7 – Auction map of a block at Keizersgracht, with annotations of prices and buyer’s names, 1667 (Copyright: Stadsarchief Amsterdam).

In total, 318 maps have remained in the different collections. A large part of those are prints, so many blocks are covered by two or more maps. A total of 144 blocks or parts of blocks are represented on the maps (Fig. 8).

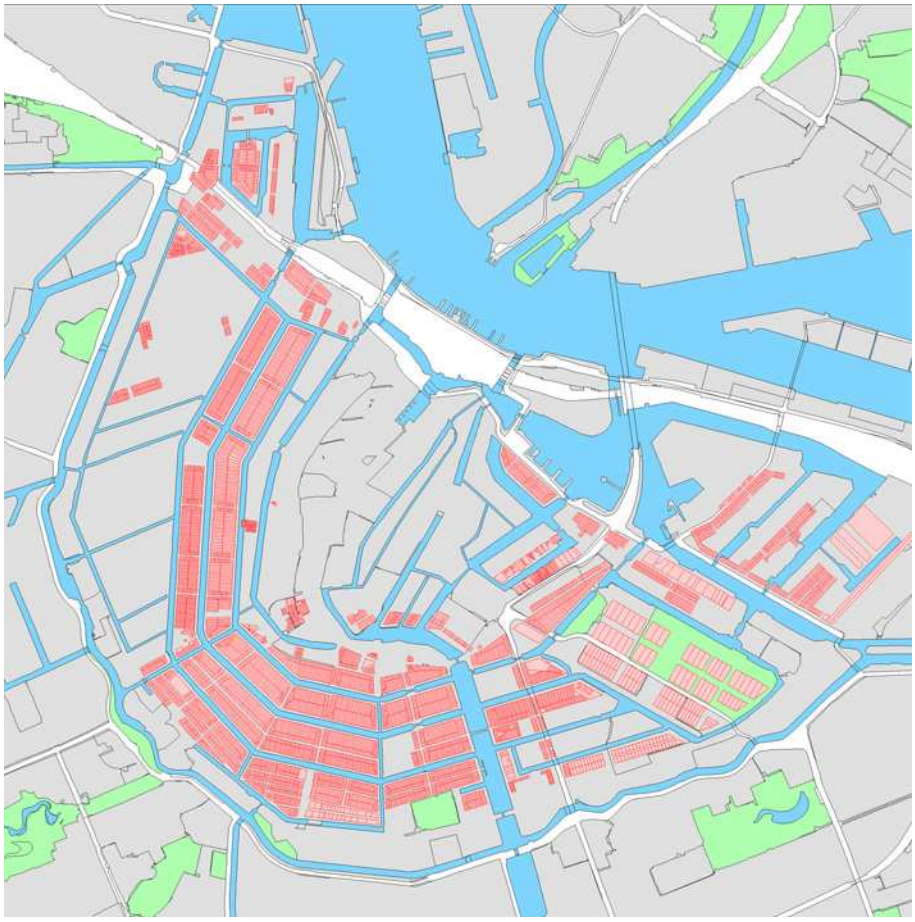

Fig. 8 – Overview of the areas represented in auction maps (Copyright: Menne Kosian/RCE).

Ground Auctions

Whoever wanted to erect a building in Golden Age Amsterdam, had to take care of the whole building process themselves. Buying a building plot was the first step in this process. In many cases, initiators went to a ground auction, organised by the city of Amsterdam.

Ground auctions in Golden Age Amsterdam would take place in an inn. At first, different inns were used for the auctions. Later on, grounds were sold at a fixed location, the *Oudezijds Herenlogement*, located at Grimburgwal. At any auction, one or two of the four burgomasters, a delegation of the treasurers and the Bench of Aldermen, and the city's sheriff, would be present to supervise the proceeding of the auction.

The auctioning of a real estate lot was carried out in two phases. At first, bidding started, and the price of the lot went up. In the second round, the price went down again. This process was called *mijnen*, which would mean something like *making it mine*. Whoever called "mijn" (*mine*) first, had bought the lot. The highest bidder of the first phase then received a small sum of money, called the *plokgeld*. If the price didn't come down during the second phase, the highest bidder of the first stage would become the new owner of the lot in question. Some bidders weren't actually intending to buy any grounds; they were after the *plokgeld* money. Sometimes, they bought a lot unintentionally, if they were counting on someone else to buy the lot in the second phase of the auction. If it turned out that they couldn't live up to their bid, they were called *sheep*, and were chased from the auction venue by the crowd while being bleated at. Their names are recorded in the auction books. The first violation was punished with two months of incarceration, the second with three months. The third time, a whipping came along with incarceration. This way, order at auctions was obviously preserved (HAMELEERS and SCHMITZ 1996).

Building grounds were auctioned by the block. Such a block was called a *park*, and was marked with a capital letter. Within these blocks, each lot had a number. In the auction books, a typical description of a lot would look like this: "a parcel of ground, marked no. 1, at the Herengracht, on the west side in the park marked "A", wide at the front 25 feet, and at the back 33 feet, long at the north side 22 feet and at the south side 30 feet, next to it the Leidsegracht at the north side, and lot no. 2 at the south side, at the front side the street and at the back no. 42". An Amsterdam foot in the seventeenth century would measure 28,3 centimetres. After this description of the plot on sale, the books contain the plot prices and details about the buyers. Of course, their names are always included, but in some cases the books mention their occupation and place of residence.

In the auction books (Fig. 9), the proceedings of the auction of one such block, or a part of it, were preceded by the conditions under which the building plots would change hands. Usually, the first condition stated the date of transfer of the ground ownership to the buyers. In most cases, the transfer would take place immediately, but sometimes this wasn't possible, for instance because of the presence of pre-urban buildings that weren't demolished yet or in the case that the ground was not yet prepared for building. In such a case, a term would be set for transfer, usually no more than a few weeks. Then, a term would be mentioned for buildings to be erected on the plots. In most cases, it was conditioned that the ground should be built on within one year. If no building activities would take place, the owner committed himself to fence off his property at the street sides with a ten-feet hoarding, to prevent illicit entrance and burglary in the building block. If no such fence was built, the owner would be fined by the day. Fines would be around three guilders per day.

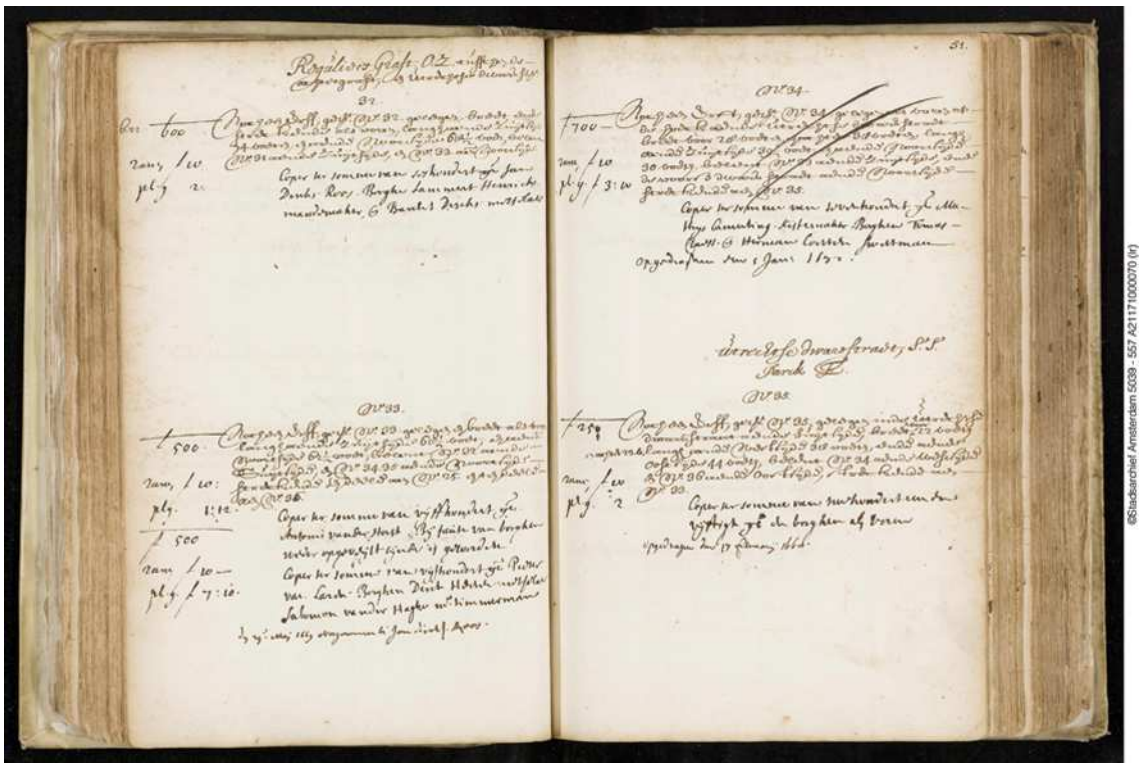

Fig. 9 – Typical page from one of the auction books (Copyright: Stadsarchief Amsterdam).

Other conditions would deal with building. The maximum size of a building, from the street, on the canals would be 100 feet (28.3 meters), in some cases 90 feet. Sometimes building heights had a maximum, mostly in the radial streets, to protect the privacy and sunshine in the gardens of the houses on the canals. In many cases, it was even prohibited to build windows at the back of the houses within eight feet of the floor level, because of the same reason. The measurements of the steps in front of the houses were also limited to a certain maximum. If necessary, functional restrictions would be attached. On the Herengracht and Keizersgracht, almost every branch of industry was excluded, so that no inconvenience from noise, pollution, or smell would be caused.

Of course, some financial details would be set down. Every buyer had to have two guarantors and had to pay the purchase price in time, either in cash or by taking out a mortgage. Apart from that, auction administration costs and the expenses at the inn had to be accounted for. The taxes that any ground owner had to pay to the city and the province, were also included in the auction conditions.

Many lots were auctioned and then resold within a few days. Obviously, many people had no plans of building their lots themselves, but wanted to earn some money on ground speculation. This, by the way, was a widely accepted and totally legal way of earning money: Amsterdam’s wealth was based on its capitalist economy, and free markets were the basic principle. It is known that in seventeenth-century Amsterdam fortunes were made – and lost – in ground and building speculation ventures (VAN EEGHEN 1961).

Sometimes building plots were divided up into smaller units, or put together and then divided up. The parcellation that was laid out by city officials sometimes wasn’t the optimal arrangement of grounds, according to the buyers. In that case, they were free to change the parcel structure within their properties. In many cases, for instance, three houses were built on two plots, but sometimes more drastic rearrangements

were carried through. This is often the case near corners of radial streets and canals. In any way, we have to realize that in many cases, the auction data give no more than an instantaneous insight into the situation.
If any buyer could not meet his financial obligations, his ground would be claimed back by the city administration and sold again. These sales are also recorded in the auction books. Thus, they also give an insight into one side of the real estate market, especially when a speculator went bankrupt. In these cases, the auction books provide us with information on ground price movements.

Canal Ring GIS Preview: the *Vienna Transect*

One part of the GIS system has been filled up with financial and land ownership data for presentation at the *15th Vienna Conference on Cultural Heritage and New Technology*, that was held on November 15–17, 2010. This transect (Fig. 10, 11) was chosen, because it contains a representative cross-section of the urban system that was introduced in the fourth extension, that was realized from 1663 onwards. It consists of two radial streets, Leidsestraat and Spiegelstraat. Spiegelstraat, which outside Prinsengracht took the form of a canal called Spiegelgracht, was not an important traffic thoroughfare: it came to an end at the city's fortifications. Leidsestraat, by contrast, was the busiest radial street in the fourth extension. It was conceived and realized as an early modern urban highway. The width of the street was dimensioned on the basis of the requirements of heavy traffic: at least three wagons or carriages should be able to pass each other. To prevent traffic jams in Leidsestraat, the bridges crossing the canals were as wide as the street itself (ABRAHAMSE 2004, 2011). Of course, traffic requirements had to be balanced out with the need for maximizing revenues from ground sales.

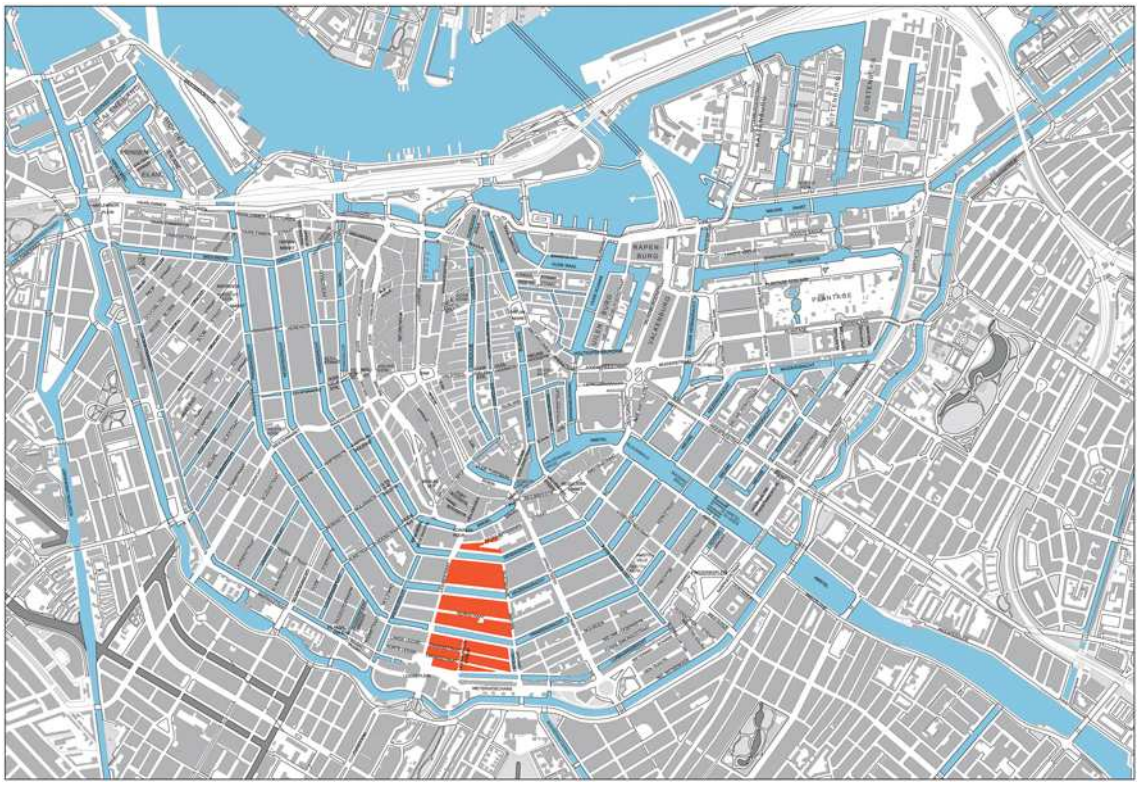

Fig. 10 – *Vienna Transect*: location in the inner city of Amsterdam (Copyright: Menne Kosian/RCE).

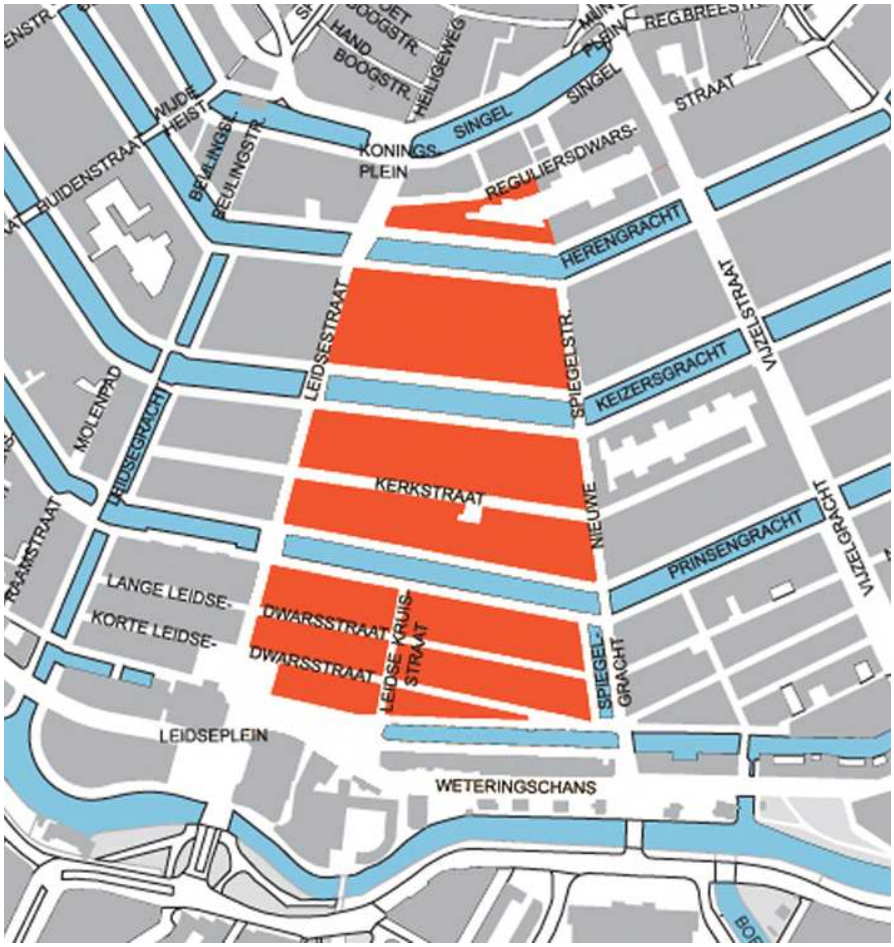

Fig. 11 – The transect on a modern map (Copyright: Menne Kosian/RCE).

Between these two radial streets, from the inner city outwards, the first concentric street was Reguliersdwarsstraat, which was the former wall street. It ran inside the fortifications that surrounded Amsterdam before the fourth extension took place. Then, it was transformed from a wall street into the backstreet of Herengracht. Anyone who had bought one or more parcels at Herengracht, had the right of first bidding for the parcels at the backside, in Reguliersdwarsstraat. This way, the wealthy principal of a canal side house would have to buy four plots, to be able to build a house with annexes like stables, a coach house, and accommodations for house personnel (Fig. 12). In the course of the seventeenth century, city houses began to bear more and more resemblance of country estates. A typical well-to-do family possessed both a city and a country house (ABRAHAMSE 2011).

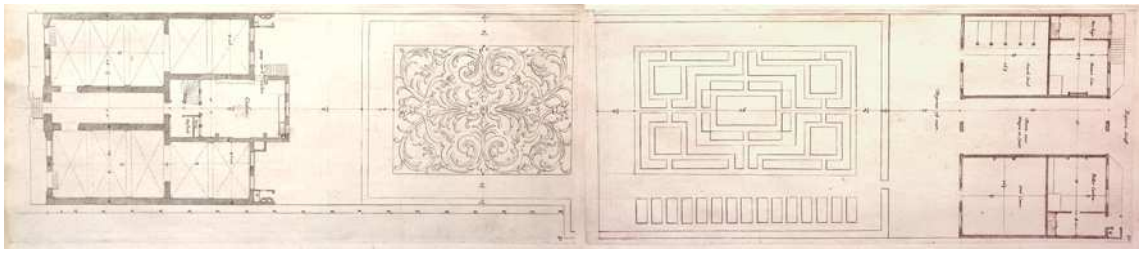

Fig. 12 – Plan of a large Amsterdam canal house, with the typical arrangement of the main house (left), the garden and the annexes (stables, coach house, personnel housing) that are opened up by a large carriage porch at the back side, by the architect Philips Vingboons, 1674 (Copyright: Stadsarchief Amsterdam).

This arrangement of urban elements has been repeated with the creation of Kerkstraat (Church Street), the second concentric street, which ran between Keizersgracht and Prinsengracht, and served the same purposes as Reguliersdwarsstraat. Both streets were meant for both local and through traffic and therefore arrived at bridges across the river Amstel (see Fig. 5), the Blauwbrug and the now famous Magere Brug. Three concentric canals pass through the transect. Close to the old city centre is Herengracht, which was the best location for luxury living. The city's merchant elite families bought building plots here. The part of Herengracht in the transect has been called the *Gouden Bocht* or *Golden Bend*, as it was primarily built with large houses on double plots. Keizersgracht, the next canal, was located more outside the city. Like Herengracht, it was meant for living only, but its presence was less imposing. Ground prices were considerably lower than at Herengracht. Prinsengracht, the third canal, had an altogether different character. In the fourth extension, Kerkstraat (*Church Street*) was the boundary between the canals that were meant for living exclusively and the more industrious areas outside the grand canals. Prinsengracht was a water traffic artery that was connected to the IJ sea-branch on both the west and east sides of the city, via locks in the sea-dykes (Fig. 4). This canal was not meant for luxury living, but for trade and industry. There was no need for gardens here. From the nature of things, warehouses always occupied the full surface area of the building lots. So many blocks are fully built-on, with no or almost no space between buildings.

Fig. 13 – Section of the *third extension*, with Lijnbaansgracht and the rope yards on the inside of the city's fortifications.

Beyond Prinsengracht was a district that was meant for middle class living and many types of industry. Streets were traced out, between which were small building blocks, with smaller plots. The layout of blocks and streets was small-scaled, compared to the canal ring area, but quite spacious in comparison with the cramped inner city. Outside this mixed-use district, just within the city's fortifications, ran Lijnbaansgracht (*Rope-yard Canal*), named after the rope-yards that were situated next to it in many places (Fig. 13). This was a narrow canal with a purely utilitarian function.

First Observations on the *Vienna Transect* GIS

To create the GIS system, all ground issue maps were geo-referenced. In the maps presented in this article, they are projected on the Gerred de Broen’s map of the City of Amsterdam from the 1730s, which of course is also geo-referenced.

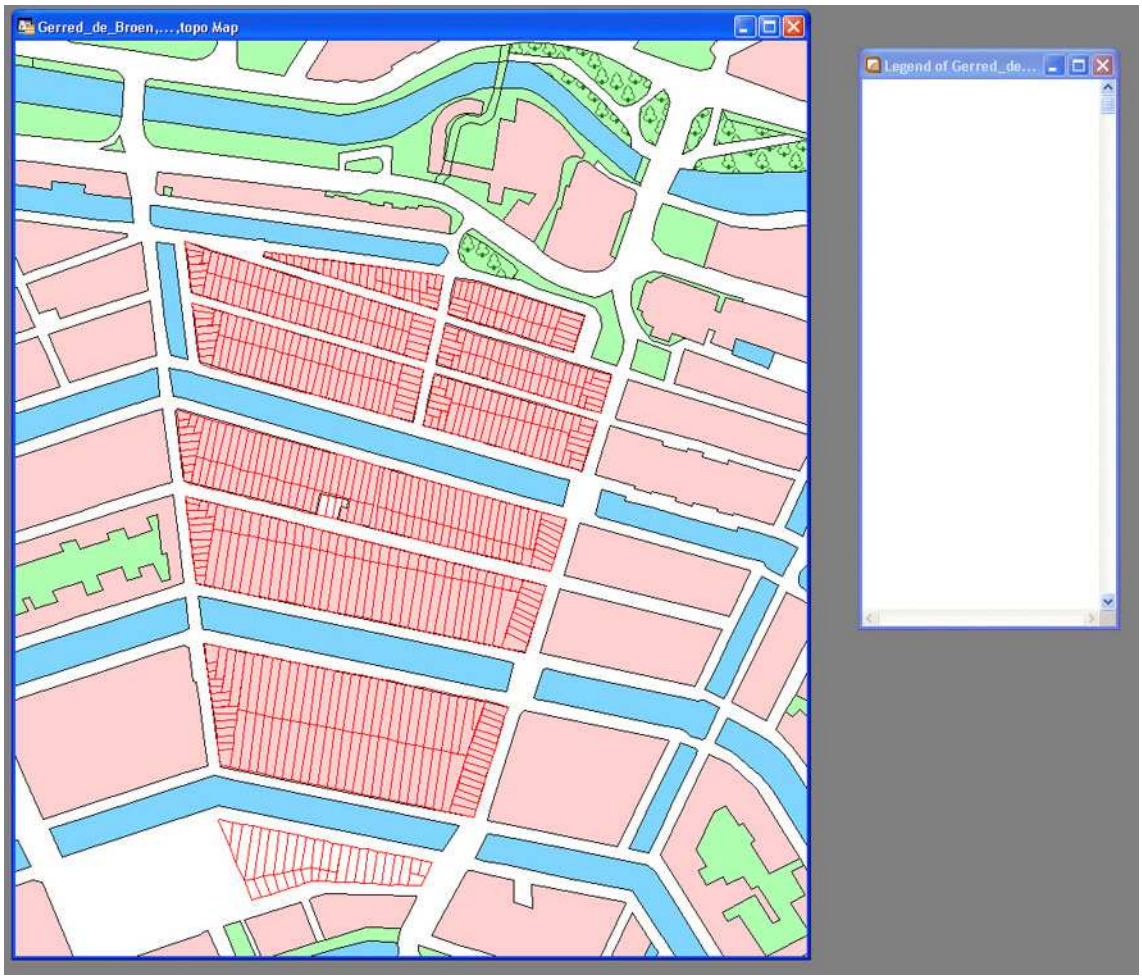

Fig. 14 – Seventeenth-century parcellation projected on modern topography (Copyright: Menne Kosian/RCE).

Figure 14 shows that the parcellation has developed over time, but the building blocks in the transect have remained unaltered. The fortifications of Amsterdam have disappeared from the early nineteenth century onwards. That did not have any effect on the form of blocks, but caused Spiegelstraat, the radial street that at first came to a dead end on the city’s fortifications, to develop into a thoroughfare from the inner city to the new districts outside the former ramparts.

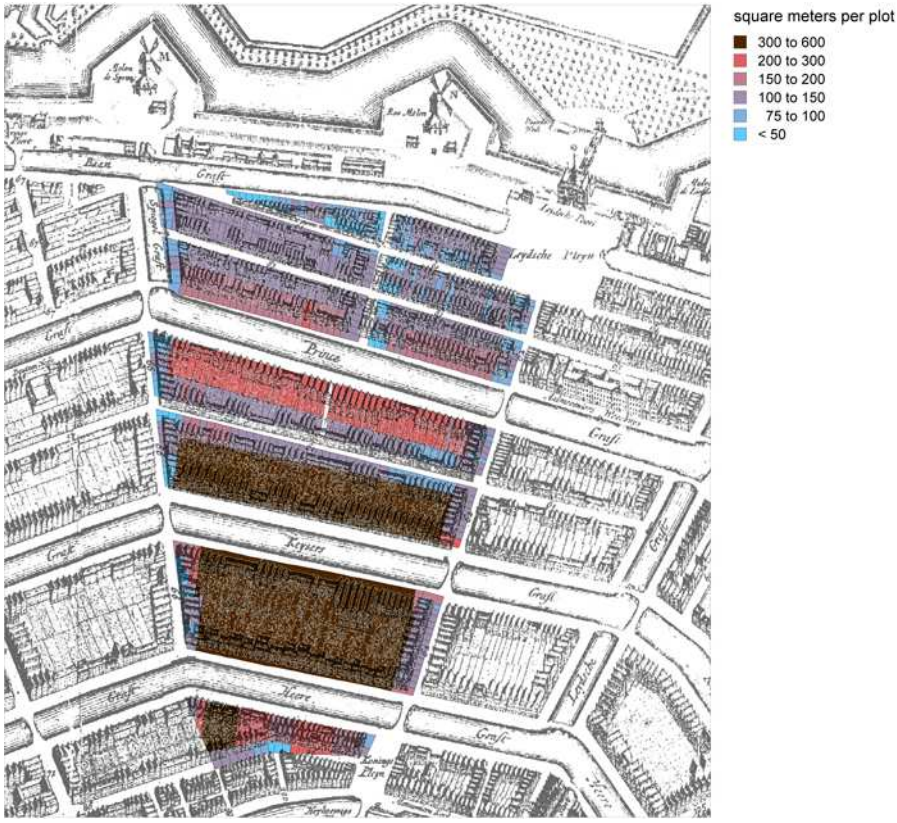

Fig. 15 – Surface area per plot, in square meters (Copyright: Menne Kosian/RCE).

Figure 15 shows plot sizes in the transect. There is a clear relation between plot sizes and their prescribed land use. The largest building parcels are located at Herengracht and Keizersgracht. In the elaborate functional setup of the fourth extension, these two canals were meant for luxury housing for the city's elite. The most prominent feature was a huge garden, situated at the back of the house. Layout of these gardens was enforced by regulations: at the canals, nobody had the right to build anything more than 100 feet behind the building line. This way, large-scale continuous garden areas would come into existence on the inside of the building blocks. The need for large houses and large gardens accounts for the large parcel measurements. Beyond Prinsengracht, many small parcels were laid out, for both middle-class housing and all kinds of small-scale enterprises. These grounds were meant to be affordable, especially to the people who had been forced to leave their houses en grounds because of the city extension (ABRAHAMSE 2011).

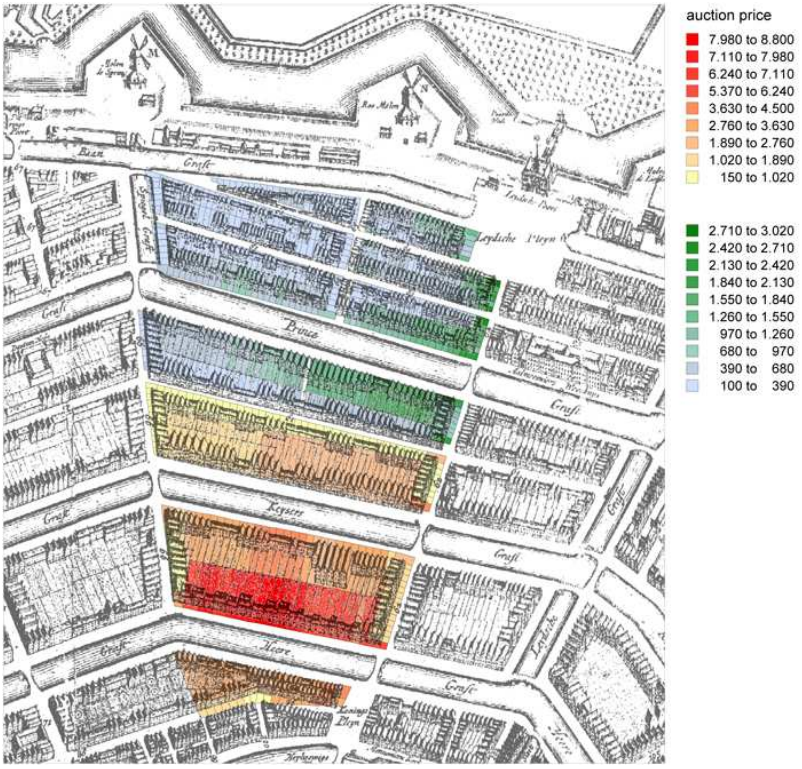

Fig. 16 – Prices paid per plot in the transect (Copyright: Menne Kosian/RCE).

When we look into the prices that were paid for plots (Fig. 16), first of all it becomes clear that the overall location of grounds in the city is a determining factor. Plot prices were highest near the city centre and fell as they were located closer to the city’s borders.

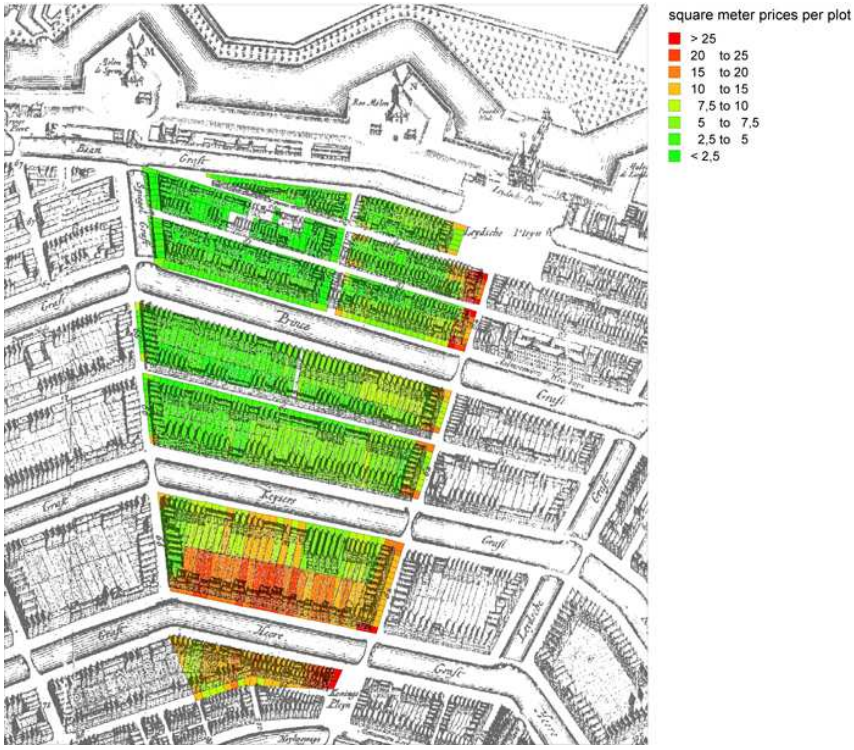

Fig. 17 – Prices paid per square meter (Copyright: Menne Kosian/Jaap Evert Abrahamse/Erik Schmitz/RCE).

When we take a look into prices per square meter (Fig. 17), it also becomes clear that the plot price is determined by the location of a plot within the entity of the canal or street. But it also becomes clear that, before we analyse ground prices, the transect should be divided up, so that only units are compared that are actually comparable. For instance, the large parcels on Herengracht were meant for luxury housing and gardens. Prices per unit for plots on Herengracht were the highest, despite the fact that a large part of these plots could not be built upon. Comfort, space and presentability were the main qualities, while beyond Prinsengracht, the attention was focussed on affordability and functional flexibility. In short, parcels on Herengracht were meant for showing off and ostentatiously spending money on architecture. They were an expression of consumption, while parcels beyond Prinsengracht were meant as a means of production. Therefore, both function and location should be part of the equation.

In Figure 18, three distinct types of plots are indicated in different ranges of colouring: the first type, indicated in red, orange and yellow, are located on the canals. The second type, indicated in green, are located in streets and the third type, indicated in blue, are located at the main radial streets, i.e. the shopping and commerce streets. This classification of different types of building plots gives insights into the price-making forces. We see that the green-coloured building plots, the ones that were meant for the city's middle class and for industry, are priced on the basis of accessibility. The influence of the presence of the main radial street, Leidsestraat (on the right side) becomes clear, as ground prices raise as plots lie closer to this main traffic route. The other radial street, Spiegelstraat, must have been a busy street, but no thoroughfare, for it ended at the city's fortifications. Its influence on ground prices was by no means as strong as that of Leidsestraat.

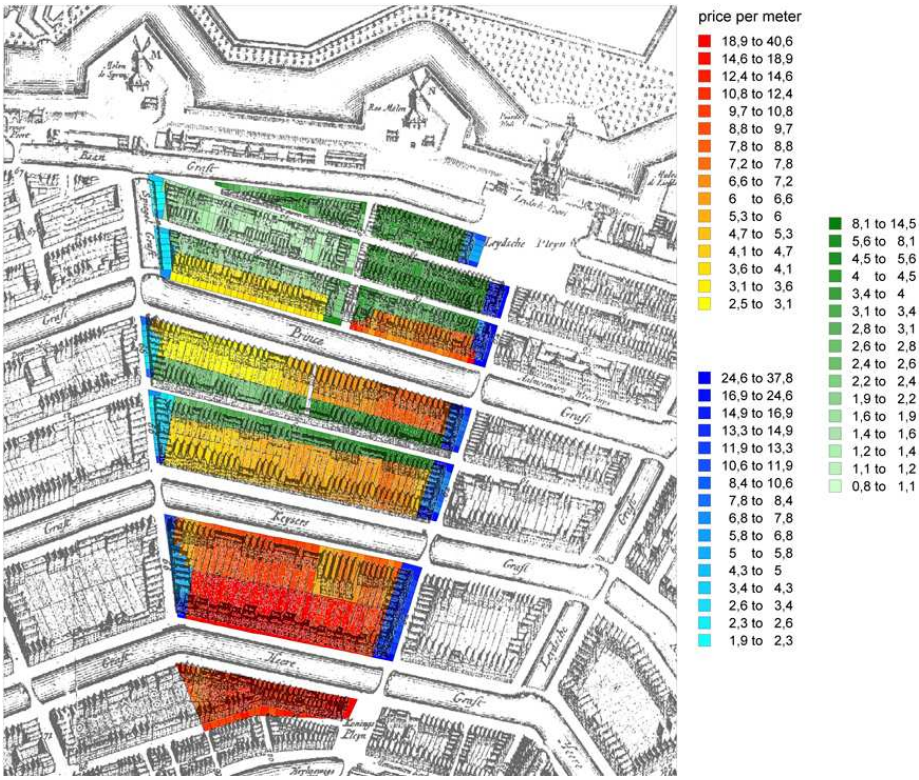

Fig. 18 – Plot prices per square meter, itemized on the basis of location on canals, streets and radial streets (Copyright: Menne Kosian/Jaap Evert Abrahamse/Erik Schmitz/RCE).

The building plots at the radial streets themselves (in blue) were used for shops. They should be considered as commercial real estate, bought by entrepreneurs to make money with. The main price-making force for this type of building plot was the amount of traffic that went by the store fronts to be built there. The main factor was visibility. That accounts for the corner plots of Leidsestraat and the canals to be the costliest building grounds of the transect, and probably of the fourth extension as a whole. The corners of radial streets and canals have ever since been the best shop locations of the canal ring district. In the nineteenth century, these corners have been the locations where large investments in shop-premises took place. This resulted in a richly ornamented shop architecture, with all kinds of balconies, bay windows and little towers on the corners, up to the point that contemporary comments were speaking of *tower mania* (VAN DER WOUD 1997). Anyhow, these buildings illustrate and highlight the original functional structure of the area. From the auction books, the volume and distribution of land ownership can be derived and made visible using the GIS system (Fig. 19). It is known that anyone who bought a parcel of land at an auction, was entitled to buy the adjacent parcel for the same price. Especially on Herengracht and Keizersgracht, but also on Prinsengracht, many plots were sold in pairs, with the obvious intention of building a large canal house. On the radial streets, by contrast, most plots were sold separately. This might be explained from the relatively high land prices and the most efficient use of floor area for retail purposes. These plots were sold to craftsmen and shopkeepers, who generally owned smaller capitals than the buyers on the canals. On the map (Fig. 19) we also see that the property of most people who bought more than three of four parcels, is located beyond Kerkstraat, outside the canal belt. This might be caused by the low prices, but also by the industrial nature of this area. Because of the low prices, the purchase of multiple plots was affordable in this area. Probably, relatively more ground was bought by speculators. The property of both of the two auction visitors who bought over fifteen plots, was located in the outer areas, near the city’s fortifications.

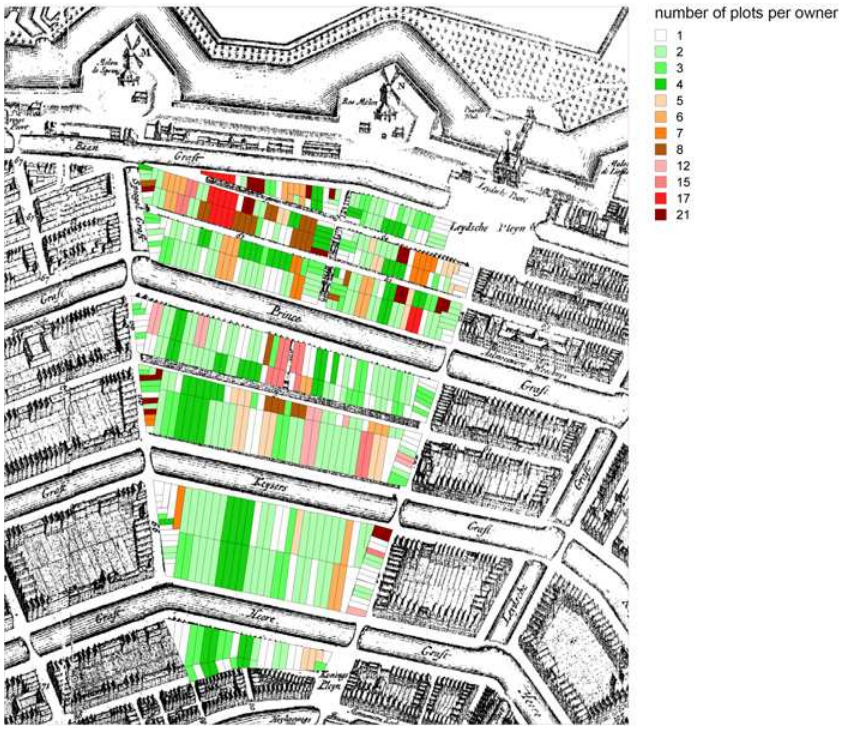

Fig. 19 – Number of parcels sold to the different buyers (Copyright: Menne Kosian/Jaap Evert Abrahamse/Erik Schmitz/RCE).

From these first observations on just a small section of the inner city of Amsterdam, we can conclude that research of ground prices yields insights not only into urban and economic history. It shows where and how the profits that were made in trade and industry were reinvested in real estate. Apart from that, it also clarifies the functioning of the early modern city. The value of land shows which plots are most in demand on the urban micro-scale of the urban streets, canals and squares, and about their use. The locations and spatial dynamics of retail trade, urban residences and small business are revealed through this research (early modern retail trade has recently become a subject of very interesting research: VAN AERT 2009; LESGER 2007). Later on, the GIS system will not only contain auction data, but also the values of plots when they are resold. This way, the dynamics of the real estate market and the functioning of the city can be monitored over time, when the plots are built-on. Because of the availability of data about the buyers' places of residence and occupations, it will be possible to develop new insights in the social stratification of the early modern city. It is obvious that some buyers were involved in land speculation, which in the early modern period was an accepted practice and source of income. The presence of professions from the building trade, like carpenters and masons, tells us where plots were bought with the intention of building for the real estate market, not so much for one's own personal use.

Also, many factors seem to be constant: research by the Centraal Planbureau (Central Planning Agency) learns us that ground prices in the modern Dutch city raise as a plot is located nearer to the city centre and that plot prices are higher as plot sizes diminish (DE GROOT et al. 2010, 23–26). But above all, it is pointed out that ground price is determined above all by location, i.e. the proximity of urban amenities (DE GROOT et al. 2010, 129). Nowadays, ground meant for residential use near the centre of Amsterdam is worth over 200 times the value of residential grounds in the peripheral parts of the Netherlands.

Future Research

At this moment, the GIS system of Amsterdam is in the making. All auction maps have been georeferenced, and in due time all of the data from the auction books will be entered into the database. This way, all auction transactions will be available with a press of the button, not only to professional historians but also online, on the archive's web site or somewhere else.

The Dutch Republic was one of the most urbanized regions of early modern Europe. In degree of urbanization, it was second only to Northern Italy. Apart from Amsterdam, quite a few other cities have grown considerably in the seventeenth century, both in the province of Holland (Leiden, Haarlem, Rotterdam) and the rest of the Republic (for instance, Groningen [KOSTER 2001; VAN ESSEN 2010] and Flushing). Amsterdam therefore is not the only city where auction data have come down to us. It is possible to extend the GIS project to other cities, which enables comparative research in urban economy and ground markets. Earlier city extensions, such as the sixteenth-century extensions of Enkhuizen, Middelburg, and Harlingen might be interesting to look into. The same goes for some of the larger cities in Flanders, such as Antwerp, Ghent, and Bruges (about Antwerp for instance, see SOLY 1977). Flanders might be of interest, because many aspects of urbanism and city management were imported into the Northern Netherlands by Flemish immigrants, after many Flemish cities fell into Spanish hands during the Eighty Years' War.

In connection with this topic, it is interesting to look back into the Middle Ages, when many new cities were founded (BOEREFIJN 2010). We know that in mediaeval Dutch cities such as Elburg, which was laid out in the end of the fourteenth century, ground was divided in regular parcels and subsequently sold to private owners by Arent toe Boecop, the estate agent of the of the Duke of Guelders, according to a plan and additional regulations (RUTTE 2003). Some more research of mediaeval cities might yield insights into the development of a fully commercial practice, and the emergence of a free ground market.

Another aspect is the urban influence throughout the countryside. The major part of the Dutch landscape has been planned from the cities. Large reclamation projects, aiming at the creation of new agricultural land by draining lakes, diking in low-lying land, or reclaiming large sands, were an essentially urban phenomenon. The organisation, techniques en financing of such projects were dependent on urban knowledge. It is well known, for instance, that the draining of the Beemster lake was undertaken by wealthy merchants, mostly from Amsterdam. By extending the GIS project to the Beemster polder (of which very good land ownership data are available), we could gain a more exact insight into the urban investments in agricultural land. The same goes for the development of country house and rural estate property. Investments in real estate were common among seventeenth-century merchants, as a part of their business strategy in which safe investments were combined with risky international trade.

In this project, the functioning of the seventeenth-century city is the central theme. But it might also be relevant for present-day urbanism. To this day, many urban extensions are based on the principles of post-war anti-urbanism. At the same time, authorities are beginning to withdraw from planning and housing. Overall, the involvement of regional and municipal administrations with urbanism, architecture and building seems to be diminishing. This will lead to a shift in the balances. The private sector will have to take over again, as in early modern Europe. This implicates, on the one hand, that the housing market will be more free, and on the other hand, that more private individuals will commission new built dwellings within urban structures that will have to be designed for this ‘new’ type of city development. This might have a considerable impact on the practice of housing and urbanism. Therefore, a better understanding of the urbanist practice of the early modern period of relatively small involvement of the authorities in planning and building, might be of interest under the present circumstances. Better understanding of the functional mechanisms of cities on the micro-scale of parcellation might contribute to the present-day practices in urbanism and project development.

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Archaeological maps of ancient urban settlements characterised by continuity of occupation: a tool for historical research and protection of cultural heritage

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Abstract: The paper concerns the contribution of archaeological digital maps to the knowledge, protection and development of two ancient urban settlements characterised by continuity of occupation: Ugento and Taormina.

Ugento (Lecce, Puglia) was the most extensive settlement of ancient Messapia in the pre-Roman age. Today a portion of the modern city overlaps the ancient settlement. The research was carried out by the CNR-IBAM, in cooperation with the Laboratory of Ancient Topography and Photogrammetry of the University of Salento (LabTAF), the Archaeological Superintendence Board of the Puglia Region and the Town of Ugento. The archaeological remains of the Messapian, Roman and Medieval periods, as well as these which were destroyed or obliterated due to the urban expansion of the last 60 years, has been located on an archaeological digital map integrated into a GIS; it was adopted by the municipal administration of Ugento and integrated into its General Regulatory Plan.

Taormina (Messina, Sicily) was the ancient Tauromenion-Tauromenium, founded at the end of the 4th century BC. The research project concerning this city is still in progress and performed in cooperation with the Department of Ancient Sciences of the University of Messina and the Archaeological Superintendence Board of Messina. The aim of this project is the production of a digital archaeological map of the ancient city, integrated into a GIS, in which all the Greek and Roman monuments still preserved and visible, and the other structures excavated in the last half century are positioned.

The final objectives of these projects are to favour a greater awareness of the ancient centres and of their expanse and articulation, by means of a prompt location of all archaeological evidence which has been pointed out up until now, as well as to preserve the ancient remains and monument, and to promote a more rich cultural tourist offering.

Keywords: archaeology, digital maps, GIS, Ugento, Taormina, protection.

Archaeological maps of continuously occupied settlements: the case studies of Ugento and Taormina

The study of ancient settlements characterised by continuity of occupation raises specific research issues and requires methods of enquiry that can be adapted to individual contexts. Archaeological maps based on high-scale digital cartography have been a fundamental tool in Italian archaeological research for over two

decades; see for example the numerous volumes published in the *Città antiche in Italia* / *Ancient cities in Italy* series, edited by Prof. P. Sommella, or in the *Città Romane / Roman city* series, edited by Profs. L. Quilici and S. Quilici Gigli. As well as scientific research, they have been used for conservation (by the *Soprintendenze Archeologiche*, the regional bodies responsible for conservation), urban planning (by local authorities), and the management and appropriate use of ancient heritage. The choice of base maps to be used for positioning archaeological data depends on the contexts and the aims of the research. Existing digital maps can be used, or bespoke cartography can be produced from scratch. It is thus essential that the archaeological maps are in vector format (so as to resolve issues arising from the scale of representation) and that the elements represented are appropriately codified (GUAITOLI 2003). This coding must include a section for the elements in the base map (i.e. geomorphology, hydrography, vegetation, the modern road network, buildings, etc.) and a section for the archaeological data.

Ideally, archaeological maps with these characteristics should be combined, within GIS platforms, with databases on documented cultural heritage items. Thus conceived, they are highly useful for the reconstruction of the ancient urban fabric and its transformation over time. This is especially the case when the remains are more or less numerous but fragmentary, with no clear topographical relationship between them; obscured by modern constructions or incorporated within buildings that have had many different functions over the centuries; or situated within an urban fabric that is still in use but is based on planning criteria that are quite different from those of the ancient settlement. Such maps have proven to be excellent practical tools for the conservation of ancient remains and for the implementation of suitable urban management policies to promote the growth and development of modern towns in a way that is harmoniously integrated with the conservation of the ancient and stratified settlements that they are built upon. In archaeological maps the ancient evidence is located with the greatest possible precision in terms of its surface area and elevation, so that, for example, its conservation can be adequately considered when planning the laying of underground utility networks (electricity, gas, sewers, fibre optic cables). These maps are thus important tools for the proper implementation of urban planning measures in our own day, helping to ensure that they respect ancient contexts in cities that have been continuously occupied. They constitute a continuously updated “census” of existing cultural heritage items, which can be studied in greater detail and from a specialist point of view, but also protected and where possible opened up to the public. They do not have problems of graphic scale (either in the input phase or the output phase) and they make it possible to digitally memorise the elements on numerous logical levels that are independent but interactive.

The archaeological maps of Ugento (Lecce Province, Puglia Region) and Taormina (Messina Province, Sicily Region) represent two case studies performed in the last few years by the Institute for Archaeological and Monumental Heritage of the Italian National Research Council (CNR-IBAM). They exemplify different issues arising from the study of the ancient topography of settlements characterised by continuity of occupation since ancient times, with a view to the conservation, management and appropriate use of cultural heritage. In both cases, the initial objective of the research was scientific, i.e. to analyse the organisation of pre-Roman settlements and their transformation under Roman rule and during the Middle Ages. In the case of Ugento we are dealing with a large Messapian settlement which developed in the Archaic and Hellenistic epochs, while Taormina is the site of a Greek city founded in the Hellenistic age. Both have specific urban features linked on the one hand to the indigenous settlements of the Salento (ancient Messapia) and on the other to

the traditions of the ancient Greek colonies in Sicily that were inspired by Hippodamus of Miletus. The creation of digital archaeological maps with precise positioning of all the known ancient evidence, from the remains of monuments to the sporadic discoveries of structures and materials, whether still visible or no longer conserved, has enabled the integration in a single homogeneous container of data that were previously fragmentary. This in turn has made it possible to carry out a series of observations on the urban structures of the two ancient settlements, highlighting connections between apparently unrelated archaeological evidence and thus acquiring new data on the ancient topography of the two cities.

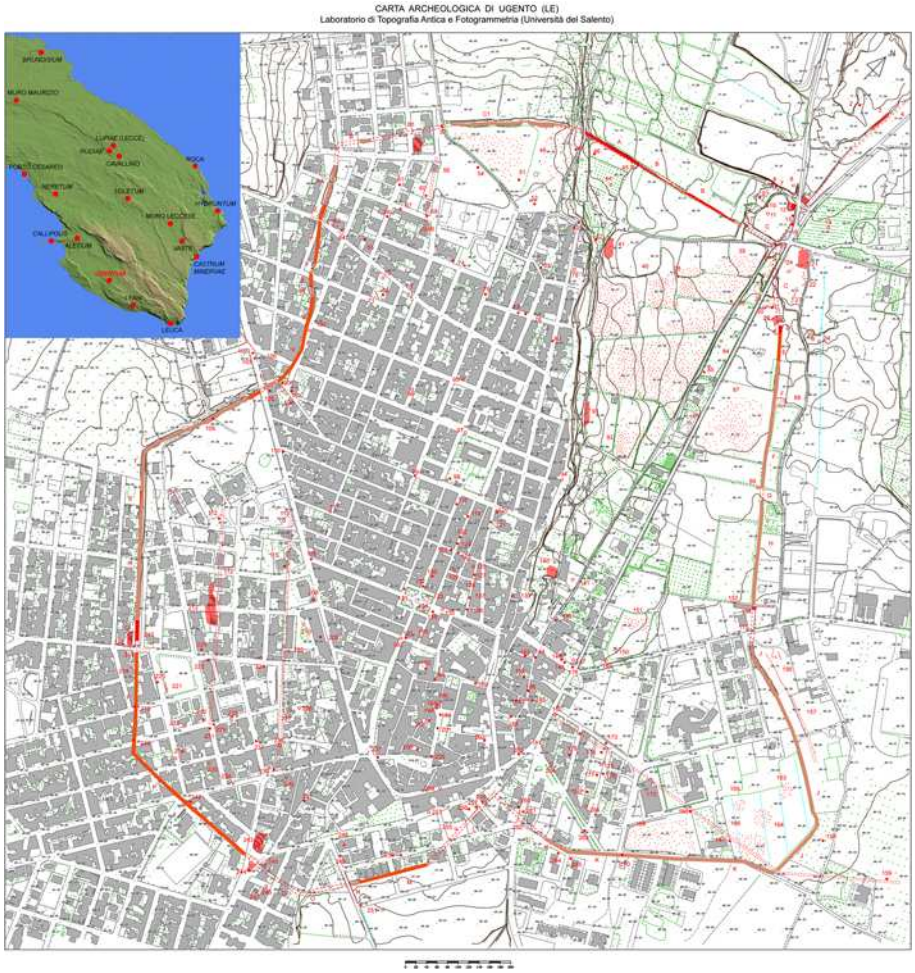

Fig. 1 – Archeological map of Ugento, located in the southern Salento peninsula.

The two cities had rather different research records. The settlement in Ugento (Fig. 1), where research began in 2002, is one of the main ancient settlements in the southern Salento peninsula but it had never been systematically studied before. Indeed, previous studies had focused exclusively on individual archaeological finds of particularly high value that had been discovered accidentally in the course of building work (see section 2 below). With the exception of a few stretches of the ancient city walls and some areas of necropolis with shaft tombs, there are no visible ancient remains large enough to attract the attention of scholars. The systematic study of all the evidence, including what is still visible and what was discovered in the past but is no longer conserved, has however led to the acquisition of a large quantity of data on the settlement's urban layout, especially in the Archaic and Hellenistic epochs, when it was the most extensive in

Messapia. In addition, the research has highlighted the location of certain public areas, residential sectors and necropolises, the latter at that time lying in close proximity to the inhabited areas, even inside the city walls. It was also possible to document the transformation of the settlement in the Roman epoch, when it still played a central role in the territorial organisation of the southern Salento, and in the Middle Ages, when it shrank considerably, becoming a small fortified town. Ugento maintained this status until the 19th century.

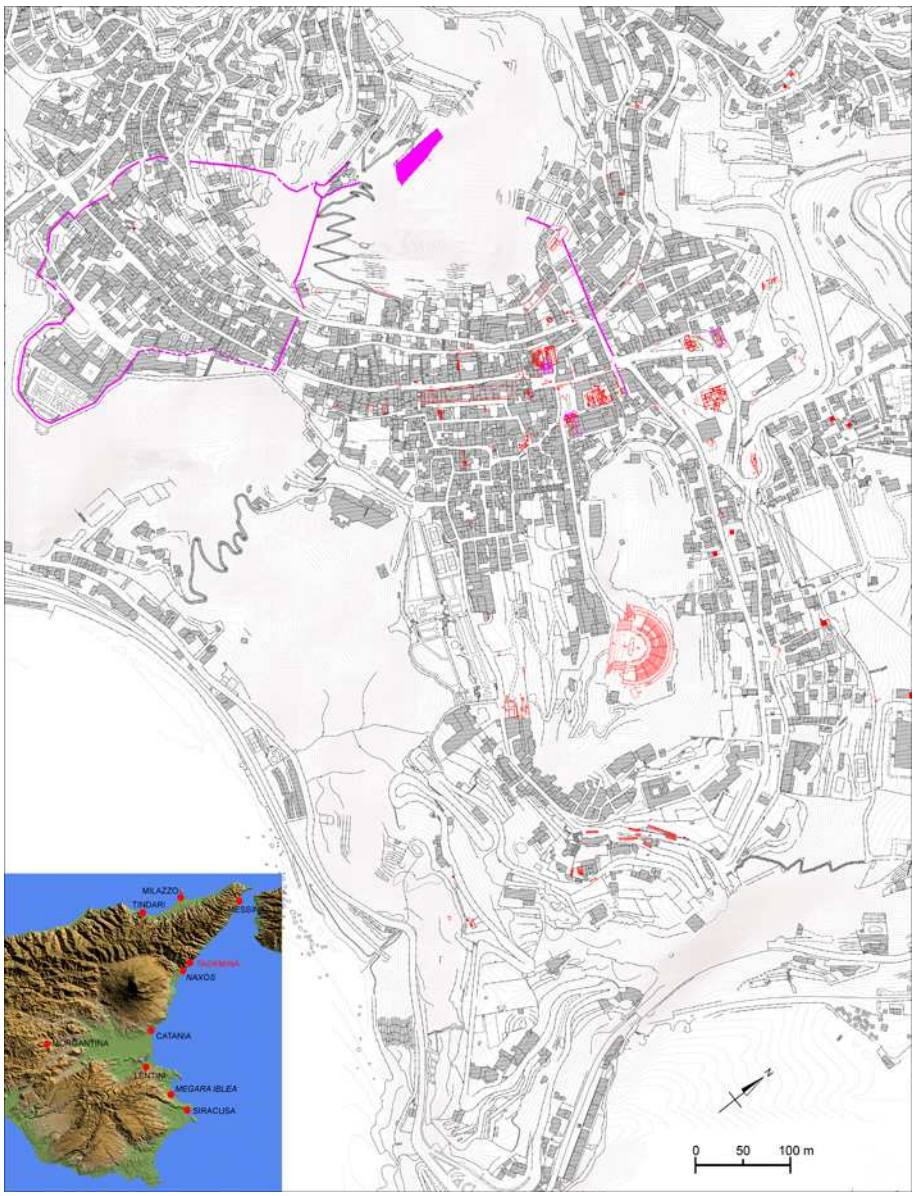

Fig. 2 – Archaeological map of Taormina, located in the eastern coast of Sicily.

The case of Taormina (Fig. 2), where the studies began in 2009, is quite different (see section 4 below). This is a city in which many monumental remains from both the Hellenistic and Roman imperial epochs are conserved. Indeed, its theatre has made it world famous. There is a long tradition of archaeological studies here, but these have essentially focused on individual monuments. Only in the last few years has attention turned to the analysis of Hellenistic and Roman town planning in Taormina, but it has become clear that this field of research requires an archaeological map showing the precise position (in terms of both the area

covered and the elevation, given the orographic conditions of the site) of all the known monuments. These monuments include both those which have always been visible and those brought to light in the 1960s and 1970s as a result of modifications to the modern city. The archaeological map also needed to be brought up to date to include recent discoveries made in the course of public or private building work, consisting mainly of fragments of walls, which acquired greater significance when integrated into the overall picture. What has always been missing in Taormina is a detailed base map in which all the known archaeological items are accurately positioned and their interrelationships made clear. The research of 2009–2010, still in progress at the time of writing, is the first in the city to be based on a high-scale digital archaeological map, and is enabling us to acquire new and important data on the city's ancient topography and relative necropolises.
In both of the case studies discussed here we are dealing with settlements that have been continuously occupied since ancient times, and as the modern towns have expanded over the last 60 years they have covered increasing portions of the ancient sites. The analysis of historic cartography (from the 16th to the 19th centuries), old documents in the property registers and aerial photographs from the 1920s, 30s, 40s and 50s has been very useful in this regard, since it has yielded important data on areas that were subsequently built over. The urban expansion of the last half century in the two cities, accompanied by the near doubling of their populations, has frequently not taken sufficient account of the archaeological evidence. Indeed, a mechanism for the adequate planning of urban growth and the modernisation of utility networks, in which the remains of the ancient settlements were precisely located, was completely lacking. In the case of Ugento, the archaeological map was adopted by the municipal administration and integrated into its General Regulatory Plan. It was subsequently used to provide protection for the most important archaeological remains still conserved, in particular the Messapian city walls, of which in the map different colours and symbols distinguish the level of conservation (preserved and visible; preserved and buried; not preserved but visible in the old aerial photos and georeferenced in the map; hypothetical). The digital archaeological map is also used by the Puglia regional archaeological authority (*Soprintendenza per i Beni Archeologici*) for planning preventive archaeological measures before the execution of public or private building work, and is updated with the results of the new excavations (Fig. 3). The results of the research conducted for the archaeological map of Ugento were also taken into consideration in the refurbished municipal archaeological museum, where the map was used as the basis for the creation of a plastic model (on a scale of 1:1,000) of the settlement in the Archaic and Hellenistic periods, with the reconstruction of both the ancient archaeological evidence and the morphology of the terrain (Fig. 4), also well documented through a DEM extracted from the cartography (Fig. 5). Furthermore, the map is used for planning measures designed to facilitate the enjoyment of archaeological heritage by the public, an important consideration given that the nearby coastline attracts large numbers of tourists in summer. It is to be hoped that all this will also happen in Taormina, where the *Soprintendenza* of Messina, which is a partner in the research project, will use the archaeological map in its urban archaeology measures. The map may also play an important role in the planning of policies to guarantee the conservation of the monuments, as part of a wider plan for sustainable urban development that respects the existing archaeological heritage. This heritage needs to be protected and made accessible to the public, again considering that the city constitutes an important destination for international tourism. Today only the theatre, with its spectacular views over the Ionian sea and towards

Giardini Naxos and Etna, is visited by tourists, while the other monuments lie practically abandoned. There is also no archaeological museum to document and showcase the city's thousands of years of history.

Fig. 3 – Recent excavations in the urban area of Ugento: A, Messapic tombs in via Peri (4th–3rd century BC); B, Roman tank in via Marconi (1st century AD).

Fig. 4 – A view of the plastic model of the ancient settlement of Ugento during the Archaic and Hellenistic periods: houses, public buildings, roads, basins for water storage and necropolises (indicated by black arrows) inside and outside the city walls are reconstructed.

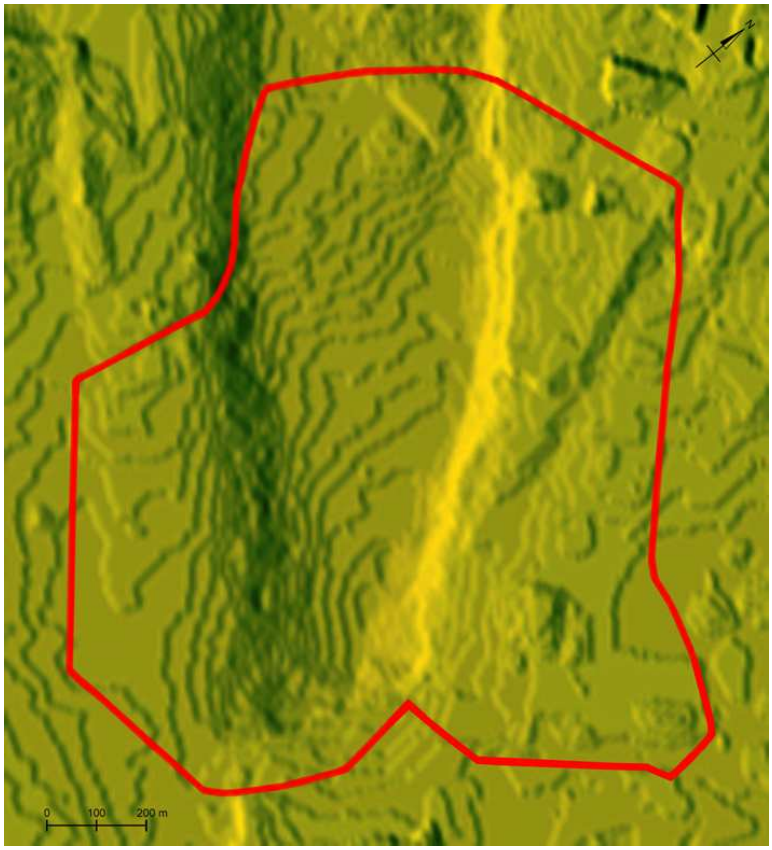

Fig. 5 – DEM of the area of Ugento: is evident that the city walls defended the hill of the Archaic settlement and the plain to the west, south and east of this relief.

Despite being affected by similar problems of protection, conservation and appropriate use of their archaeological heritage, the two contexts of study considered here have different characteristics, which make it necessary to apply different solutions in the creation of the archaeological maps and their associated databases, managed by GIS platforms. Indeed, in the case of Ugento, the absence of basic cartography that was adequate for the research meant that it had to be created from scratch, up-to-date (from aerial photos of 2002) and in vector format (on a scale of 1:2,000), in the Laboratory of Ancient Topography and Photogrammetry (LabTAF) of the Salento University (see section 3 below). In addition, since a third of the area of the ancient settlement was still free from modern structures and could thus be studied by means of a systematic archaeological survey, a descriptive record of the ancient evidence, specially developed to document ancient remains identified in the course of research on the surface and already in use in the LabTAF, was used. In the case of Taormina, where the modern city completely overlays the ancient city and its necropolises, a pre-existing map was used: the Technical Map of the Sicilian Regional administration. This map was up-to-date (from aerial photos of 2004–2005) and in vector format (on a scale of 1:2,000), and required only light editing and a few additions in order to adapt it for the specific needs of the archaeological research (see section 5 below). In addition, a special record was developed for the descriptive database of the ancient evidence, based on the characteristics of the available documentation, almost all of which is archive data from previous excavations and discoveries. (G. S.)

Archaeological map of Ugento: from historical reconstruction to protection

The study of the city walls of Ugento provides interesting opportunities for reflection on the methods and objectives inherent in the creation of an archaeological map of an ancient settlement characterised by continuity of occupation. The study was conducted as part of a larger and more complex research project involving CNR-IBAM in Lecce and the LabTAF of the University of the Salento working in collaboration. The aim of this research project, for which the creation of the archaeological map was a precondition, is the reconstruction of the ancient topography of the city and settlement patterns in the area over long periods (SCARDOZZI 2007, 2010a and 2010 in press).

Ugento is one of the most important ancient settlements in the Salento peninsula, which was called Messapia in the pre-Roman epoch. It is situated about 45 km South of Lecce, at the southern end of a ridge lying along a North-west/South-east axis parallel to the Ionian coast, which lies roughly 6 km to the West. Although the site appears to have been occupied since at least the 8th century BC, there is no clear evidence of an organised settlement before the 6th century BC. In the second half of the 4th century BC, at a time of intense instability in the area in the run-up to the Roman conquest (third quarter of the 3rd century BC), the town was defended by a circuit of walls (Fig. 6) approximately 5 km long that enclosed an area of nearly 150 hectares, making *Aozen(tum)/Ozan(tum)* the Messapians' most extensive settlement. After the Roman conquest it became a municipality with the name *Uzentum* and remained a relatively important town of the Lower Salento. In the Middle Ages the town shrank considerably, with just a castle occupying the highest part of the hill, but it continued to play an important role in the area and was the seat of the diocese. Ugento maintained this character during the Byzantine, Norman, Swabian, Angevin, Aragonese and Spanish

(Hapsburg and Bourbon) periods. In the late 20th century, expansion resumed, with the modern city now covering two thirds of the area of the Messapian town (about 100 hectares).

Fig. 6 – Ugento: remains of the Messapian city walls in loc. Porchiano (second half of 4th–3rd century BC).

The research in support of the archaeological map of Ugento entailed the use of traditional methods for the study of ancient topography, including systematic reconnaissance on the ground and consultation of literary sources, archive documents and the existing bibliography. This was accompanied by analysis of historic maps and the reading and interpretation of all the aerial photographs available, looking at vertical and oblique photographs from historic and recent flights as well as high-resolution satellite images. The case of Ugento in particular has shown the importance of historic aerial photographs in the reconstruction of ancient landscapes. This is exemplified by their significant contribution to the reconstruction of the route of the Messapian city walls, the most important monumental evidence of the ancient town that was still intact in the mid 20th century (Figs. 7–8). Indeed, the aerial photographs from this period, taken during flights by the Italian Geographical Military Institute (IGM) in 1947 and 1955, show long stretches of the walls (about 1,550 m) which are no longer conserved today. These stretches of the walls have disappeared as a result of the expansion of the city in the last few decades in the absence of urban planning regulations that took account of the archaeological evidence. Until the beginning of the research by CNR-IBAM and the LabTAF in 2002, in collaboration with the *Soprintendenza* of the Puglia region, very little was known of the structure of the ancient settlement, since the archaeological research in Ugento was limited to ad hoc measures applied in response to fortuitous discoveries made during the execution of public works or the construction of private buildings. These include the discoveries of the statue of Zeus (one of the very few examples of Archaic bronze statuary from the Greek colony of Taranto) and the so-called Tomb of the Athlete (with rich funerary objects, also including items imported from Greece, showing the high level of culture attained by the local aristocracy in the Archaic and classical epochs), both of which occurred in the 1960s, highlighting the importance of the ancient settlement of Ugento.

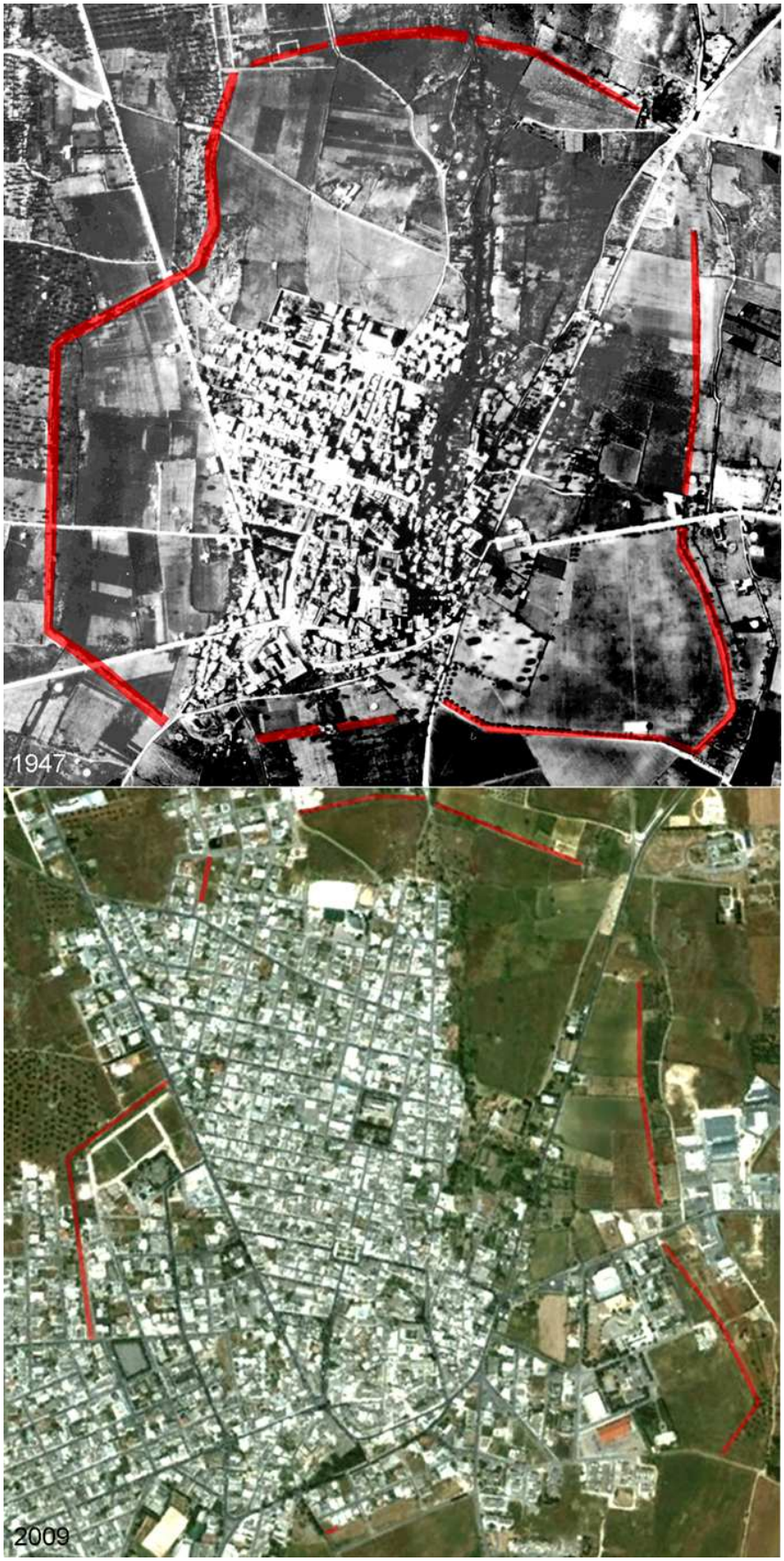

Fig. 7 – Ugento in a mosaic of IGM aerial photographs taken in 1947 and in a QuickBird-2 image of 2009: remains of the Messapian city walls are highlighted in red.

The progressive destruction of the stretches of the Messapian walls visible in the aerial photographs of 1947 and 1955, which intensified in the 1960s and 1970s, is documented by the subsequent images provided by the Italian Air Force (1968), the US spy satellite Corona KH-4B (1970), the Italian Geographical Military Institute (IGM) (1972), and private companies including Rossi Rilievi Aerofotogrammetrici (1979), AeroTop (1988) and Compagnia Generale Riprese Aeree (1998). The 1947 and 1955 images were integrated with the data that emerged in the course of the research and georeferenced in the aerophotogrammetric restitution that was specially created by the LabTAF. This restitution forms the cartographic basis of the archaeological map of the city (see section 3 below). The current state of the town is documented by the aerial photographs taken by the Italiana Aero Servizi company in 2002, which were used for the restitution of the new cartography, and by satellite images taken by QuickBird-2 in 2004, 2005 and 2009.

Fig. 8 – Ugento. Remains of the Messapian city walls in loc. Acquarelli visible in an IGM aerial photo of 1947 and in a QuickBird-2 image of 2009.

The archaeological map of Ugento was drawn on a scale (1:2,000) appropriate to the correct and accurate positioning of the stretches of the walls (both still conserved and destroyed but visible in the historic aerial photographs) and all the other archaeological evidence identified in the course of the research or already familiar from previous studies. The map was also integrated into the Geographical Information System developed and implemented by the LabTAF and the CNR (GUAITOLI 2001 and 2009) in which the archaeological evidence of various Regions in central-southern Italy (particularly Lazio, Abruzzo, Campania and Puglia) is systematically documented. The archaeological map was thus associated with a descriptive database containing records of all the ancient evidence. It thus constitutes an important tool for the reconstruction of the ancient topography of the town and its transformation during the Messapian, Roman and medieval epochs. As it contains organised data, it represents a research tool in its own right, able to produce new data, enabling researchers to carry out comparative spatio-temporal analyses that contribute meaningfully to enhancing our knowledge of the city's archaeological and monumental heritage. However, the archaeological map also represents an excellent tool for the protection of the ancient items in that it provides support for the proper planning of the city's growth and functions. Indeed, as early as 2005 the Municipal Administration of Ugento used data from the research as the basis for modifications to its General

Regulatory Plan (Fig. 9), enabling a more effective application of the prohibition on construction near the route of the Messapian walls. Such a prohibition had existed since 1983 but had never been supported by an accurate positioning of the ancient remains on the map. In addition the *Soprintendenza* of the Puglia Region now uses the map – which, being a dynamic tool, is constantly updated – to enhance the effectiveness of its measures for the protection and conservation of ancient remains by means of preventive excavations conducted before the construction of new infrastructure or public or private building work. These excavations help to acquire further data on the ancient city, which are then inserted in the archaeological map.

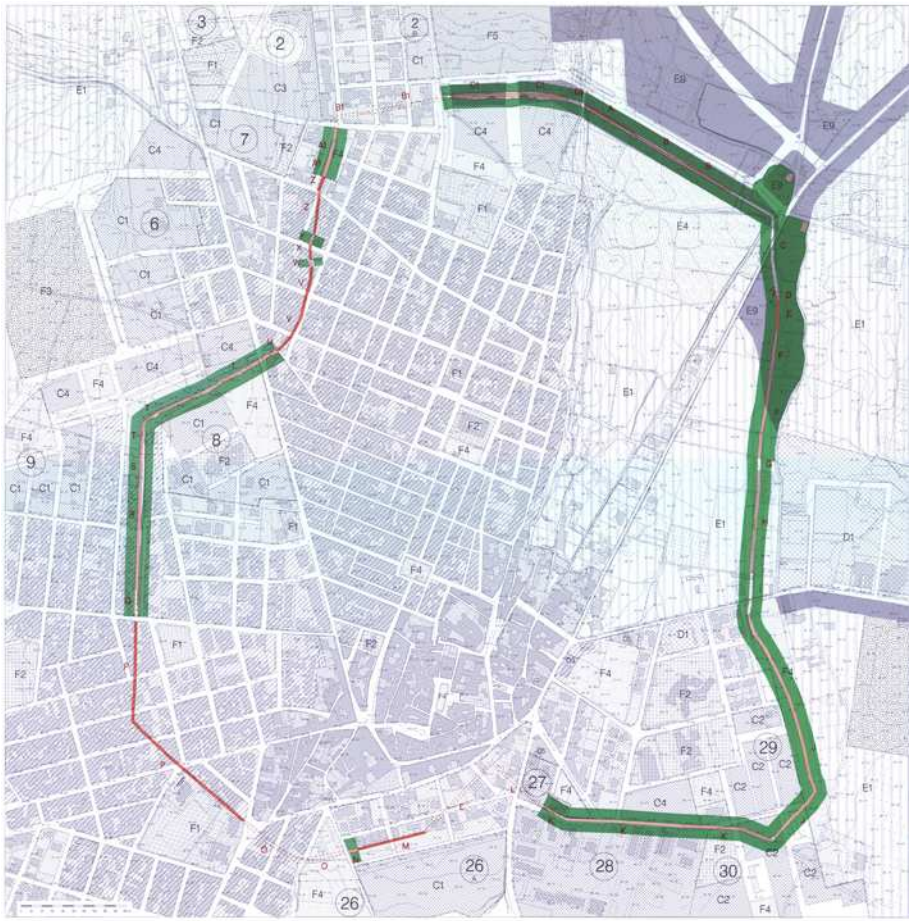

Fig. 9 – General Regulatory Plan of Ugento (modification of 2005): the areas in which is enabled a prohibition on construction, near the route of the preserved stretches of the Messapian city walls, are highlighted in green.

In the final analysis, the archaeological map also plays an important role regarding those areas of the ancient settlement that have not yet been affected by the urban expansion of the modern city. Indeed, starting from the knowledge base already acquired, it is possible to plan new research in these areas in order to resolve specific historical issues concerning the structure, organisation and transformation of the ancient settlement. Finally, the archaeological map also represents a tool for the conservation and enjoyment by the public of the archaeological heritage of Ugento. The data it contains have been extensively used in planning both the city's new archaeological museum and the itineraries for visitors to the ancient remains that are still visible (stretches of the city walls, necropolises, crypts, etc.), with a view to including these in a new archaeological park. (L. C.)

Archaeological map of Ugento: aerophotogrammetry for archaeological research

For a few decades now, archaeological research into ancient settlements, both characterised by continuity of occupation and abandoned, has benefited from the consolidated use in many research centres of maps drawn using aerophotogrammetric restitution by specialist archaeologists or cartographers supported by archaeologists (PICCARRETA and CERAUDO 2000; PICCARRETA 2003). The maps have proven to be a fundamental tool for supplying missing information and remedying the inadequacies of the regular commercial cartography that is often used for topographical reference in archaeological research. Compared to specialist archaeological photogrammetry, commercial cartography is often not up to date and is drawn on inadequate scales, which may not be large enough to enable precise positioning of the archaeological evidence. Another problem is the lack of accuracy in the representation of relief, fundamental to a correct reading and interpretation of the morphology of the terrain. In addition, with specialist archaeological photogrammetry it is possible to emphasise elements that may be more significant for the reading of the archaeological map in general or the positioning of individual finds during field work. An archaeologist who is also an expert photo-interpreter is able to enrich this type of cartography by adding traces and anomalies that correspond to ancient buried elements.

Fig. 10 – Detail of the existing cartography of Ugento, based on aerophotogrammetry from 1988 on a scale of 1:2,000. It was in raster format and was affected by deformations due to its age; it was not up to date and detailed in the representation of orography.

The specialist archaeological photogrammetry of Ugento was created in order to provide an adequate cartographic support on which to position the known archaeological elements within a context that is difficult to read due to the partial continuity of occupation of the ancient settlement. The existing cartography, based on aerophotogrammetry from 1988 on a scale of 1:2,000, was produced by Cemit company and subdivided into five sheets of which four (numbers 1–4) cover the ancient city, was not suitable for this purpose (Fig.

10). Although the scale was appropriate, it was not up to date and did not include a part of the modern town that was built over the ancient settlement. In addition, it was available only in raster format, based on a scan (unfortunately not conducted with state-of-the-art equipment) of a paper original affected by deformations due to its age. For these reasons and because of the intrinsic inadequacy of the commercial product with respect to the various purposes that the archaeological map was supposed to serve, this cartography was considered completely unsuitable for the correct positioning of the ancient evidence. Some of this is still visible on the surface or is perceptible only from the morphology of the terrain, such as certain stretches of the Messapian city walls. The latter constitute the most significant archaeological evidence currently available (SCARDOZZI 2007), in terms of both their length (about 4,900 m) and their size (they were between 6 and 8.5 m wide and in some points are still conserved to a height of 4.5–5 m). The walls are partly recognisable in the maps of 1988, as the cartographer included them more or less 'inadvertently', labelling them in general terms as dry stone walls, escarpments and field boundaries. However, this symbolic representation is fundamental to the reading of the map and the identification of ancient evidence that is still visible. Thus it should be represented in the most precise way possible.

Fig. 11 – Detail of the archaeological map of Ugento (1:2,000). Various kinds of ancient evidence are located and different colours and symbols distinguish the level of conservation of the Messapian city walls: stretches preserved and visible (in red); stretches preserved but buried (in pink); stretches not preserved but visible in the old aerial photos and georeferenced in the map (in orange); hypothetical stretches (in red and dashed).

It was therefore necessary to create specialist cartography so that the archaeological research could benefit from a valid tool for studying the development of the ancient city over the centuries and for protecting the evidence that is still conserved. The specialist photogrammetry was produced by the Laboratory of Ancient Topography and Photogrammetry (LabTAF) of the University of the Salento via the restitution on a scale of 1:2,000 of specially commissioned stereoscopic aerial photographs, taken by the Italiana Aero Servizi

(I.A.S.) company based in Perugia on October 27th 2002. The result obtained is a topographic vector map, updated to the year when the research began and on a scale that is adequate for the field work and for the precise positioning of the ancient evidence.

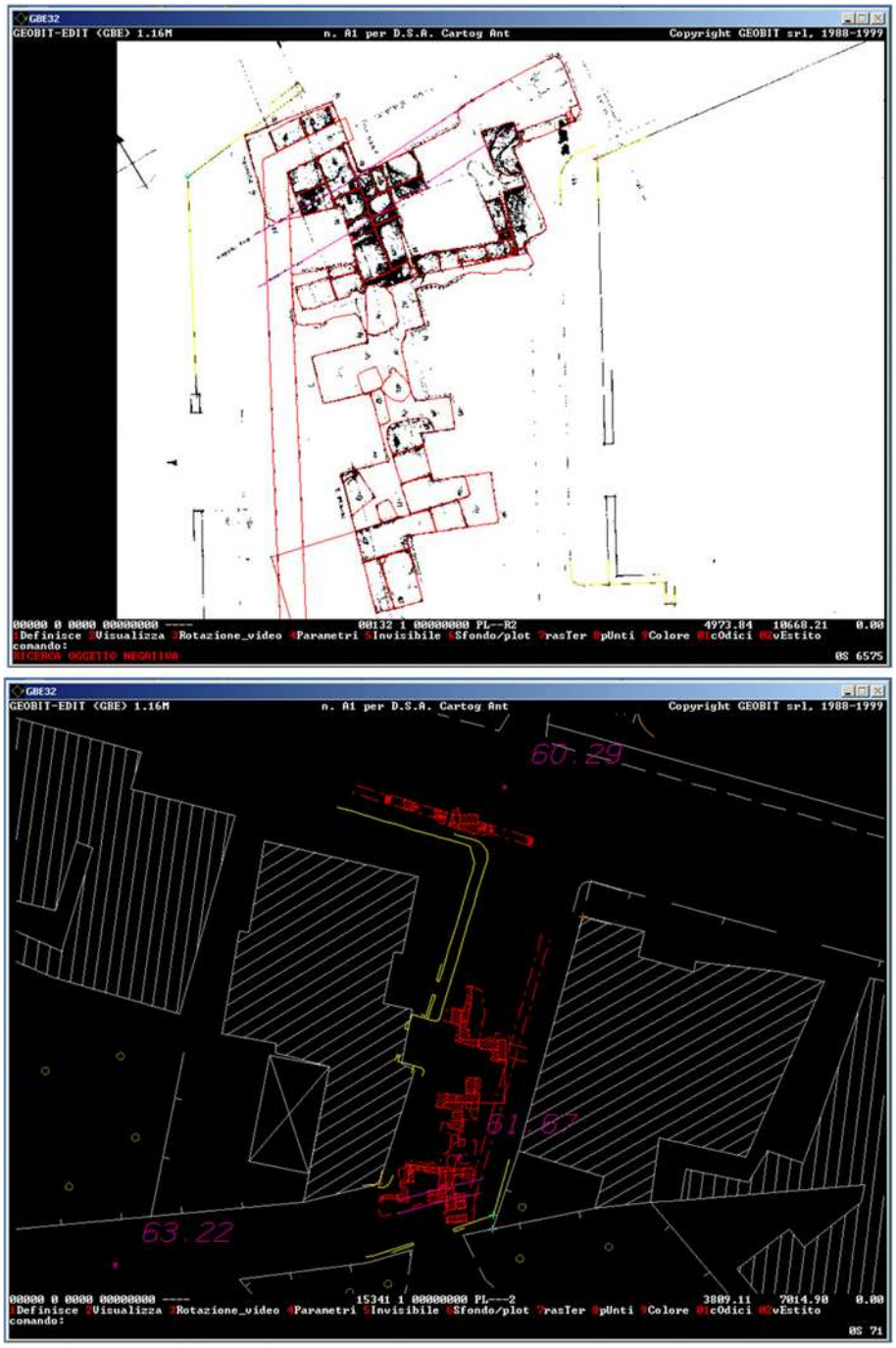

Fig. 12 – The plan of the gate of via Peri along the Messapian city walls during vectorization and georeferenced in the archaeological map.

Particular care was taken in the representation of the orography, with a 1-metre interval between contours (on the map of 1988 the height difference between the contours was 2 m). A more detailed representation of the micro-relief and the depressions was thus obtained, useful for the identification of traces and anomalies resulting from remains of buried walls or partially filled-in ditches. Compared to the pre-existing cartography,

numerous spot elevations were added, enabling easy reading of the morphology of the terrain, inside and outside the urban area. The new cartography covers a surface area of about 200 hectares, which does not include the whole of the modern town but only the part which overlays the ancient urban area (about 149 hectares) and its immediate outskirts. In terms of modern features (buildings and infrastructure), the new map used the same set of symbols as the commercial topographic maps and was thus similar to the aerophotogrammetry of 1988. It was more detailed however in terms of the areas not subject to urban expansion, where it is easier to recognise traces and evidence of ancient occupation on the ground. It shows field boundaries, and the trees are shown in their actual position and not merely symbolically, as are electricity pylons. All these features help archaeologists to orient themselves on the terrain while conducting research on the surface and to position correctly the archaeological remains identified during field work. Unlike the previous map, in black and white, the new cartography is in colour, with greater legibility of the features represented: all the features are colour-coded (grey for buildings, roads, property boundaries and all the modern topography; green for woody vegetation and field boundaries; ochre for the contours; blue for drains and water channels) and held in a database at the LabTAF where they are identified with a specific descriptive code (PICCARRETA and CERAUDO 2000). The new map was drawn by a cartographer who is also an archaeologist and is thus able to read the information in the aerial photographs with a trained and critical eye. It therefore includes traces of buried archaeological elements (in pink), all of which were verified on the ground during the reconnaissance, and the ancient structures still visible on the surface (in red), again identified by a specific descriptive code in the database.
On the basis of this new cartography, a knowledge tool characterised by a high level of precision, heterogeneous archaeological data were then converted into vector format (Fig. 11), where possible corresponding to the actual size of the ancient evidence (SCARDOZZI 2007, 2010, and in press). These data included items identified during the systematic reconnaissance of the territory (intact stretches of the city walls, other walled structures, tombs, stretches of road, areas with dispersion of ceramic fragments); the plans of old excavations and discoveries that are no longer visible today (Fig. 12); archaeological traces and remains (including long stretches of the city walls that were destroyed during the urban expansion of the second half of the 20th century but are visible in the numerous aerial photographs taken between 1947 and 1988 and in the topographic maps of the 19th century). All these items have been georeferenced in the new cartography and the archaeological data have been codified in the associated database and labelled in accordance with the type of ancient evidence (wall, road, tomb, etc.), the way in which the evidence was acquired (from direct reconnaissance, interpretation of aerial photographs or historic maps) and the precision of its positioning (i.e. whether real or symbolic and whether it is the result of a report that can no longer be verified. (I. D.)

Archaeological map of Taormina: a tool for the reconstruction of ancient topography and the protection of archaeological and monumental heritage

Taormina (from the Greek *Tauromenion*, Latin *Tauromenium*) was founded around the middle of the 4th century BC, occupying the natural terraces that lie, with various orientations, on the slopes of the hill known as Monte Tauro. The settlement was built around the two heights on which the Castle and the Theatre still

stand, at an altitude of between 180 and 220 m above sea level, close to the Ionian coast, about 35 km South-west of Messina (LENTINI 2005; CAMPAGNA 2009). The city was initially under the control of Syracuse, but in the last few decades of the 3rd century BC, it became part of the Province of Sicily as a *civitas foederata* of Rome. In the early Augustan age a colony of Roman citizens was founded there. Under the Byzantines it became an important strategic centre, as it was an obligatory staging post for communications between Messina and Catania along the coast.

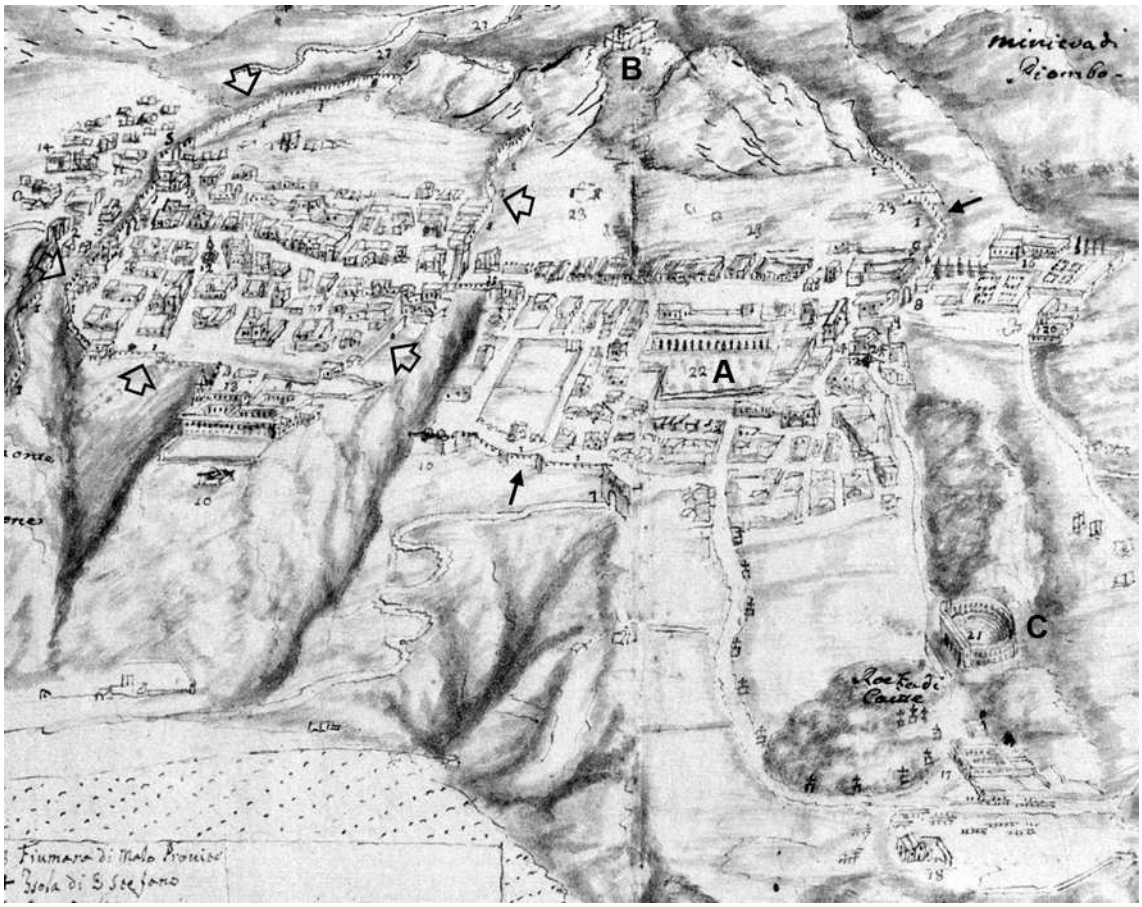

Fig. 13 – *Pianta e veduta della Notabile e Fedele Città di Tauormina* (beginning of the 18th century): big arrows show the Medieval city walls; small arrows indicate the new city walls; A, Naumachia and Giardinazzo; B, Castle; C, Theatre.

At the beginning of the 10th century AD, it was conquered by the Arabs, who destroyed it. It was then rebuilt on the terrace immediately below the Castle, where the oldest part of the modern city lies today (Fig. 13), at the extreme South-western end of the Hellenistic-Roman settlement, the ruins of which lay outside the new city walls (outside the gate known as Porta di Mezzo). Following the Norman conquest in 1079, in the 12th century the town expanded into the areas lying North-east of the early-medieval city, on the site of the Hellenistic-Roman settlement. In the following centuries, when Taormina became part of the Kingdom of the Two Sicilies, the area of the ancient *Tauromenion* was delimited by a circuit of walls and was progressively urbanised, as documented by historic cartography, although in the first half of the 20th century there were still numerous spaces that had not been built over. For this reason, interesting data on the ancient topography of the city can be obtained from the aerial photographs of the 1920s, 30s and 40s. These are photographs taken by the Regia Aeronautica, the Italian air force (oblique images of 28/8/1927 and 28/5/1930, obtained

from the Aerofototeca Nazionale, the national archive of aerial photographs, in Rome; vertical images of 24/5/1943 obtained from the archives of the IGM, the Italian Geographical Military Institute in Florence) and from the Royal Air Force (25/6/1943 and 5/7/1943, obtained from the Aerial Reconnaissance Archives of the Royal Commission of Ancient and Historical Monuments of Scotland), taken only four days before the heavy bombardment of Taormina and five days before the Allied landings in Sicily. These images show some areas still free of the construction that began in the 1950s and subsequently wiped out the last traces of the layout of the Hellenistic and Roman city and the organisation of the urban area and relative necropolises. Indeed, today the modern city completely covers the ancient settlement, including the sepulchres, which lay mainly on the North-east side of the castle and the Theatre and on the eastern side of the latter, towards the sea.
Taormina is characterised by a long tradition of studies, which have focused mainly on individual monumental complexes. Some of them have remained visible over the course of the centuries, such as the famous Hellenistic Theatre, rebuilt in the Roman epoch, the complex from the imperial epoch known as the Naumachia, and the Temple of Serapis, again from the Hellenistic age, incorporated in the 17th century into the Church of San Pancrazio. In contrast, others came to light in the course of archaeological excavations carried out as a result of building work, both at the end of the 19th century (such as the Odeon from the imperial epoch and the nearby Hellenistic temple incorporated into the 17th century Church of Santa Caterina) and in the 1960s and 70s, during the transformation of the city as a result of urban development. The latter discoveries include the Hellenistic building known as the *bouleuterion* and the baths of the imperial epoch in the area of the Zecca, the so-called Gymnasium (probably a private residence) on the South-western slopes of the hill of the Theatre, the large urban *domus* of Villa San Pancrazio on the slope facing Monte Tauro, and the structures brought to light below the Palace of Congresses, which was built over the medieval Church of Santa Maria in Valverde.
It is only in the last few years however that researchers have attempted to reconstruct the urban layout of the city in the Hellenistic epoch and assess the transformations it underwent in the Roman age. It soon became clear that there was a need to consider holistically what was then still a mass of extremely fragmentary data, whose interrelationships were effectively obscured by the urban fabric of the modern city. Hence the need for an archaeological map that could integrate, in an internally consistent manner, all the previously known archaeological data with the new data arising from the unplanned and small-scale excavations of the last few decades. The latter data had only been partially published, but the documentation was made available by the archaeological service of the *Soprintendenza* in Messina, a partner in the research project together with the Department of Ancient Sciences of the University of Messina and CNR-IBAM.
Although the research is start only in 2009 and not yet finished, we have already achieved some interesting results in the reconstruction of the ancient topography of the city and its necropolises. Among them concerning Taormina, the still in progress research is the first based on a large-scale digital archaeological map, in which all the known archaeological items are accurately positioned and their interrelationships made clear. It now seems certain that *Tauromenion* in the Hellenistic epoch already had a regular urban layout that was modelled on the configuration of Monte Tauro's natural terraces and was thus adapted to various orientations and gradients. There appear to have been two main roads, one corresponding to the route of the modern-day thoroughfare known as Corso Umberto I, along a South-west/North-east axis, and one corresponding to Via del Teatro Greco. At the intersection of the two roads, in the saddle between the hill of

the Theatre and that of the Castle, is Piazza Vittorio Emanuele II, on the site of which there is known to have been an open space in ancient times, identified as the *agorà* of the Greek city and then the forum of the Roman colony. A series of excavations have enabled us to identify the buildings and the structures that delimited the area on three of its sides, but what stood on the South-western side, in the direction of the Naumachia, is still completely unknown. The Naumachia is a monument of the imperial age, built to a rectangular plan and highly elongated; it lay along a South-east/North-west axis and had an imposing brick façade with large apses. Recent research has shown that it was the result of the transformation of a pre-existing monumental *stoà* from the Hellenistic age (CAMPAGNA and LA TORRE 2008). The building also functioned as a containing wall for the terrace above, about 5 m higher up, on which ran the ancient thoroughfare corresponding to the modern-day Corso Umberto I. The building, inside which was a large water tank, looked on to a piazza; this open space was conserved more or less intact until the 1920s, when it was occupied by a garden known locally as Giardinazzo. The presence of a broad, flat open space in front of the Naumachia is documented in the historic cartography from the 16th century (DUFOUR 1993: fig. 193).

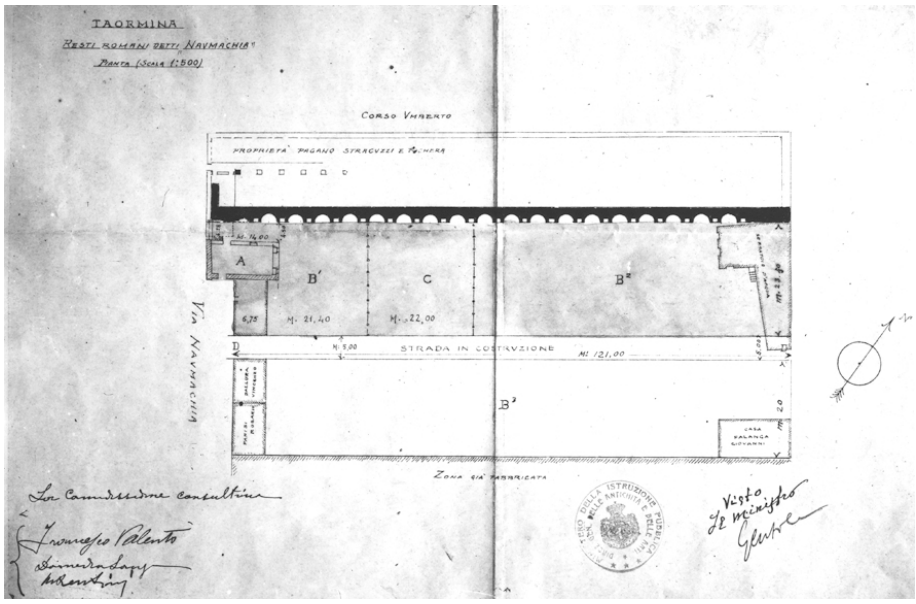

Fig. 14 – Taormina: the so called Naumachia in a map belonging to the office of the property register (1923–1924).

A map belonging to the office of the property register of 1923–1924, recently recovered from the Italian national photographic archive (*Fototeca Nazionale dell’Istituto Centrale del Catalogo e della Documentazione*), shows the area of Giardinazzo before it was completely built over (Fig. 13, A; Fig. 14). It can be seen that the Naumachia, today partially obscured by modern constructions, had a length of about 121 m and a width of 18 m (the original *stoà* may thus have measured 400 x 60 Attic feet, but to judge from some alignments visible in the old property register maps it may even have been more long in North-western direction). It can also be seen that the Giardinazzo had a width (along its North-west/South-east axis) of 48.5 m, as also attested by accounts of the 19th century. The aerial photos of 1927, 1930 and 1943 show the progressive urbanisation of the area, which in the period after the First World War was limited to the South-eastern half of the Giardinazzo; it would only be completed after the Second World War. It is thus highly probable that the Giardinazzo represented the survival in the modern urban fabric of a large piazza of the

ancient city, the North-eastern limit of which however is not known. The aerial photos of the years 1920 and 1930 and the map of the property register of the same period (Fig. 15) show the open space of Giardinazzo extended in this direction for a further 43 m, well beyond the façade of the Naumachia, almost as far as Piazza Vittorio Emanuele II, suggesting a possible direct link between the two piazzas (between which there was a difference in elevation of about 6 m), though they may have served different functions.

Fig. 15 – Taormina, map belonging to the office of the property register (1930s); the green line is the hypothetical perimeter of the Giardinazzo, while the red line highlight the front of the Naumachia and the extension of its alignment in North-western direction. The modern regular urban fabric of the area to the South-east of the Giardinazzo probably reflects the orthogonal layout of the Hellenistic-Roman city.

Furthermore, the vertical aerial photos of 1943, particularly those of the RAF on a medium-to-large scale, also clearly show the regular urban fabric of the area known as Piano Bagnoli (Figs. 15–16), to the South-east of the Naumachia, which probably reflects that of the Hellenistic-Roman city. The photographs, taken before the transformations of the second half of the 20th century and the insertion of new buildings that hamper the reading of the urban network, confirm the hypothesis that here the urban layout included a system of artificial terraces, which served to impose regularity on the two slopes that characterise the area (CAMPAGNA 2009): the first is the descent from Corso Umberto I in a South-easterly direction, on which the first terrace is occupied by the Naumachia and the piazza in front of it; the second, steeper slope descends from the North-east to the South-west, and corresponds to the southern slopes of the hill of the Theatre.

Fig. 16 – Taormina in aerial photographs from 1943 (RAF) and 1966 (IGM).

These are just some of the data that are emerging from the new research into the urban layout of *Tauromenion*, thanks to the correct cartographic positioning of all the known evidence. The archaeological map of Taormina has been inserted in a WebGIS with a specially structured descriptive record of the ancient evidence that can be implemented and consulted on-line by the project partners; it will be used for both scientific research and conservation. It is to be hoped that the archaeological map will be used by the municipal administration of Taormina as a tool for planning the development of the city that respects the ancient monuments and includes them in measures to ensure their conservation and open them up to the public. This is an important consideration given that the city has been a destination not only for mass tourism but also cultural tourism since the 17th century. (G. S.)

Archaeological map of Taormina: cartographic support and integration with archaeological data

The fundamental characteristics of any thematic map are its readability and reliability: indeed, even if the aim is to represent only a part of the data available for a given region, this type of cartography must be able to integrate heterogeneous information consistently, using a language that is easy to interpret. In the specific case of an archaeological map, the experience acquired over the years has led us to prefer, where possible, the use of specialist aerophotogrammetry (see above). However, it is often not possible or economically convenient to create specialist archaeological maps from the photorestitution of stereoscopic images. In these situations the choice of cartographic support for the implementation of archaeological data is fundamental. This is the case of the archaeological map of Taormina, where the area of the ancient *Tauromenion* is almost completely covered, and hence obscured, by the modern city (Fig. 17). A restitution designed for archaeological research would not have contributed meaningfully to the work in the field or to the management of the data.

In fact, up-to-date digital cartography on an adequate scale already exists for the site: the Technical Map ("Carta Tecnica") of the Sicilian Regional administration, created from photographs taken between August 2004 and June 2005. This digital cartography, on a scale of 1:2,000, was developed especially for urban areas in Sicily. Included in the Technical Map of the Region on a scale of 1:10,000, the more detailed map is also based on the Gauss projection in the national geodetic system (Hayford ellipsoid oriented to Monte Mario in Rome). The planimetric network is made up of all the vertices of the geodetic network of the IGM (Italian Military Geographic Institute) of the 1st, 2nd and 3rd orders, the IGM95 vertices and the vertices of the regional network and the property register network, with a planimetric error tolerance of 0.80 m. The interval between the height contours, linked to the national elevation network, is 2 m with a tolerance of 0.90 m. Considering these characteristics and this level of detail, the cartography is a particularly valid tool for the implementation of thematic data, although a small amount of editing is necessary to achieve optimal results. This involves gathering the data already present in the aerophotogrammetric restitution into new, homogeneous, logical layers that correspond more closely to the needs of the archaeological map.

As well as the preparation of the basic cartography, it was also necessary to organise and digitalise, using CAD software, the layouts of the various known monuments and the plans of the limited and unplanned excavations carried out in the last few decades, which were kept in the archive of the *Sovrintendenza per i*

Beni Culturali e Ambientali (archaeological authority) in Messina. For the former, the work was relatively simple, since it was possible to directly verify the quality of the planimetric drawings, adding information where necessary. For the excavation plans however, the work was more difficult, especially in cases where the ancient remains have been covered over again. To establish the location of these excavations with maximum precision, differential GPS was employed to measure the trilateration points used for drawing up the original plans or the external references (corners of buildings, obvious crossroads, etc.) reported in the surveys. The plans were then acquired with a flat scanner and imported in raster format to the CAD software. The surveys were linked to the real coordinates measured by GPS and subsequently digitalised using appropriate ortho-rectification plug-ins (Fig. 18).

Fig. 17 – Detail of the archaeological map of Taormina: the colours distinguish remains of different periods.

The GPS used for the acquisition of the coordinates of the points is a differential GNSS (*Global Navigation Satellite System*: Sokkia GSR 2700 ISX), composed of two antennae with 72 channels connected to each other via a VHF radio modem, each of which is capable of simultaneously receiving signals from satellites in the GPS and GLONASS constellations (Fig. 19). This system, as it was configured at the time of the survey, is able to acquire absolute coordinates with great precision, with a tolerance in urban areas of about 2 cm: in densely populated areas, the latency of the signal increases due to both the shadow generated by the buildings and the quantity of *electromagnetic* noise normally present in cities, which lowers the quality of the

reception of the radio signal transmitted by the positioning satellites. These problems were mitigated by the integrated use of a Total Station.

The differential GPS also proved to be very useful for verifying the quality of the base maps, which were analysed from both a formal point of view, checking against the modern topography, and from a metric point of view, via the systematic measurement, in a number of sessions, of baseline values and base points. This verification was necessary because of Taormina's distinctive orography, which, in both ancient and recent times, conditioned the city's urban fabric. Indeed, before the archaeological features could be inserted in the map it was important to ensure that the aerophotogrammetric restitution was sufficiently consistent with the reality on the ground.

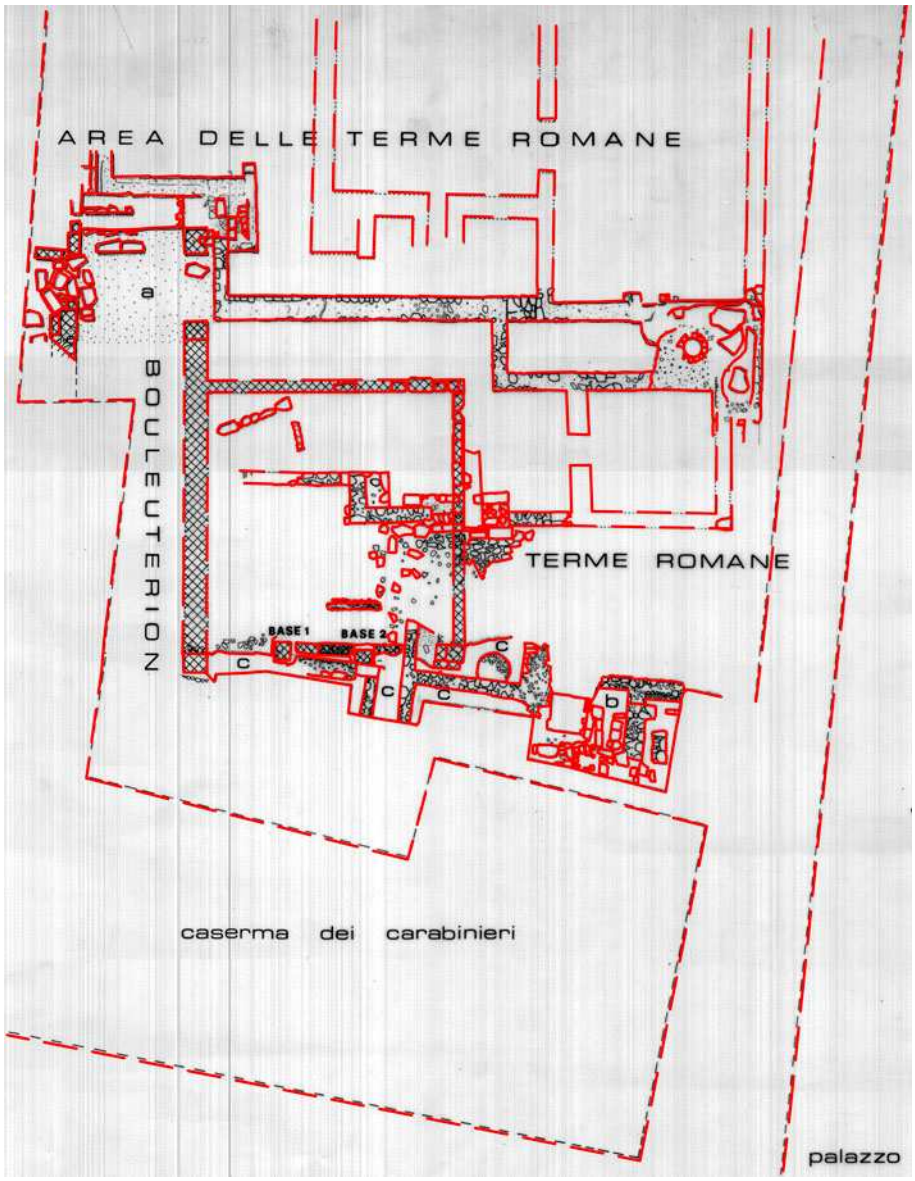

Fig. 18 – Taormina: plan of the Roman baths in the area of the Zecca during digitalizing.

After being converted to vector format, checked and validated, the digitalised surveys of the archaeological excavations and planimetric drawings of the monuments were inserted in specific layers of the 1:2,000

aerophotogrammetric map, manually performing slight corrections and editing in order to optimise the archaeological data and make it consistent with the cartography, without modifying the original plan other than adapting it to the scale of the map.
Finally, the spot elevations derived from the Regional Technical Map, together with the contours with height intervals of 2 m, were used to create a Digital Terrain Model, useful mainly for providing a better perception of the morphology of the terrain for those with no grounding in topography. This model will be used in the final presentation phase of the data acquired. Using the now widespread draping techniques, aerial photographs and satellite images can be linked to the DTM so as to obtain a measurable virtual model of the area of Taormina.

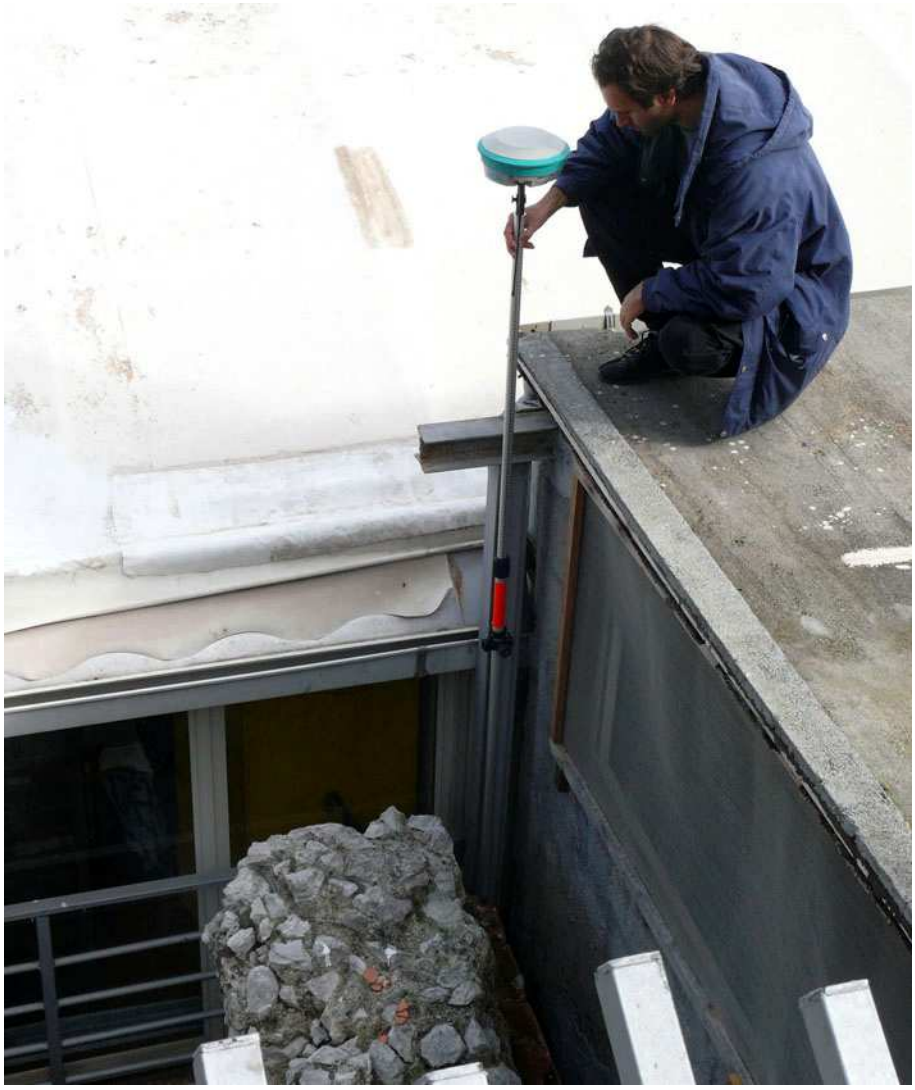

Fig. 19 – Taormina: location of the remains of a funerary monument using a differential GPS.

The creation of this archaeological map in digital format is the precondition for the subsequent implementation of a webGIS that will make it possible to link the individual archaeological finds to the relative descriptive records, which can be consulted by the project partners via an internet site dedicated to this research.

Fig. 20 – Taormina: remains of the Roman baths in the area of the Zecca.

At the end of this contribution, it is important to remember that one of the main objective of the work in Taormina is also the creation of a tool for planning the development of the city that respects the ancient monuments and includes them in measures to ensure their conservation and open them up to the public; in fact, today some archaeological remains and areas are in poor state of preservation (Fig. 20). (G. D. G.)

Acknowledgment

The archaeological map of Ugento was produced thanks the suggestions and cooperation of Drs. Giuseppe Andreassi and Assunta Cocchiaro (Archaeological Superintendence Board of the Puglia Region) and Dr. Massimo Lecci (Municipal Administration of Ugento). The base cartography for the archaeological map of Ugento was drawn by Dr. Veronica Ferrari under the supervision of Prof. Giuseppe Ceraudo, using an APC4-1 analytical stereoplotter installed in the LabTAF (Department of Cultural Heritage of the University of Salento), one of the main Italian research centres producing topographic maps for archaeological research, directed by Prof. Marcello Guaitoli. The plastic model of Ugento in the Archaic and Hellenistic periods was produced by Arch. Fabrizio Ghio.

The archaeological map of Taormina is cooperation project of the CNR-IBAM, the Department of Ancient Sciences of the University of Messina (Dr. Lorenzo Campagna and Prof. Gioacchino Francesco La Torre) and the Archaeological Superintendence Board of Messina (Drs. Maria Costanza Lentini, Gabriella Tigano and Mariagrazia Vanaria). The surveys in Taormina are also performed thanks the help and cooperation of Dr. Alessio Toscano Raffa (University of Messina).

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GIS Application in Archaeology – Advantages and Problems

Topography changes from the Middle Ages to the Present in the Area of the Palatium of Ingelheim

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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 place was carried out at the beginning of the 20th century. After that, archaeological research was resumed twice, in 1960 and 1993.
The presented study area includes, in addition to the Carolingian Palace, the expansion area from the Staufen-period with the surrounding remains of the fortification.
The Geographic Information System and its application in archaeology play a crucial role in this paper. This paper focuses on the georeference and interpolation process, as well as on the use of map algebra. Each of these processes will be discussed with the use of case studies and various sources. As an example of the first process, georeference of old cadastral map and modern topographical map will be provided. These sources were applied to reconstruction of some of archaeological objects, i.e. the first moat on this area, and to generate a Digital Elevation Model. The DEM was also adopted for further analyses. Subsequently, the interpolation of the historical Digital Elevation Model will be discussed. In this example elevation points from different excavations in the city of Ingelheim were used as data sources. In this context map algebra and its application in the calculation of terrain changes will be presented. Each process was carried out with the use of the ArcGIS 9.2 program.
The results of the project will be discussed through the advantages and problems of GIS applying. This paper intends to demonstrate how the results depend on the analyses when different methods and various sources are used.

Keywords: GIS, Georeference, Interpolation, DEM, Map Algebra.

Introduction and Case Study

The topography of the Palatium in Ingelheim has been mainly formed by human impact. There were more intensive changes associated with an extension of the whole area of residence and a minor renovation inside single buildings. Also natural elements, such as a slope or an exposition are visible in the present terrain form as well as in its reconstructions for all historical periods. In this study, attempts were made to combine the two elements of the residence landscape, i.e. anthropogenic-sharp boundaries and the elevation of utility levels of the different buildings of the palace and the natural slope.
The Geographical Information System proved to be a great “tool” in visualising and carrying out an analysis of the topography changes of the palace in Ingelheim. This system was applied at almost every stage of the

research; starting with collecting data in a database, through selecting the test methods, conducting them and with the final presentation of the results.

Goals

The main aim of this paper is to restore the historical topography of the Palatium in Ingelheim – understood as a historical utility level – using tools available in ArcGIS. In addition to the historical digital terrain models (DTM), representation of the contemporary surface of the research area was generated.
A further goal of this paper was presentation and comparative analysis of the terrain changes of the territory of the Palatium for the period of time between the 8th and the 21th century.
Subsequently, the method of reconstruction of the terrain and analysis of its changes was developed.
The application of Geographical Information System played a crucial role in this study. With the presented case study the advantages and problems of the GIS application in archaeology will be discussed. A critical approach is an important element at each stage of the research, either in the data collection, interpretation or executed analysis.

Study Area and Research History

The city of Ingelheim is located in the south-western part of Germany, in the state of Lower Rhineland-Palatinate, in the district of Mainz-Bingen (Fig. 1).

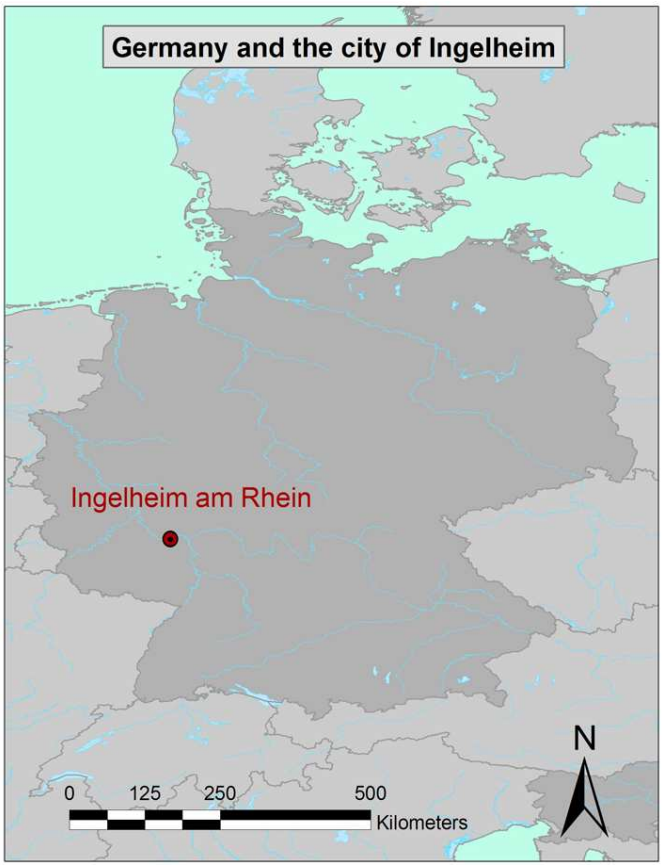

Fig. 1 – Map of Germany and location of the city of Ingelheim (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

The study area covers the territory of the 'Kaiserpfalz'-Palatium in Ingelheim, which is located in the eastern part of the current municipal area of the city in Saal. The study area of this project includes, in addition to the Carolingian palace, the expantion area from the Staufen-period with the surrounding fortification (Fig. 2). It covers the territory of the so-called *Saalgebiet* (area of the Saal) in the city district – Lower-Ingelheim [in German: *Nieder-Ingelheim*].

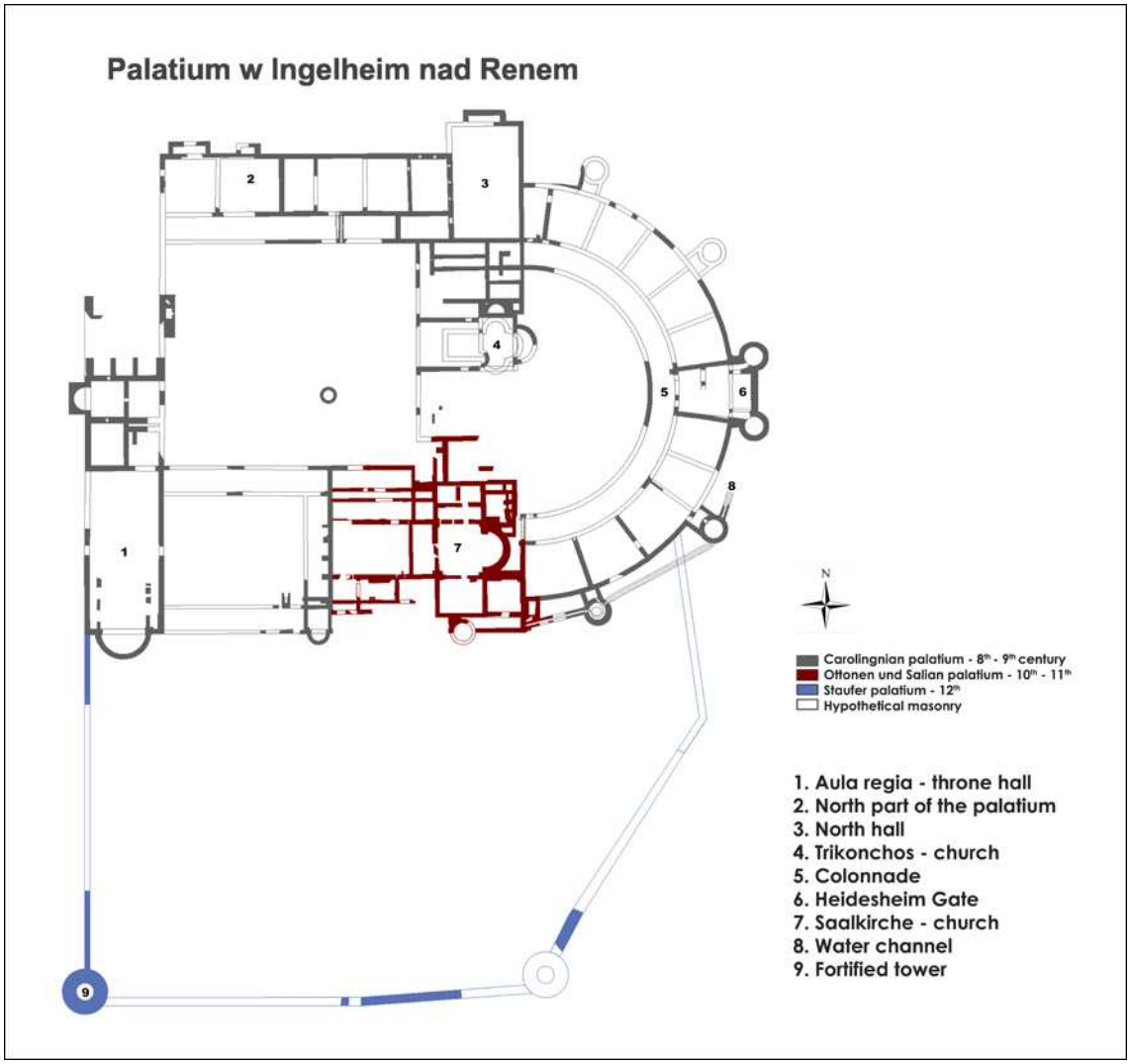

Fig. 2 – The Palatium in Ingelheim, the building phases and main constructions (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

The first archaeological excavation in this place was carried out at the beginning of the 20th century. These were conducted by the art historian Christian Rauch from 1909 to 1914 (GREWE 1998, 2001; JACOBI et al. 1976). Exploring the palace at that time was limited only to the Carolingian area. After that, the archaeological investigations were resumed twice, in 1960 and 1993 (SAGE 1968, 1976/1977; WENGEROTH-WEIMANN 1973). For almost the last twenty years research has primarily focused on the area of the residence. The archaeological investigations were undertaken every year since 1993. The area of the excavation is about 1,785 m^2, divided into about 50 single trenches (Fig. 3).

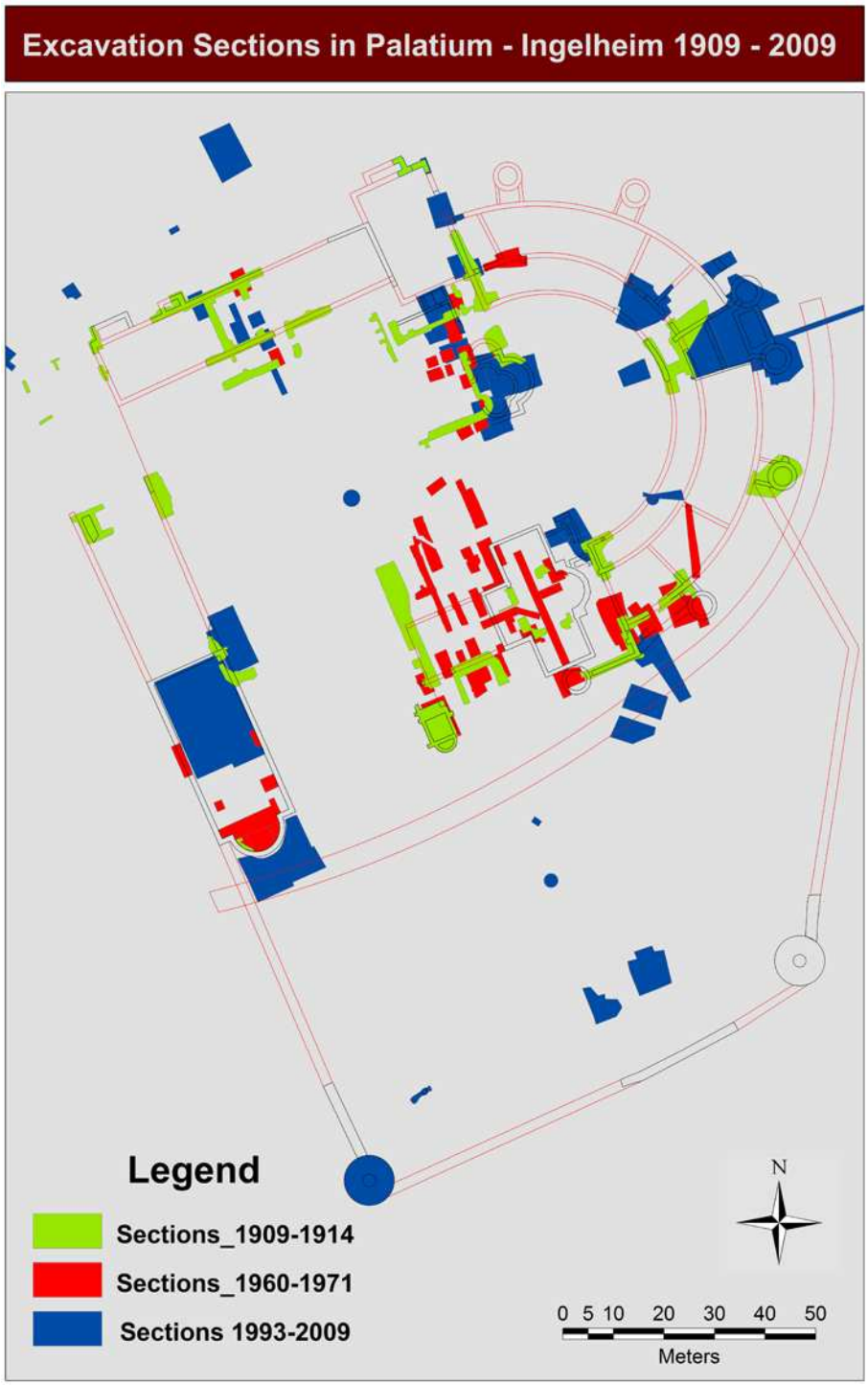

Fig. 3 – Location of the archaeological trenches in the Palatium in Ingelheim between 1909 and 2009 (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

Data Sources

A basis data sources for the presented research constitute archaeological documentation, cadastral maps and field measurements. They were divided into spatial data, among other plans, maps and non spatial data, e.g. reports, descriptions of archaeological features (Fig. 4).

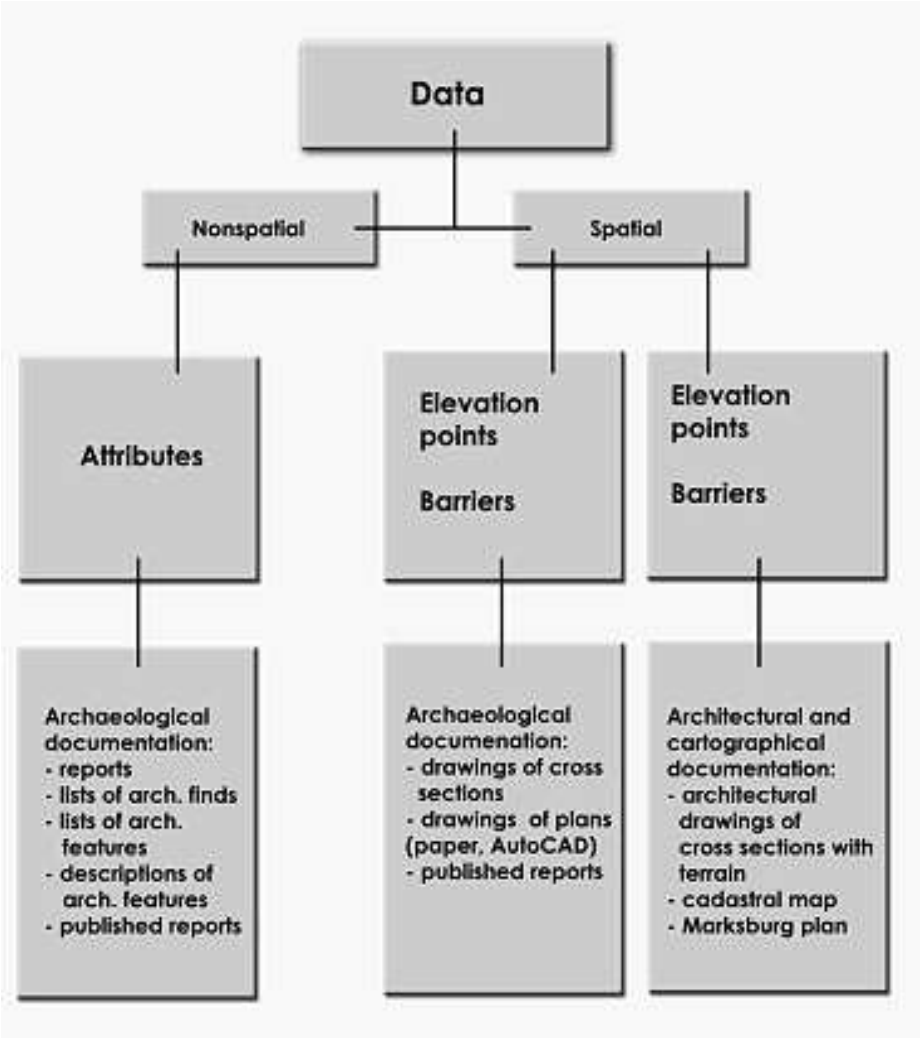

Fig. 4 – Sources and data (elevation points and barriers) used to generate of the DTM (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

The height values were collected from the field drawings and analysed. They were obtained from the documentation of all excavation between 1909 and 2009. Subsequently, the entire study area was measured to create current digital terrain model (DTM).

The outlines of buildings, places or other anthropological structures were used to define the limits (barriers) of different areas. Some of the barriers were extracted from historical map from 17th century-Marksburg plan (FLATH 2005) (Fig. 5). The data were supplemented with other cartographical sources: cadastral map (dxf file) (Office of Measurement and Cadastre in Bad Kreuznach [in German: Vermessungs- und Katasteramt in Bad Kreuznach] and topographical map in the scale 1: 5000 as an appendix to this project to show the influence of the source on the results.

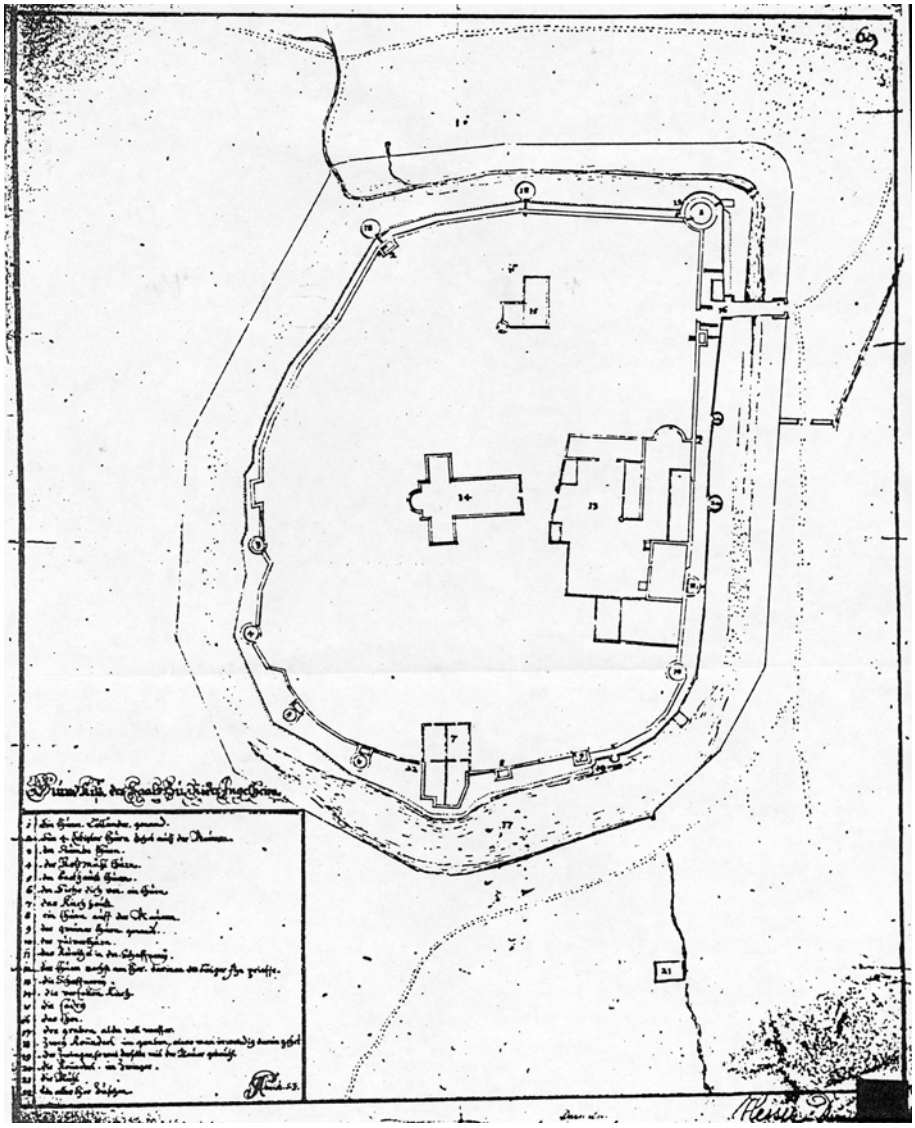

Fig. 5 – Marksburg plan for the city of Ingelheim from the 17th century (Copyright: Europäisches Burgeninstitut in Braubach)

Method

This project was conducted in several phases. Firstly, all of the data: the elevation values and the barriers were collected in a database. To get more information about fortification of the Palatium the historical map (Marksburg plan) was transformed and georeferenced. From the elevation points and the barriers the DTMs were interpolated.

The chronological range of the project includes the Middle Ages, and the moment of the foundation of the Palatium in Ingelheim in the 8th century to the present. Five building phases of the residence area were distinguished for generation of the digital terrain models:

1. The moment of preparation of the terrain for the building of the Palatium – 8th century
2. Carolingian phase – 8th/9th century
3. Ottonian and Salian phase – 10th and 11th century
4. Staufen phase – 12th century
5. Present – 21st century

Finally, the differences between each building phases were calculated and presented with the map algebra and the cross sections of the terrain.
Additionally, the topographical map was georeferenced and the same analyses were done for this source. The whole process was carried out by the use of ArcGIS 9.2. The preparatory work was done in AutoCAD 2008 because all of the excavation drawings have already been digitised in this software.

Input data and their verification

The database with two feature classes was created for the elevation data and the lines of discontinuity. The height points were collected from drawing, reports and publications of archaeological excavations between 1909 and 2009 (JACOBI et al. 1976, WENGEROTH-WEIMANN 1973). Additionally, the terrain of the residence was surveyed. The data have been linked over editing of the database to the specific building phase – 1st to 5th. Some of them were characteristic for many phases. The points, which do not correspond with the real utility level, had to be removed. The distribution of the high values was verified with a classification process and comparing of the neighbouring points. The total number of points used for all of the interpolations was 1649; some of them were used for more as one phase.
Some other points were digitized from the topographical map and added to the database as a separate *Feature Class*.
The discontinuity lines-barriers express changes in the terrain and its elevation. They are conditioned mainly by human activities. This includes boundaries of archaeological objects, such as the moat and stone buildings or defensive walls of the palace. The data which designate a significant part of the borders of the objects derived from both the excavation and from the historical cartographical sources. Some of them have been completed on the basis of the reconstruction of specific parts of the residence.
The discontinuity lines were obtained from dxf-file, which was imported to ArcGIS. The barriers were generalized. Most of the buildings have been treated schematically without dividing their interiors into smaller spaces. There were no elevation points in some of the areas. The barriers had to be removed to make the surface continuous. Also the attributes were added during this process. Each barrier got a number of the building phase of the residence.
The data used to the generation of the historical digital terrain models have been subjected to double verification. It was carried out separately for the elevation data in each location, and the lines of discontinuity (barriers). In the first verification the numerous group of the points were classified and significantly different values were reduced. Also other neighbouring values were compared and the error points were removed from the analysis. The second verification of the elevation data were performed using the barriers.

Georeferencing

The Marksburg plan was scanned, transformed and georeferenced with the spline method with 18 control points from the whole area. They are mainly characteristic points – spots, for example: corners of the buildings (Fig. 6): The location of these points was identified from modern cadastral map, remains of the historical buildings and from the archaeological documentation. The values of the coordinates of the control points correspond to the local map projection Gauss-Krueger Coordinate system DHDN Zone 3 (FLACKE 2007).

The quality of this source was controlled with a distortion grid and by comparing the distribution of the buildings and archaeological features (NIEŚCIORUK 2006, 2007; FORSTNER et al. 1998) (Fig. 7).
For the georeferencing process of the topographical map the polynomial method was used. In contrast to the Marksburg plan this source had to be only rotate and received the spatial position. Some of the elevation points for the comparative digital terrain model of the modern surface were obtained from this source. Finally contour lines were digitized as the points and the elevation values were added as attributes (Fig. 8).

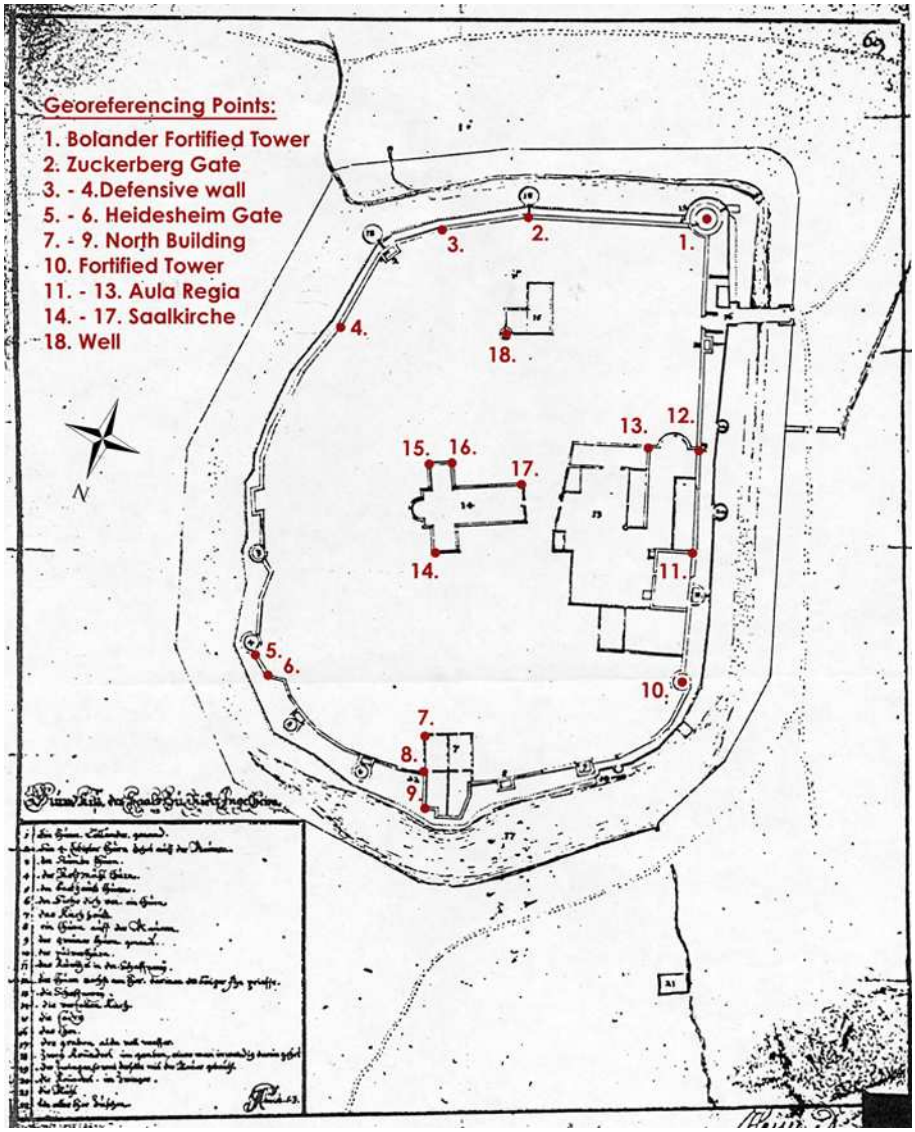

Fig. 6 – Marksburg plan including the control points (Copyright: Forschungsstelle Kaiserpfalz Ingelheim, Copyright: Europäisches Burgeninstitut in Braubach).

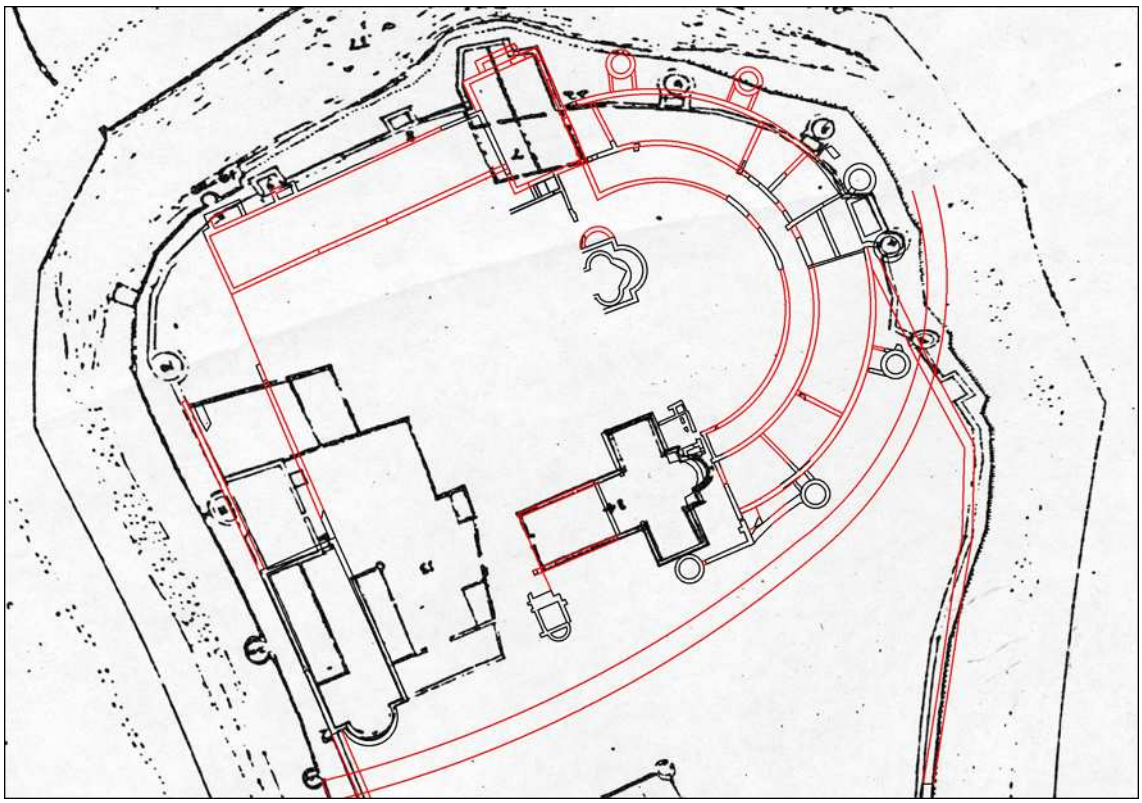

Fig. 7 – Excerpt of the Marksburg plan, georeferenced with the spline method with the reconstruction of the Palatium (Copyright: Forschungsstelle Kaiserpfalz Ingelheim, Copyright: Europäisches Burgeninstitut in Braubach).

Fig. 8 – Topographic map (TK5) with digitised elevation values (Copyright: Forschungsstelle Kaiserpfalz Ingelheim, Landesamt für Vermessung und Geobasisinformation Rheinland-Pfalz in Koblenz).

Interpolation

The next step in this project was an interpolation of the digital terrain models.

There are many interpolation methods that could be divided into two main groups. Some examples of the specific method are listed here:

- the stochastic interpolation methods: e.g. Kriging
- the deterministic interpolation methods: e.g. inverse distance weighting, spline (KAPPAS 2001, ArcGIS 2008).

The possibility of adding the barriers to the process of interpolation played a significant role. In ArcGIS 9.2 inclusion of these features is possible in two methods, namely: inverse distance weighting and spline.

In the first stage of the investigation for the generation of 2.5-dimensional terrain models different non-statistical interpolation techniques were used, among others inverse distance weighting (IDW) and spline (Fig. 9–11).

The results of the initial interpolation were evaluated via the visual-subjective-method. Both models performed for the first two building phases were visualised in ArcScene and checked for their correctness. After trial interpolation also some of the barriers were generalized and removed, mainly due to a lack of elevation data for individual areas (Fig. 12).

For the further interpolation only one of these methods was chosen. All of the models were interpolated with the spline method, which allows the use of the barriers and completely fills the surface of the raster.

The digital terrain models for five periods of time (building phases) were created. Sample DTMs for the second building phase of the Palatium are presented in the figures 13 and 14.

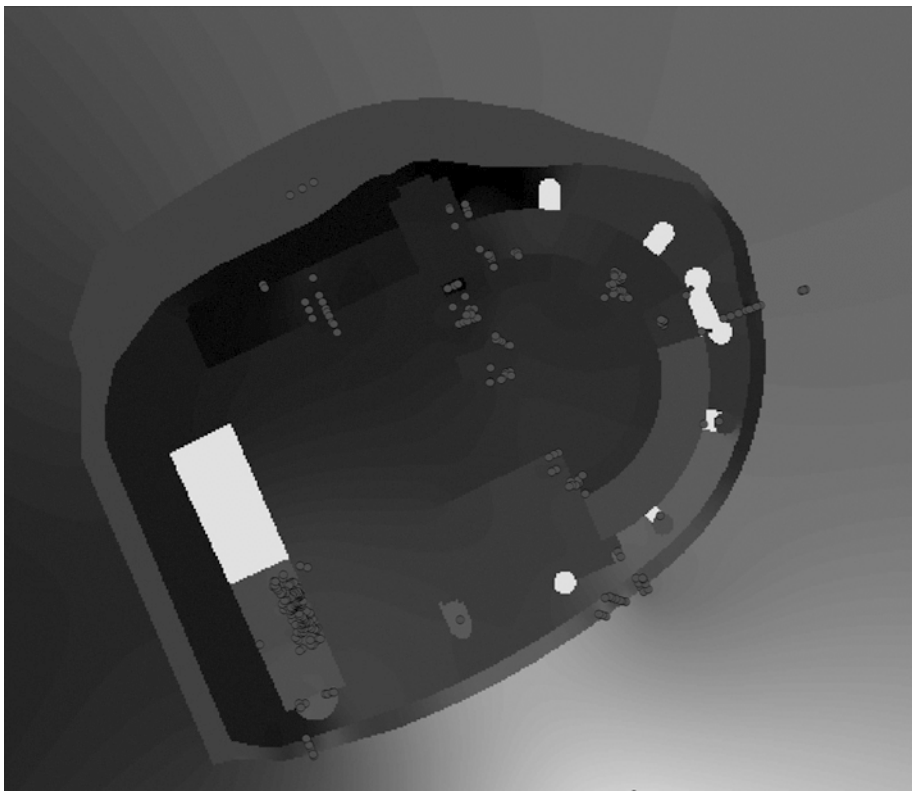

Fig. 9 – Results of the preliminary interpolation before generalisation of the barriers (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

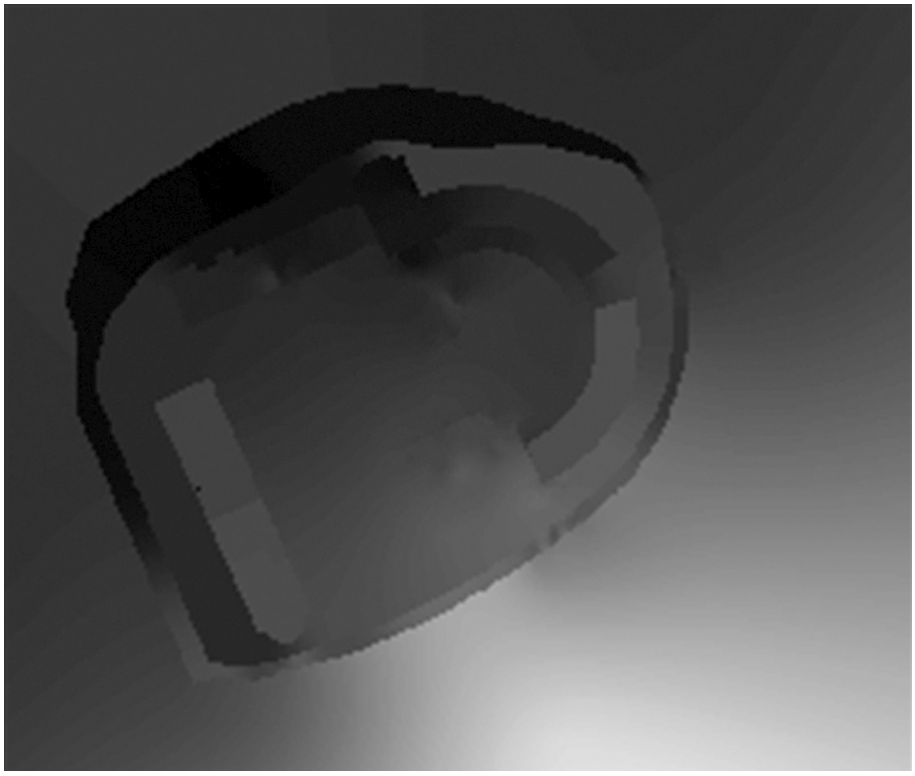

Fig. 10 – Second trial interpolation using the spline method (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

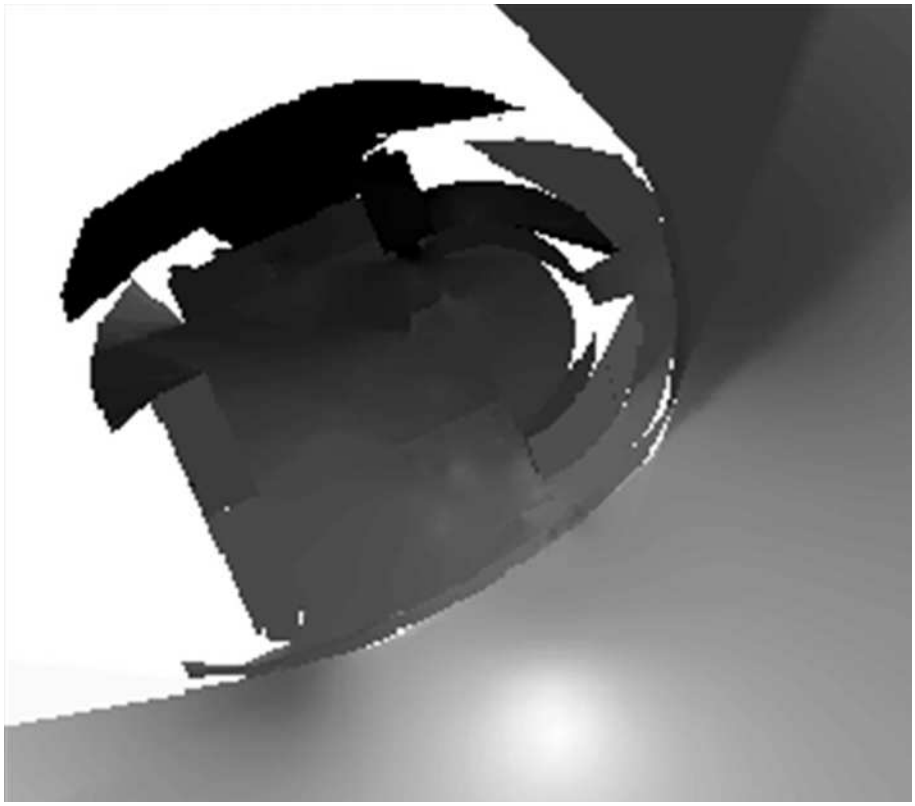

Fig. 11 – Second trial interpolation using the IDW method (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

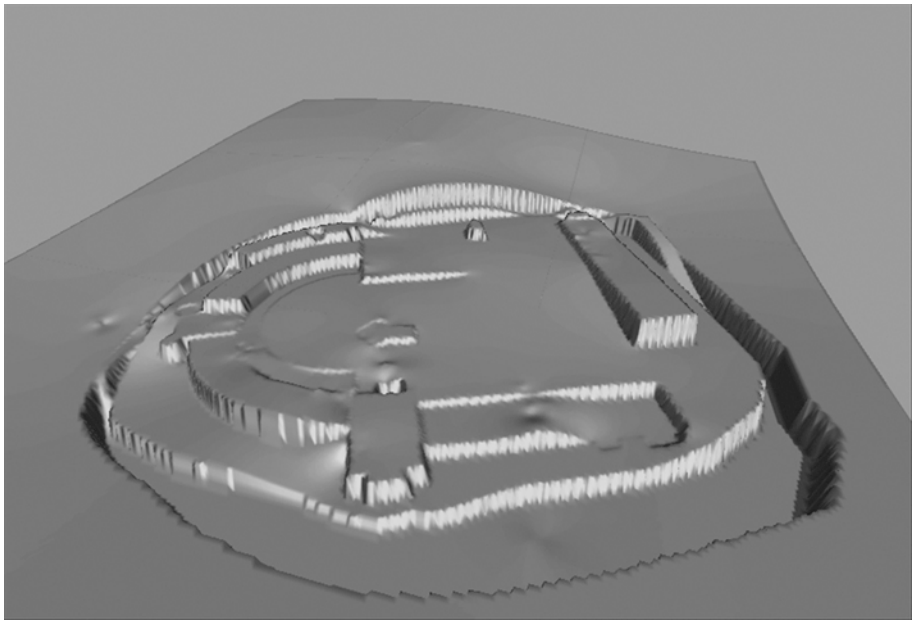

Fig. 12 – DTM of the Palatium (2nd phase) after preliminary evaluation (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

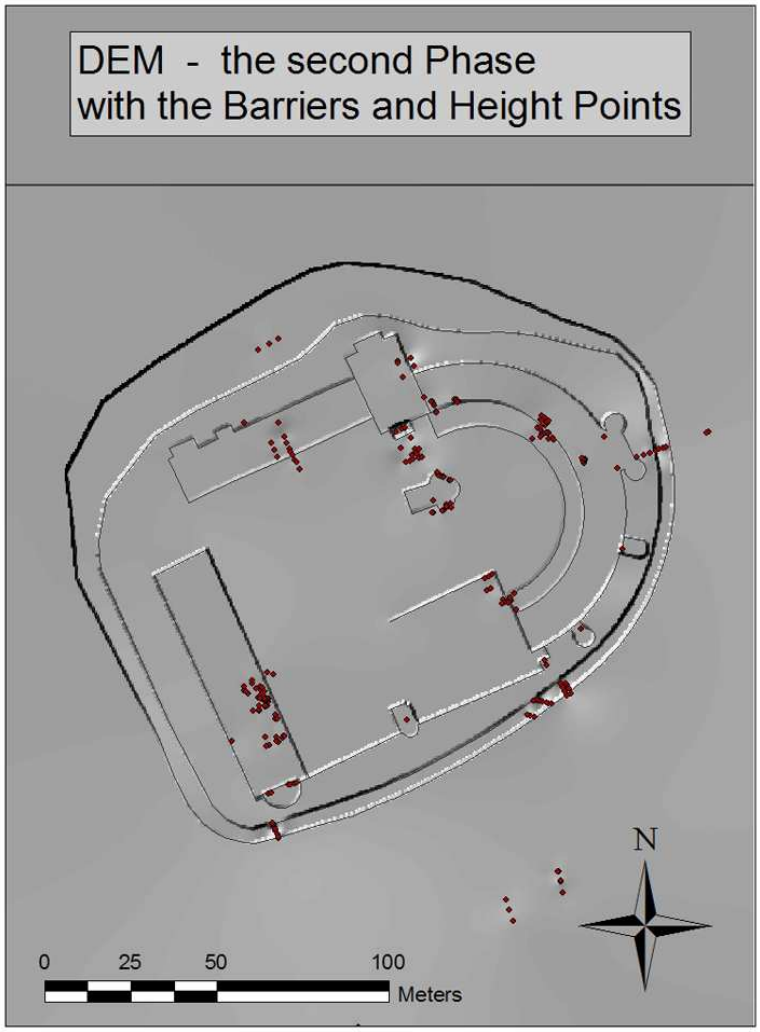

Fig. 13 – Digital terrain model with the elevation data and the barriers for the second building phase of the Palatium (206 elevation points) (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

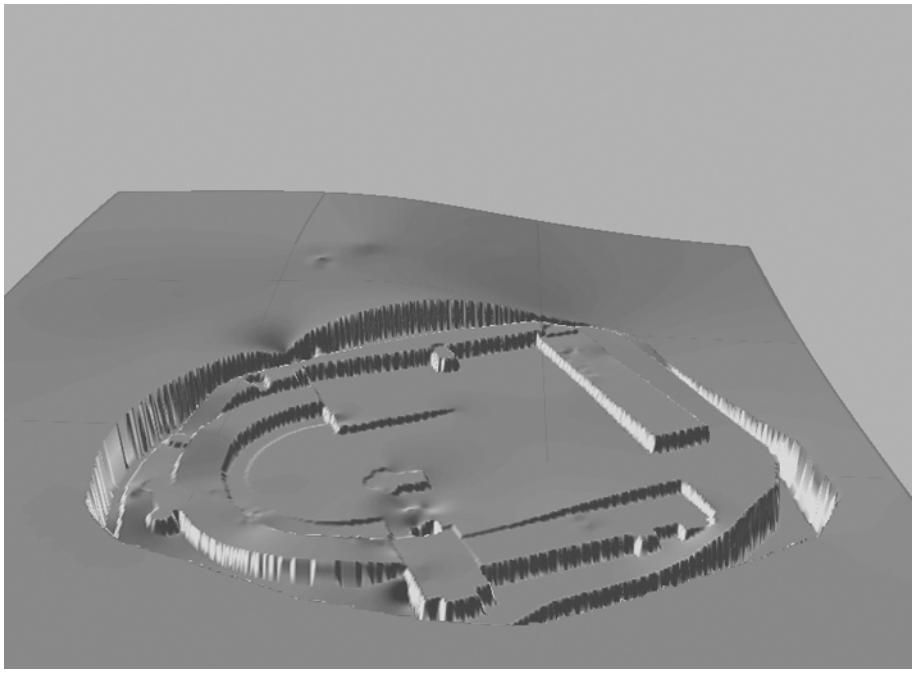

Fig. 14 – Digital terrain model of the Palatium (2nd phase) (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

Map algebra

Dimension of the changed area were calculated with map algebra and compared for the selected bulding phases of the residence (Fig. 15).

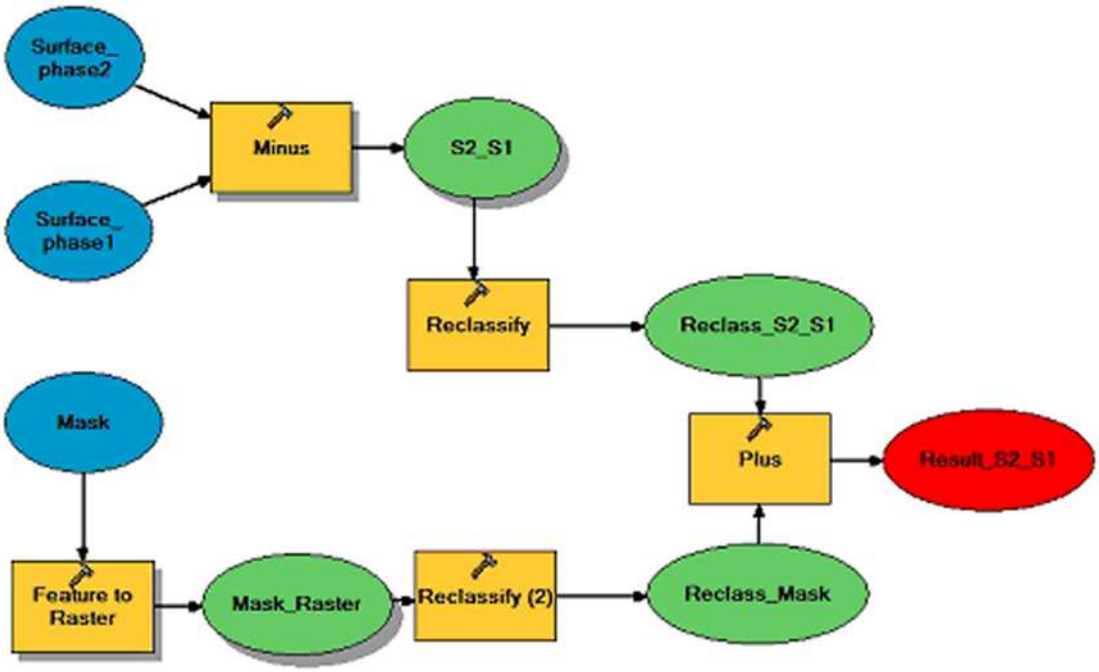

Fig. 15 – Diagram of the proceedings during the comparative analysis of the surface for various building phase of the Palatium, an example of 1st and 2nd phase (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

Cross sections

The crucial tool for comparison of the terrain from the different periods of time and verification of DTMs were the cross section analyses. After interpolation of DTMs the cross section were created with the 3D Analyst application of ArcGIS. Part of the cross sections was determined by cutting from the north to the south through the southern part of the moat, the central area of the residence, the northern building and the northern part of the moat. Other cross sections were marked from the eastern to western direction. A shape of the moat and the utility levels of the individual buildings are clearly visible in the images of the cross sections. The form of the surface inside the residence is characteristic; the profiles indicate a relatively large terrain decline, which was also confirmed by archaeological data.

Analysis

The analysis of the land formation and the height differences for the individual periods of the expansion of the Palatium were carried out using the map algebra and as a comparison of the cross sections of the terrain.

The first analysis shows that the differences were designated primarily for the buildings and the central part of the Palatium. The area of the moat and the internal part of the palace was almost unchanged. In the second analysis many fewer differences could be noted. An impact on this had the process of a minimal expansion of the palace, which took place between the 8th and 10th centuries. Differences between the next building phases are higher than those recorded for previous periods. This is correlated with the expansion of the residence, the digging of a new moat and the enlargement of the old one in some sections. In the time between the 4th and last building phases almost the entire area increased significantly. As one example the differences between the 1st and 2nd building phase of the Palatium were shown in the figure 16.

Significant differences are noticeable between the 1st and 2nd phase, which is related to the process of building of the Palatium. The first cross section is decline reflection (negative) of the surface, which was deepened for the foundations of the residence buildings, while the second one represents the first settlement level.

The first cross section shows the elevation and form of the terrain which was prepared to build the first palace at Ingelheim (Fig. 17). Some of the depressions are illustrated there, namely a foundation trench and a trench for the moat around the residence. The construction of the Palatium is handled as a unique building phase, although it is known that all the buildings could not occur simultaneously. The whole middle part of the profile illustrates the decline in the natural terrain with a small foundation trench for the church with three apses. In comparison with other major buildings, the foundations were slightly embedded in the substrate.

The cross section for the 2nd phase, which was generated from the DTM, shows the surface shaped almost completely by human activity (Fig. 18). Individual spaces were aligned and the changes of the terrain are in some places quite sharp and rapid. The flat surfaces illustrate the utility level inside the building, while the lower area illustrates a moat. In the central part of the palace building a kind of reservoir for water was built. The differences of the levels depend on the specific areas of the residence. In places with the foundation trenches this was about 3 m, while in the central part of the palace only small changes within a few

centimetres can be observed. Despite the modelled level of utility for the individual buildings a natural slope of the terrain is still visible in the northern direction.

Between the 2nd and 3rd phase only small changes of the terrain are noticeable. The church, the so-called Saalkirche is constructed in the southern part of the residence. The approximate height difference between the church and the surrounding area is about 1 m. This could be an error of the results, which was influenced by the lack of the data from this area, or by occured terrain differences and was mitigated by the ramp or stairs leading to the church. The next two analyses were made for the palace area, enlarged in the 12th century and the contemporary surface. The difference of settlement levels in this case is up to four metres, which seems to be rather too high a result. On the DTM of the contemporary surface the old moat is still visible.

Fig. 16 – Differences between the 1st and 2nd building phase of the Palatium (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

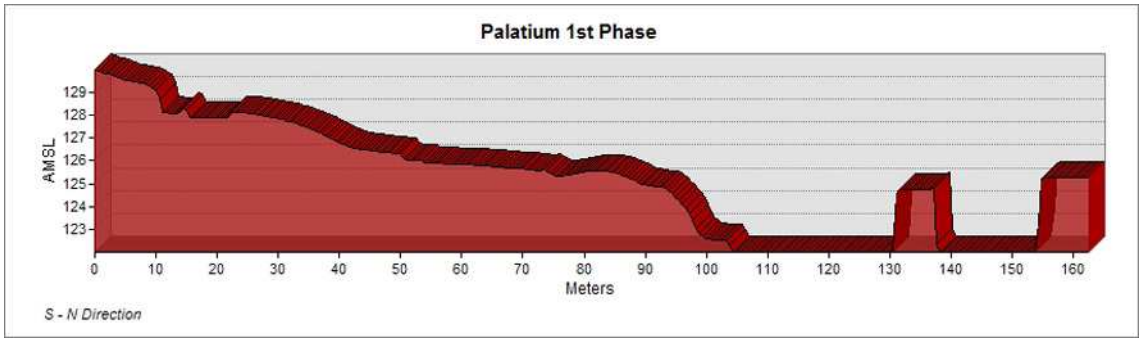

Fig. 17 – North – south – cross section – the 8th century (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

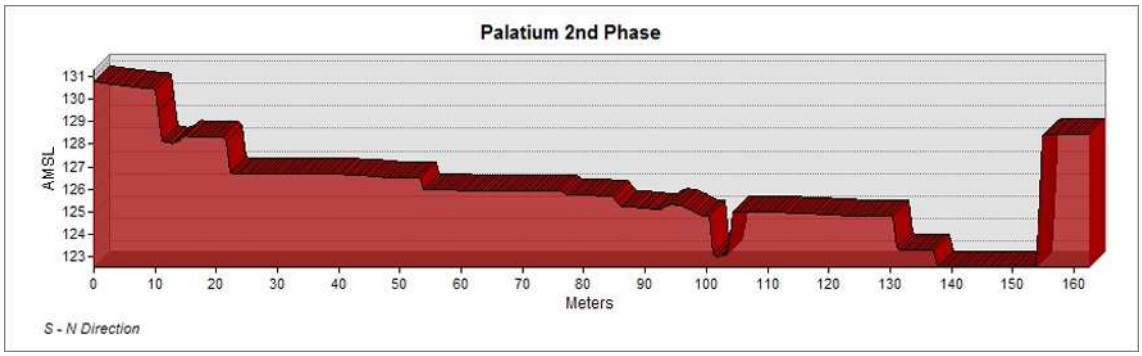

Fig. 18 – North – south – cross section – the 8th/9th century (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

Other analysis

The further analysis of the terrain changes were also done for a single elevation value of the unique area of the Palatium, as is shown in this figures 19 and the table 1. This allowed noting not only the dimension of the changes, but also some errors in the terrain model. For example, for so-called Saalkirche one of these values is incorrect.

AMSL for each phase	1st phase	2nd phase	3rd phase	4th phase	5th phase
1. Aula regia	126,60	127,50	127,50	127,51	129,78
2. North Part	123,24	124,97	124,97	124,97	125,78
3. North Building	122,01	124,88	124,88	124,86	125,44
4. Exedra – N	123,50	125,71	125,71	125,69	126,15
5. Exedra – S	126,55	127,23	127,24	127,18	129,11
6. Exedra – Middle	125,66	125,97	125,97	126,62	127,80
7. Colonnade	124,53	125,65	125,64	125,64	127,68
8. First Moat – N	122,01	122,01	122,01	122,01	123,31
9. First Moat – S	127,18	127,18	127,16	129,13	130,31
10. Second Moat	–	–	125,77	122,07	128,35
11. Centre of the residence	125,51	125,72	125,69	125,46	126,62
12. So-called Saalkirche	127,10	126,65	128,75	128,75	128,80
13. S-Part of the residence	–	–	–	128,93	131,65

Tab.1 – Differences of the elevation (AMSL) for each building phase of the Palatium.

To explain the influences of the interpolation results on the further analysis is the two DTMs of the contemporary surface with the elevation data from the topographical map and from the surveying were generated. The analyses of the topography changes were made with both of these surfaces. Results are

presented on the two maps (Fig. 20). The differences in the both pictures are visible. The Input data have an influence on the DTMs and on the results of the analyses.

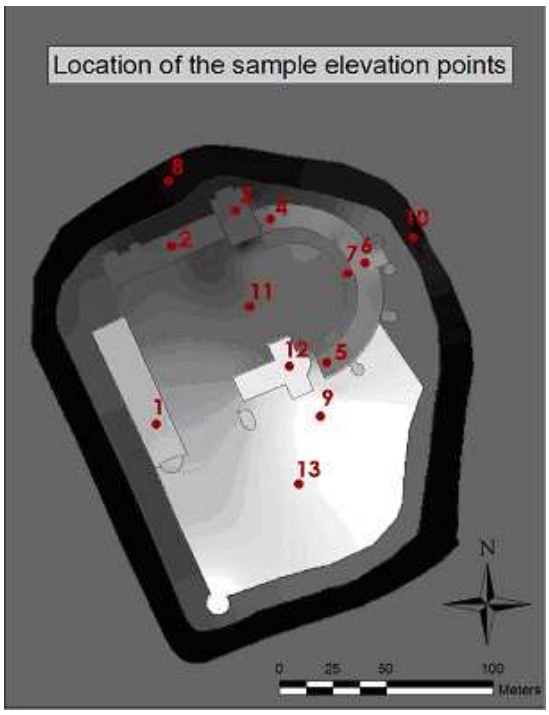

Fig. 19 – Location of sample elevation points (white to black – increase of the elevation) (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

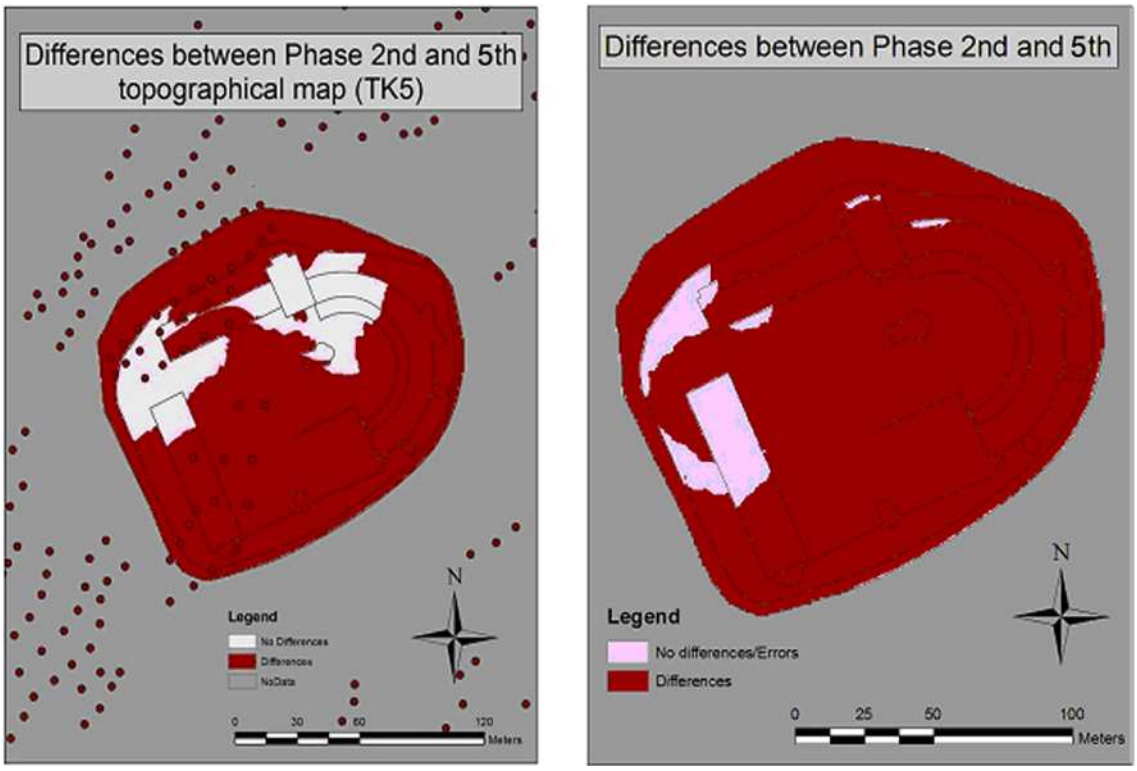

Fig. 20 – Differences between the 1st and 5th building phase of the Palatium (Copyright: Forschungsstelle Kaiserpfalz Ingelheim).

Conclusion: Problems and Advantages

The interpolation outcomes are highly affected by interpretation of the excavation results. The models are not exactly the historical surfaces, but an example of the approximate utility level. The distribution of the high values has a cluster character, what has a negative influence on the generating of the DTMs. It is also depend on the form and location of the barriers.

The selection of the representative set of the elevation points was a part of the research. The high quantity of the points in one area was reduced by classification and elimination from the preliminary set of the data. Also the incorrect values from the whole dataset were removed. This was very time-consuming but has an influence on the form of the models.

The spline method was chosen for the interpolation of the models because of the possibility of including the line of discontinuity and the form of the continuous surface (raster).

An important point of this study was the reconstruction of the historical surface that has been irrevocably destroyed. An exact determination of the error limits was not possible, not least because of the total change of this area. All DTMs were controled with subjective-visual method.

Both in the case of map algebra as well as in the cross sections of the terrain, besides some of the errors, a trend of development and changes in the research area was indicated. This process was automated and in a similar form used for all the models. This allowed very quick comparative analysis.

This work was an attempt to link the GIS and archaeological methods. This procedure could be used both for further research of the Palatium in Ingelheim as well as to research historical DTMs for other find spots.

It is very important to take into account the quality, quantity and spatial distribution of the data. Both the distribution and inaccurateness of the data have an influence of the results.

The choice of the georeferencing and interpolation method plays also a crucial role. The further analyses depend on these methods.

Some parts of this procedure were very time consuming, especially the data collection. This processing has also many advantages, e.g. it could be quickly repeated with various methods for different sets of the data. The farther information could be also added to the database and supplementary analysis could be done, what is an immense gain of the GIS application.

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The archaeological map on digital support. The cases of Trieste and Cividale del Friuli

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Abstract: Following the building restoration of “Cittavecchia” in Trieste through the project “Urban” started in the 90s, it was possible to follow several archaeological investigations on a very large area of ancient Tergeste. During the same period it has developed a series of topographical studies on the city of Cividale, the ancient Forum Iulii. Both sites were well covered by thesis and then doctoral dissertation and later professional studies.

By creating a topographic network to cover the entire area of the old town and through georeferencing of the main landmarks using GPS, were made several measurements which has been documented the urban development of ancient cities of Trieste and Cividale del Friuli (Friuli Venezia Giulia, Italy). In this way we created thematic maps on absolute coordinates within which were included extensive data archive of a different nature. It was created an archaeological cartography dedicated to the areas on which the city developed during the Roman period in general for the reconstruction of the ancient city.

The base map was used as database support for the creation of a GIS which includes the majority of archaeological and topographical data.

The GIS has been linked to a database containing all information relating to the data documented during archaeological excavations and obtained from archival data.

In this way, by the overlap of the current urban terrain and the archaeological data known and stored in archives, it was possible to create a series of thematic maps having as objective the identification of archaeological risk zone, thus providing a useful tool for design of new urban development.

Keywords: GIS, topographical relieves, archaeological risk map, Friuli Venezia Giulia, archaeology.

Introduction

This work is the result of two PhD in Geomatic and GIS done in the University of Trieste about the creation of an archaeological map of the ancient city of Trieste (*Tergeste)* and another of Cividale del Friuli (*Forum Iulii*) – Friuli Venezia Giulia – Italy and the making up of a GIS with its own database for the creation of the risk map. The two cities are completely different because of the different kind and the different amount of the documentation and the excavations done during the last two centuries.

This work is done in collaboration also with the MiBAC, Ministero per i Beni e le Attività Culturali, and the same methodology is followed for other important archaeological areas in the region, like Aquileia, Grado and Zuglio.

Brief studies of urban development of the two sites

Since the 90s, the Superintendence for Archaeological Heritage of Friuli Venezia Giulia[1] has promoted the creation of vector maps on CAD support for the registration and implementation of topographic data resulting from instrumental measurements, which then serve as supporting documentation created by operators working in the areas of stratigraphic excavations. Inside these maps are then merged archived data from previous documentation and bibliography; in this way, with the progress of studies and research, these maps have become one of the most comprehensive tools to archive and search available to the study on the development of the two cities considered here.

The first attempt to a general topographic reconstruction of the ancient *Tergeste* was made by the scholar Pietro Kandler in1856 (ZORZON 1989): this document proposes the extension of the roman city according to the data known at that time compared to the profiles of the city in the 19th; this method of representation will be particularly effective enough to be a guideline for further topographic studies. Others works that has to be remembered her are those of V. Scrinari in 1951 (SCRINARI 1951; SCRINARI, FURLAN and FAVETTA 1990), F. Maselli Scotti in 2001 (MASSELLI SCOTTI 2001), M. Verzar Bass in 1999 (VERZAR BASS 1999) and P. Ventura in 1996 (VENTURA 1996).

Fig. 1 – Pietro Kandler; 100 J. n. Chr. Die (Römishe) Colonie – ZORZON 1989.

[1] Ministry of Heritage and Culture (MiBAC).

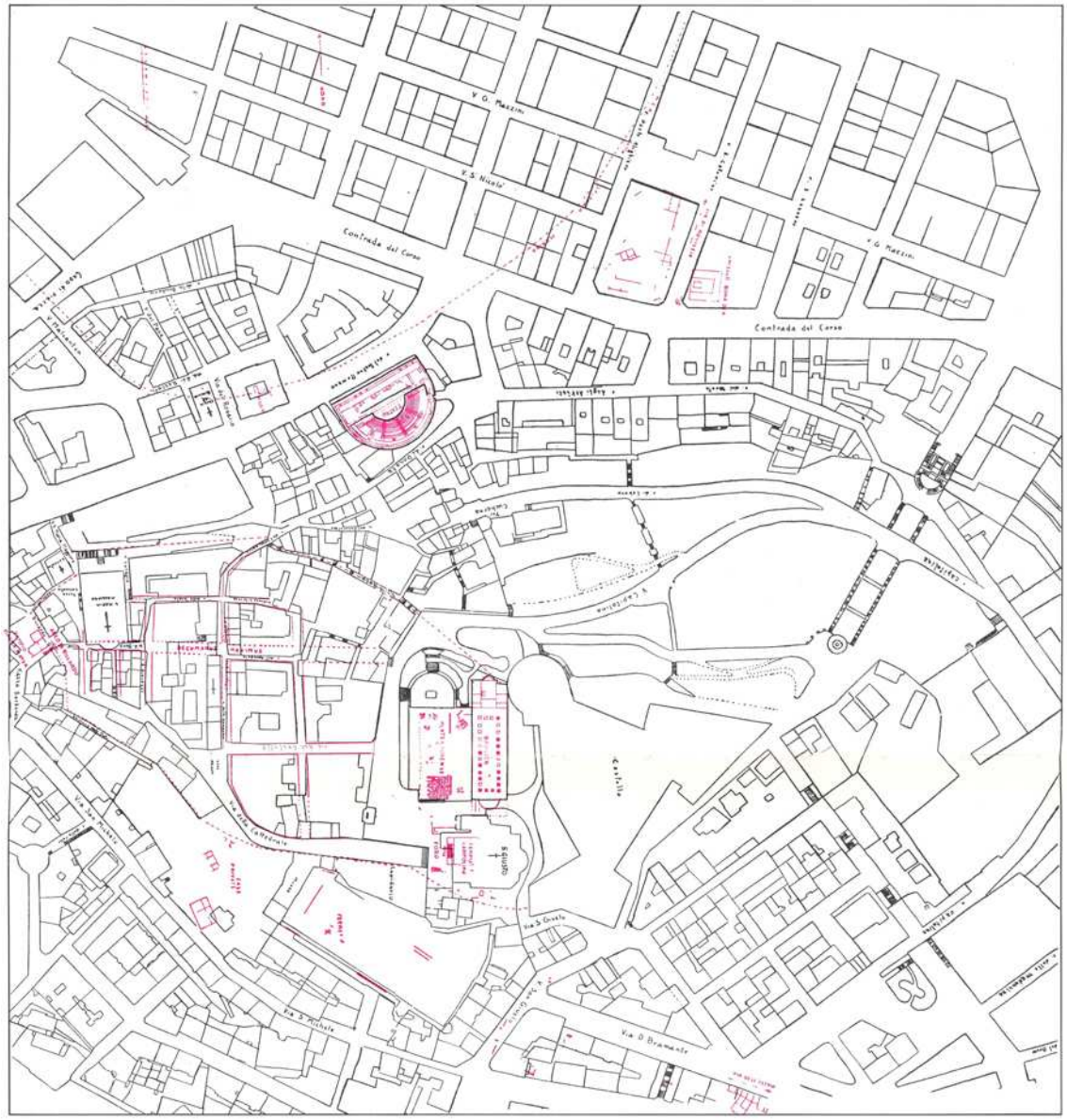


Fig. 2 – Valnea Scrinari; *Tergeste* – SCRINARI, FURLAN and FAVETTA 1990.

Each of these studies reported here has reported on the urban fabric of the modern city the updates of archaeological and topographic knowledge of the city in the roman period. It is from this moment that is systematized the used of the instrumental relief and that the archaeological map on digital support is implemented with a huge amount of data, set by geom. G. Meng (MENG 1999) especially on behalf of the Superintendence. Another area of depth investigation into the history of the development of the city was done by the University of Trieste that has conducted, from 2000 to 2002 an archaeological excavation in a very important sector of the urban fabric of “Cittavecchia”, reconstructing the entire sequence of the development of this sector from I B.C. until the 20th century (MORSELLI 2007). All the data list above were then merged into a graduation thesis and subsequently developed in a PhD, and are still subject of periodic updates (BRAINI 2003).

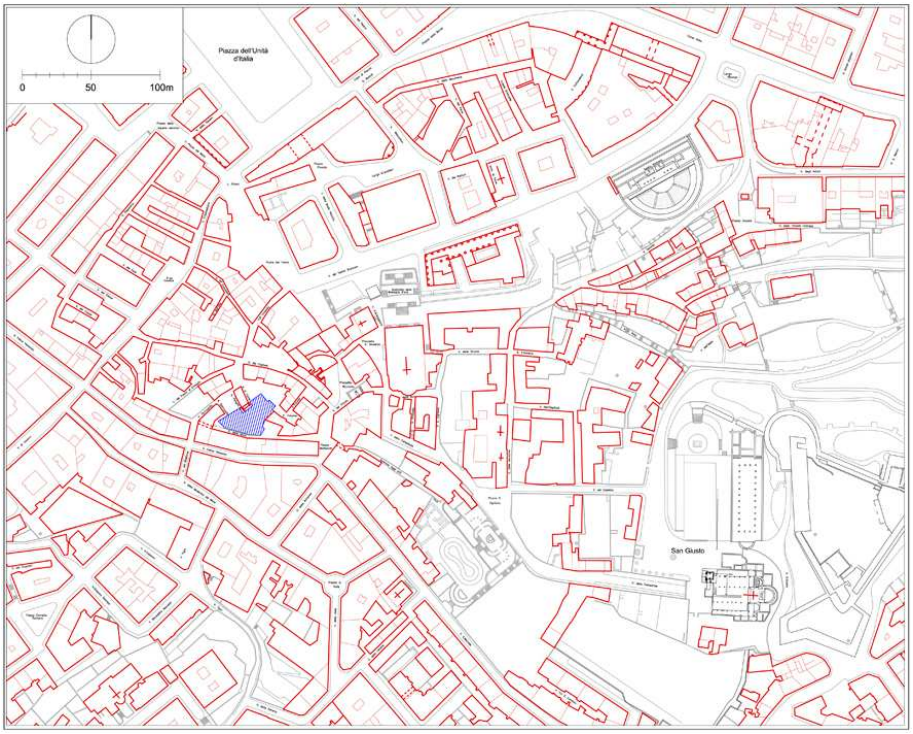


Fig. 3 – Archaeological excavation area in Cittavecchia conducted by the University of Trieste; base map "Piano Müller".

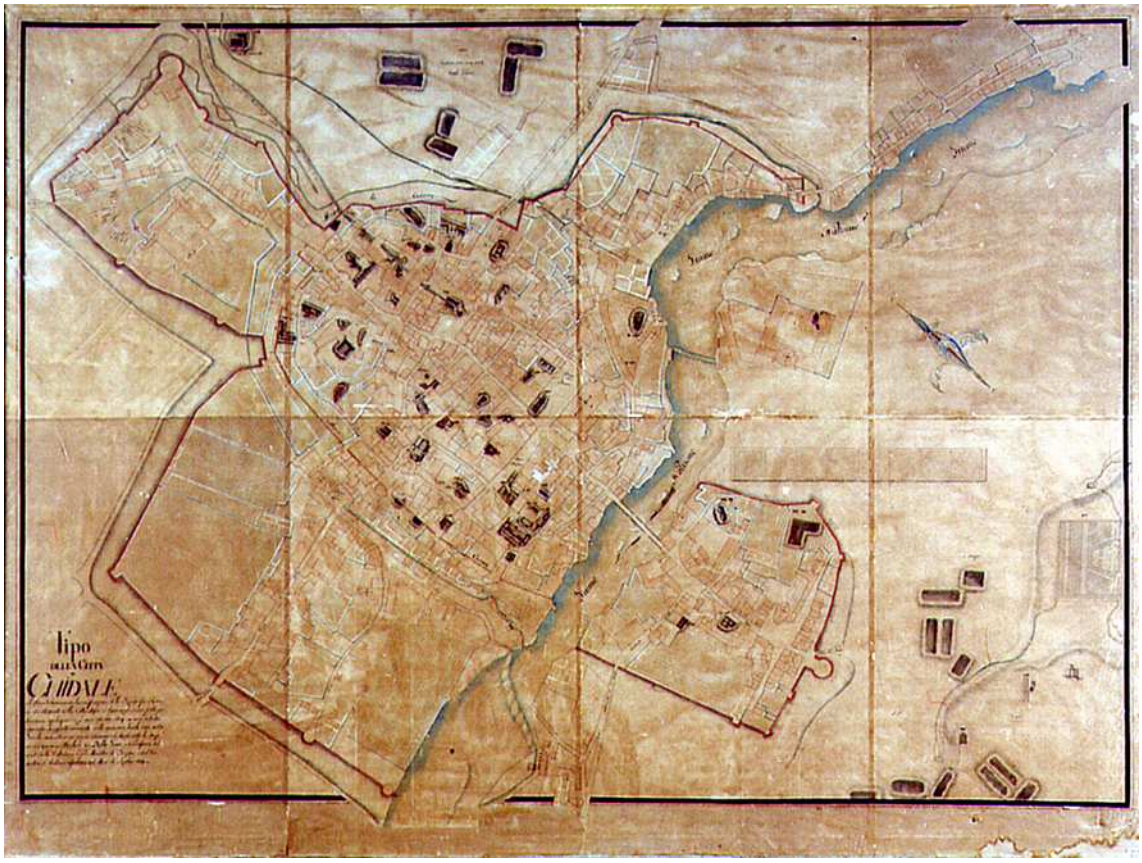


Fig. 4 – Michele Della Torre; archaeological map 1827.

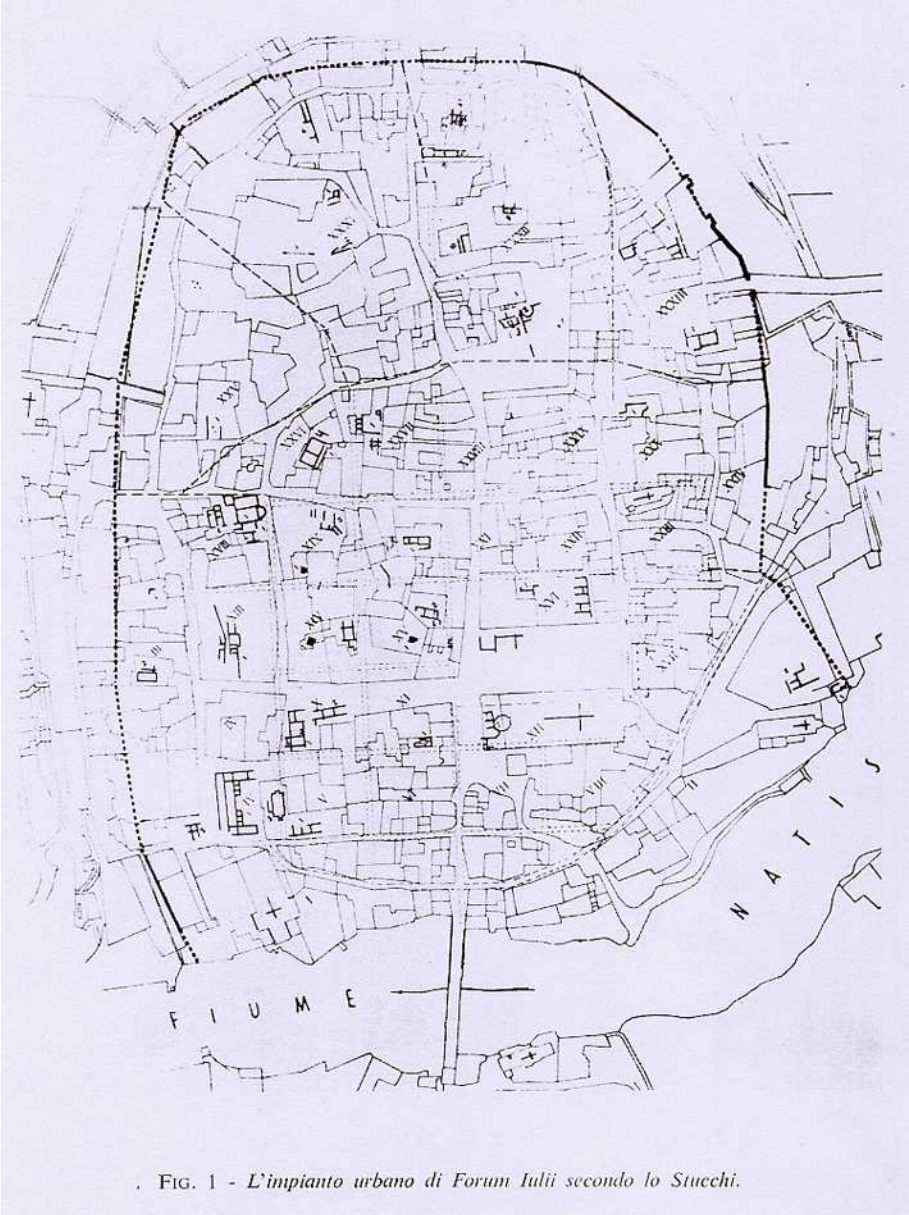


Fig. 5 – Sandro Stucchi; archaeological map 1951.

For Cividale del Friuli, the path of the studies is similar: the first one to deal with the analysis of the urban structure of the ancient city was the canon Michele della Torre (DELLA TORRE 1816–1827), which from 1816 to 1827 has done a lot of excavations, left diaries, drawings and a map of the city with the position of all the excavations that permitted to understand in which part of the city he worked and, most important, he left a table with the name of the landlords whose property was interested in investigations and the cadastral number of the properties. This table was really useful with others archaeological maps done in the 20th century from M. Brozzi (BROZZI 1971, 1975), A. Tagliaferri (TAGLIAFERRI 1986, 1991), L. Bosio (BOSIO 1972, 1977) and S. Stucchi (STUCCHI 1951) who collected and analyzed the documentation of M. della Torre and advanced some proposals on the ancient city of *Forum Iulii*: S. Stucchi made the most careful positioning on the modern cadastre of the various excavation made from M. della Torre, M. Brozzi focused primarily on its development in the Lombard period, while L. Bosio and A. Tagliaferri proposed two different

urban structures of the roman town. Finally, from the ‘80s the Superintendence has promoted a large number of excavations that helped to expand the knowledge of the ancient city’s topography (COLUSSA 2010).
Also in this case all the data were collected and studied first in a graduation thesis (GONIZZI BARSANTI 2003) and then in a PhD (GONIZZI BARSANTI 2008).

The archaeological map on digital support

Trieste

For the city of Trieste it was used as basis map the so-called "Piano Müller”, a cartography dedicated to the city center whose design dates back to 1868, which was updated in time and that in recent times has been computerized and made suitable to the current city planning requirements. Through the creation of a polygonal network, all the areas related to archaeological excavations have been linked together from the ‘90s investigations till now, especially in the northern part of the neighborhood “Cittavecchia”, which has Via dei Capitelli as the main north to south ridge. The polygonal network has been hitched up the Piano Müller by high visibility references; therefore, all the cartographic data directly surveyed and the other obtained from the archival research were put into the same cartography. Through the creation of a vector drawing of this data, the graphic rendering was made uniform ad was created a limited set of layers dedicated to the different graphic attribution of the objects represented.

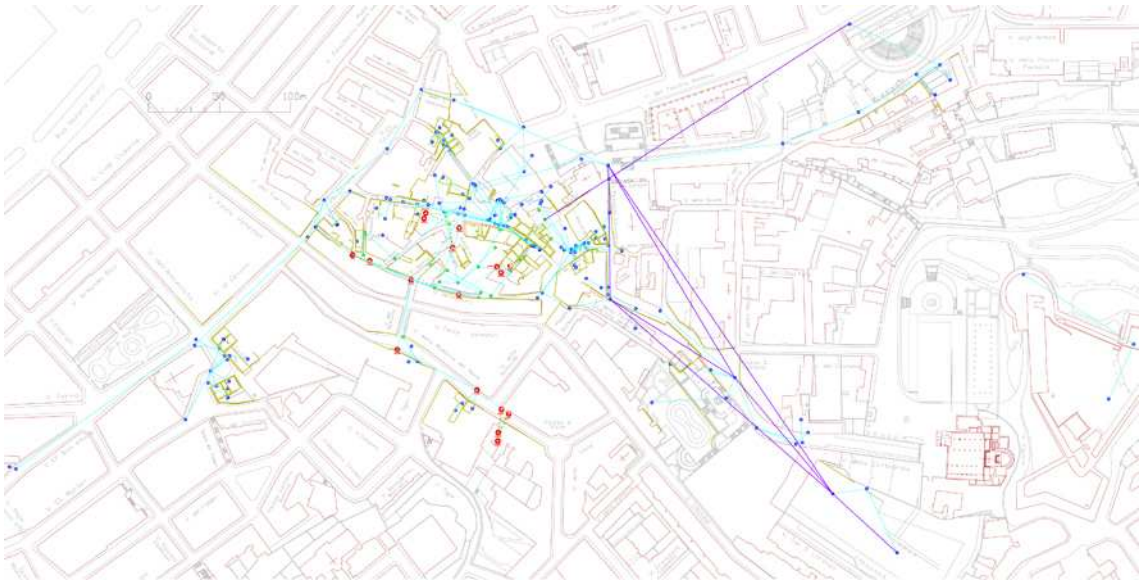


Fig. 6 – The polygonal network on the Piano Müller.

As many of the drawings, especially the ones result of recent archaeological excavations, had a scaling of detail very high (from 1:5 to 1:50 scale), it was decided to create two levels of representation by first digitizing the detailed performance and in an opposite way through the schematization of the same drawings as to ensure a fair representation in terms of the orientation and the topographic position of the elements represented (particularly walls, floor plans and other useful elements for the planimetric reconstruction of the

investigated sites). For the representation of details also photo – plans and photo – straightening were used where the context allowed it.

At first, the entire cartographic system was based solely on Cassini - Soldner coordinate system, and thereafter, through the registration of some first level benchmarks of the polygonal network with GPS, it was also possible to rototranslate the map on WGS84 coordinate system and consequently on Gauss Boaga coordinate system.

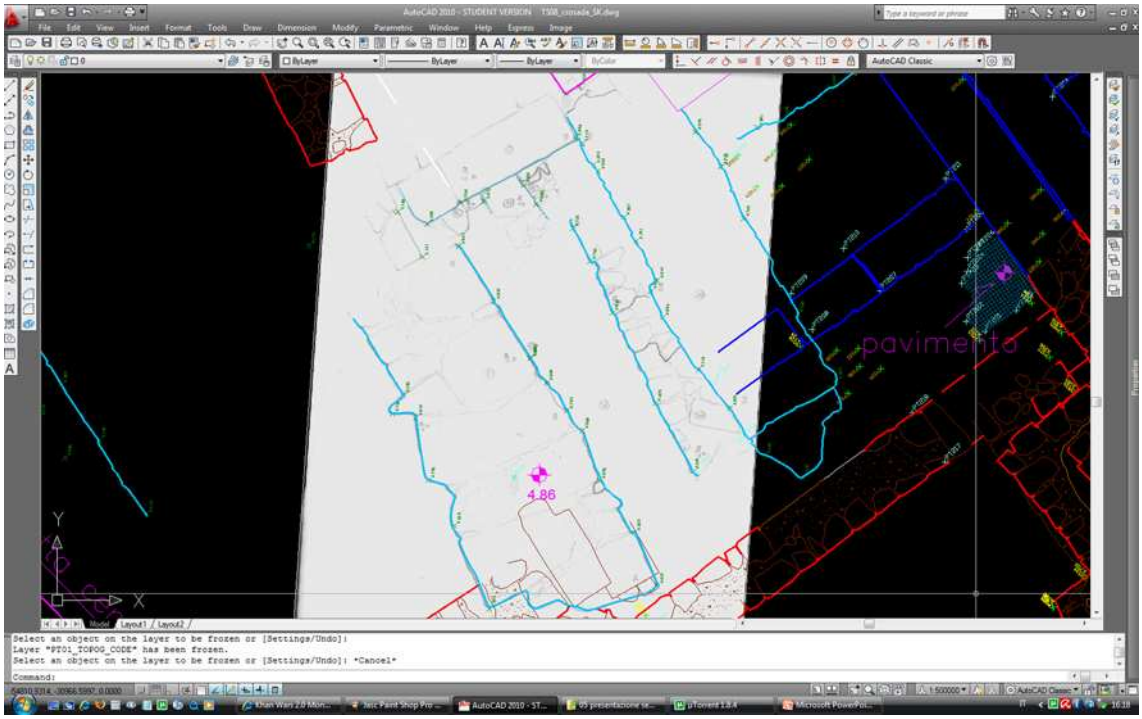


Fig. 7 – Vector drawing of details plan.

The topographic grid, in this way, has been reported on the Piano Müller and also on the Carta Tecnica Regionale (regional technical map) of Friuli Venezia Giulia on 1:5.000 scale and on the cadastral map of the city of Trieste. These multiple references allowed to have many interrogations in the GIS subsequently created with these cartographic basis.

We have to say that during the topographic relieves and with the development of the polygonal network, several profile of modern buildings, which were often the limits of the archaeological excavation area, were also registered. In this way, besides getting a detailed cartographic rendering of the archaeological structures, it has been possible to create, for a large number of areas, a very high detailed graphic representation of the urban context in which we operated. This representation was in several cases a useful correction and clarification of the basis maps (especially piano Müller).

The final result is a vector map in CAD in *.dwg / *.dxf format within which it can be easily extrapolate the levels dedicated exclusively to the topographic grid (vertices of different levels, 1–4; intervisibility reports, elevation data and individual survey points), the levels of the urban fabric of the modern city, the levels of the graphic rendering of the ancient city (with graphic devices for different thematic and chronologic maps) and finally the levels of the detailed graphic rendering (large-scale detailed maps).

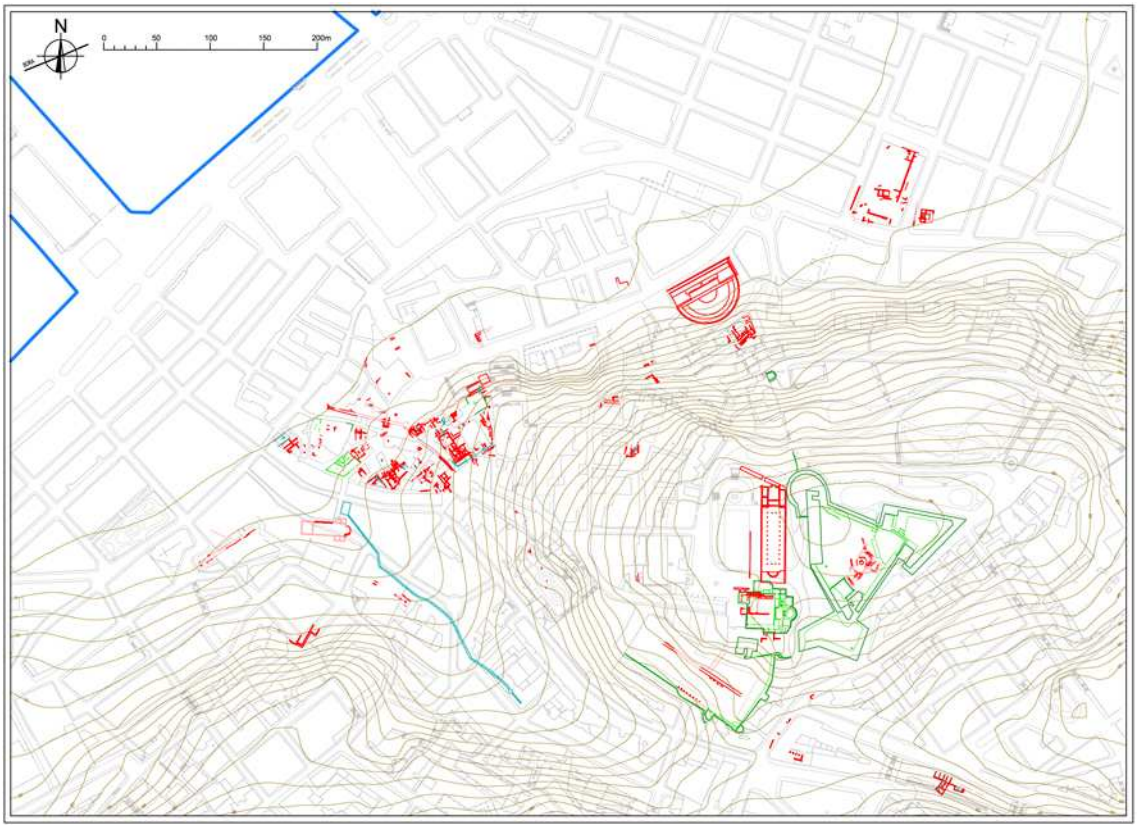


Fig. 8 – The archaeological map of Trieste.

Cividale del Friuli

The old town of Cividale del Friuli, unlike the area of “Cittavecchia” in Trieste, did not have several archaeological excavations in the center of the city, concentrated in a relatively short period. Some of the major excavations can be dates back to the ‘60s, in the following decades several investigations were made in several areas of the old town and in recent years, the Superintendence, in cooperation with the city administration, has made some important excavations in the areas of “Corte Romana” and “Foro Giulio Cesare”.

During these latter works, the Superintendece promoted a systematic mapping of the interventions already completed and required the creation of a topographic network of support for the creation of an archaeological map on digital support, based on similar experiences already upgraded in other sites of the Region. In 2006, then, a topographic network has been created through the implementation of benchmark collected with GPS. Consequently others second level benchmark has been added to reach some areas of the downtown center. Within the city some significant points have been identified in which were placed the benchmarks for each of which has been created a monograph. The grid is currently regarded as a topographic base plan both for the work of Superintendence and of the municipal administration becoming an instrument for the protection and subsequent interventions.

From now on, all the results from archaeological excavations have been implemented into a mapping system which has as its basis map the Regional Technical Map on 1:5.000 scale of Friuli Venezia Giulia and the cadastral map of the Municipality on 1:1.000 scale, both expressed in Gauss Boaga coordinates system.

Within this cartographic archive were then inserted all the archive data from territorial operations since 1800. Again, the final result is an archaeological map on digital support in which the contemporary urban fabric superimposed on the archaeological map appear together; the graphical representation of the archaeological data is very heterogeneous: because for not all the areas investigated was possible to realize a precise topographic placement or to obtain full planimetric data, often appear on the archaeological map punctual positioning that are joined to planimetric descriptions topographically precise.

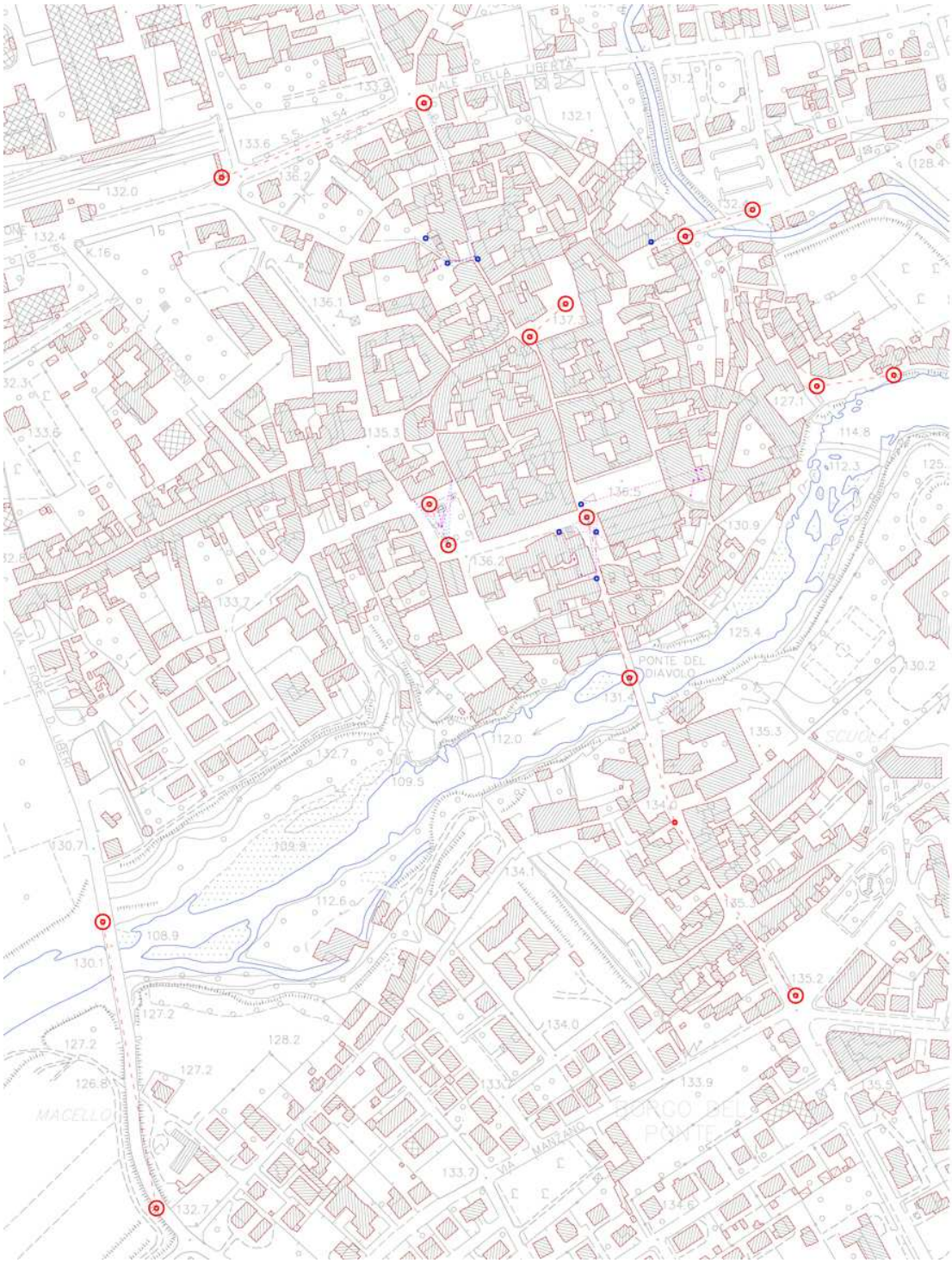


Fig. 9 – Benchmarch collected with GPS (red points) and other benchmark (blue points).

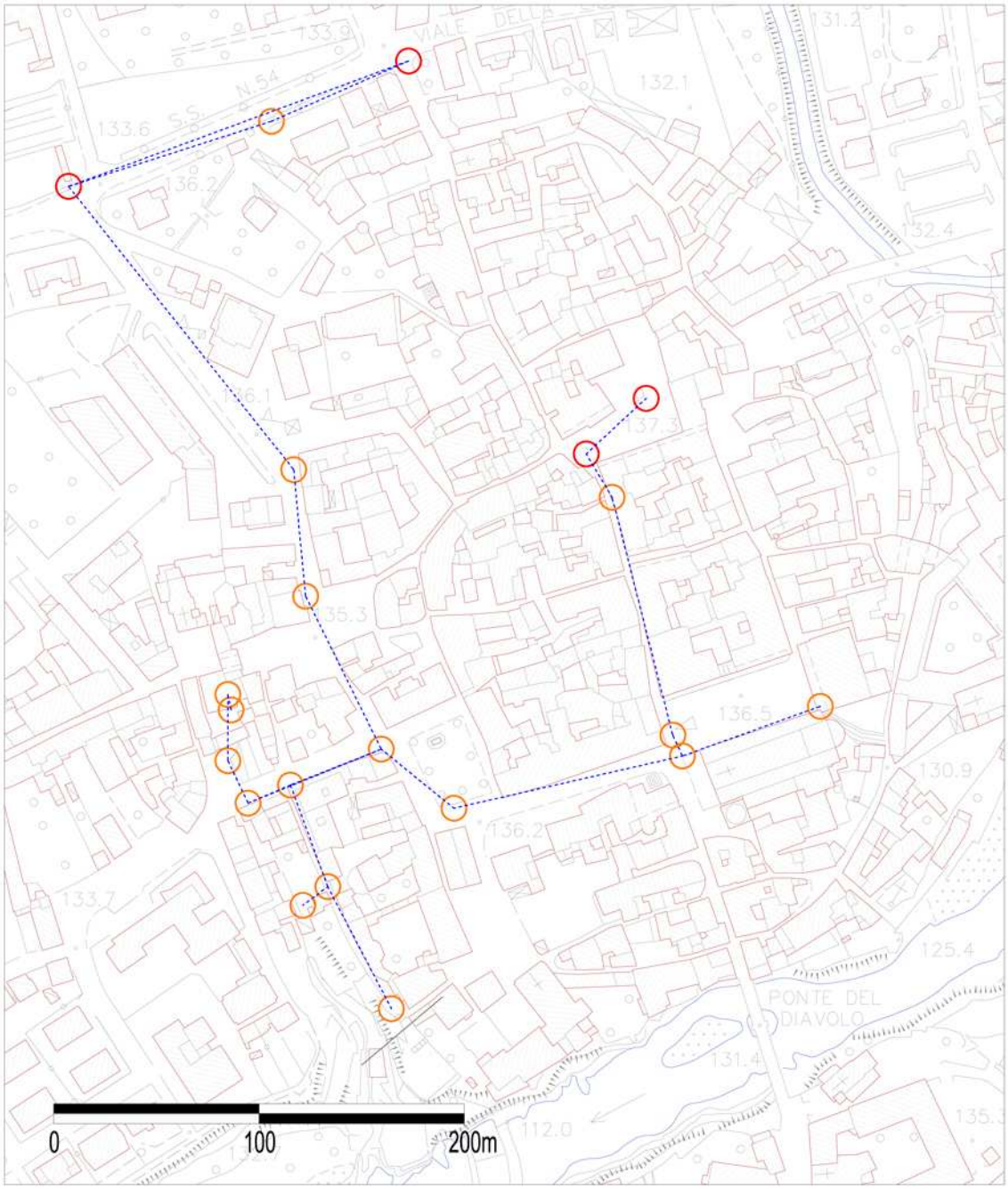


Fig. 10 – Detail of the central area with the second level benchmark.

CIVIDALE DEL FRIULI (UD)
RETE TOPOGRAFICA DEL CENTRO STORICO

MONOGRAFIA del PUNTO TOPOGRAFICO

nome vertice: 0611

coordinate piane: (Gauss-Boaga)
est 2398727,085
nord 5105611,874
quota 135,736

materializzazione: chiodo acciaio punzonato

ubicazione
indirizzo: piazza Duomo
comune: Cividale del Friuli C.A.P. 33043
provincia: UD
regione: Friuli Venezia Giulia

note
limite del marciapiede all'angolo tra piazza Duomo,
e via P. d'Aquleia; chiodo in acciaio
con punzonatura e rondella marchiata, inserito tra
i cubetti di porfido e reso solidale a questi mediante mastice
solido bicomponente poliestere

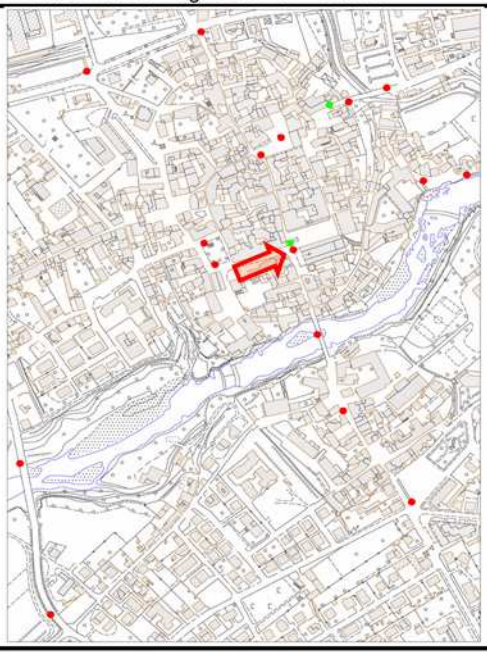
data rilevamento: 11 aprile 2006

rilevatore: STM s.r.l. - via G.Baglivi, 3 - 00161 ROMA
tel. 0644292905 - fax 0644261527
mail stm.arch@yahoo.it

STM archeologia architettura

RIFERIMENTI CARTOGRAFICI

CTRn scala 1:5000 - foglio 067104 - stralcio



FOTOGRAFIE

EIDOTIPO

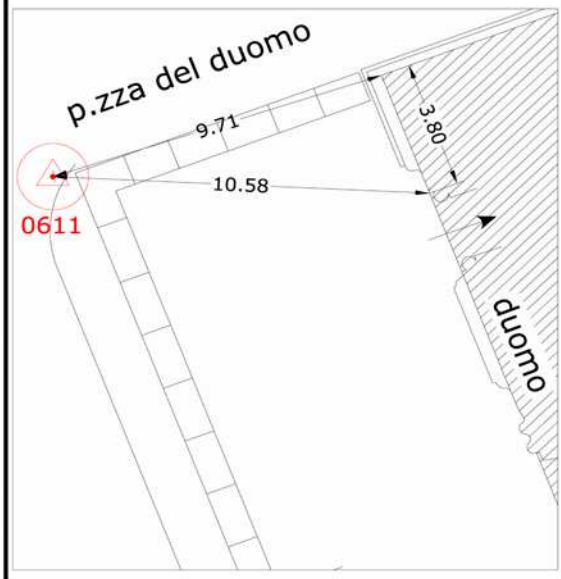


Fig. 11 – Monograph of a GPS benchmark.

Fig. 12 – Archaeological map on the cadastre.

The database and the Geographic Information System

For each of the two sites were created a GIS that in many ways reproduces the same structure but taking into account the fundamental differences between the two sites analyzed and in particular between the two types of available databases.

To this GIS was connected a database containing a variety of topographical and archaeological information accessible through targeted questions and a series of descriptive fields recording information on the excavation and all the archive documentation such as vintage photographs, floor plans or further outputs.

For Trieste the database in access was made using the fields of the Central Institution for the Catalogue and the Documentation (ICCD).

Within the database have been joined up all the documentation data about the single archeological areas studied, such as photographs, graphics reworks or explanatory tabs. The database is structured in a series of information fields associated with the general plan superimposed on both the base mapping (Piano Müller) that the cadastre. Each cadastral lot is associated with a range of archaeological data relating to it, proposing data resulting from recent surveys and data archives.

In agreement with the Superintendence of Archaeological Heritage of Friuli Venezia Giulia, for the sites considered in this report and others for which regular and ongoing archaeological investigations are done and for which there is a systematic topographic survey, there is a continuous and constant acquisition and

processing of topographic, archaeological and archival data with the goal of keeping the most updated each of these multimedia archives.

In this article we chose to highlight in particular the data relating to the Roman period because this chronological period was gone into depth during the two PhD in Geomatics and GIS at the University of Trieste.

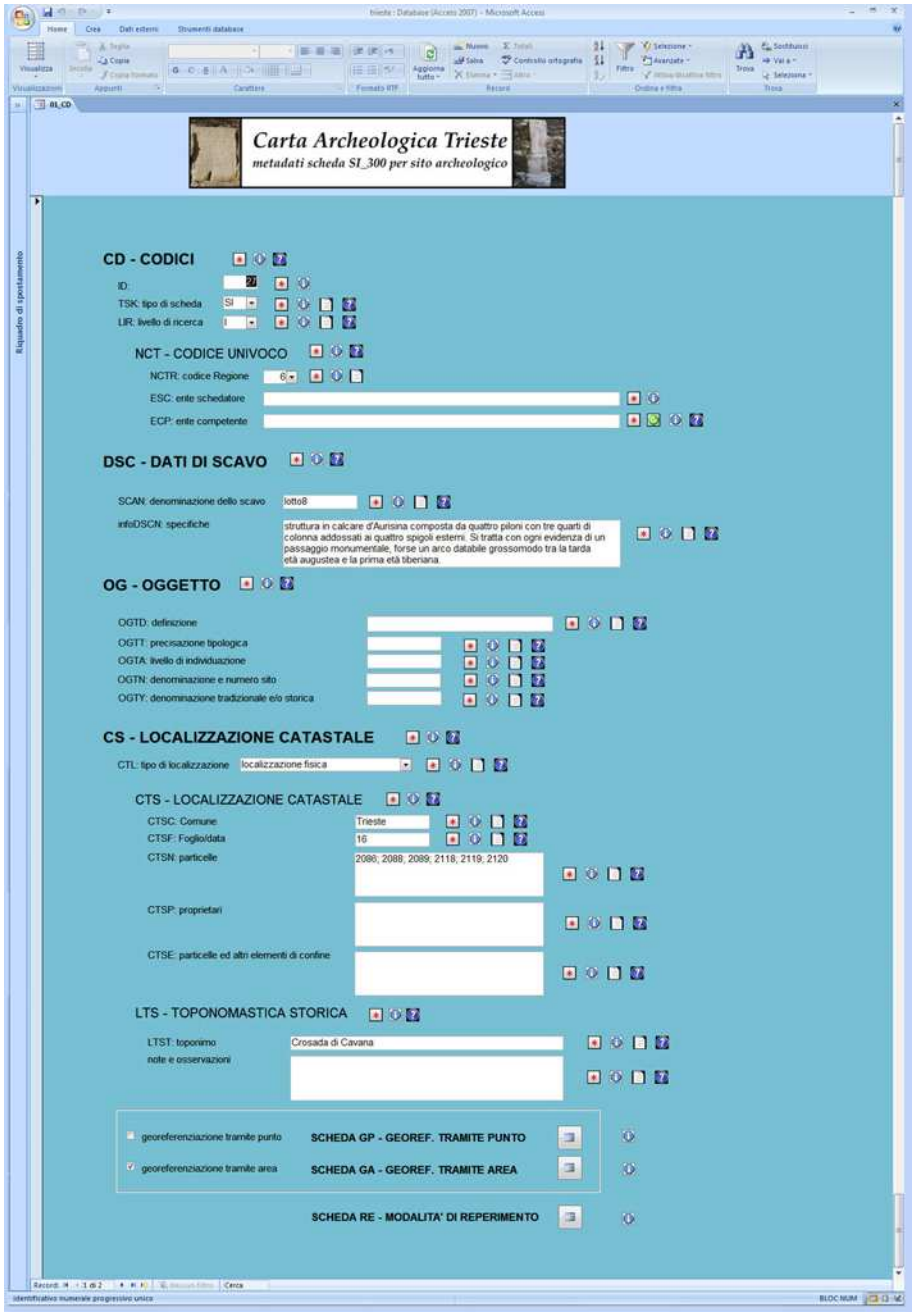


Fig. 13 – The database with the fields of the Central Institution for the Catalogue and the Documentation (ICCD).

To the various sites documented, especially for the city of Trieste and its central and the oldest area, data concerning to successive stages have been also implemented in order to make possible diachronic analysis relating to different historical periods that have marked the urban development of the sites analyzed.

Unlike the case of Trieste, where the sites documented planimetrically are very large and then the reconstruction of old urban fabric in its various stages is more immediately visible and understandable, to Cividale most of the data archive consists of information localized through the cadastral number identification, and then placed on a map but generally undocumented planimetric able to give back the profiles of the structures highlighted.

The database collected to the GIS incorporates all the archaeological archive data for archaeological investigations to the most ancient and recent. For the sites most recently investigated, were made detailed computerized relives put into the archaeological map, for which has been possible to make thematic maps. Within the GIS, the data contained into the database were used for queries of various kind, such as some related to obtain statistics on the various depths of archaeological outcrops in order to arrive at a possible risk archeological map.

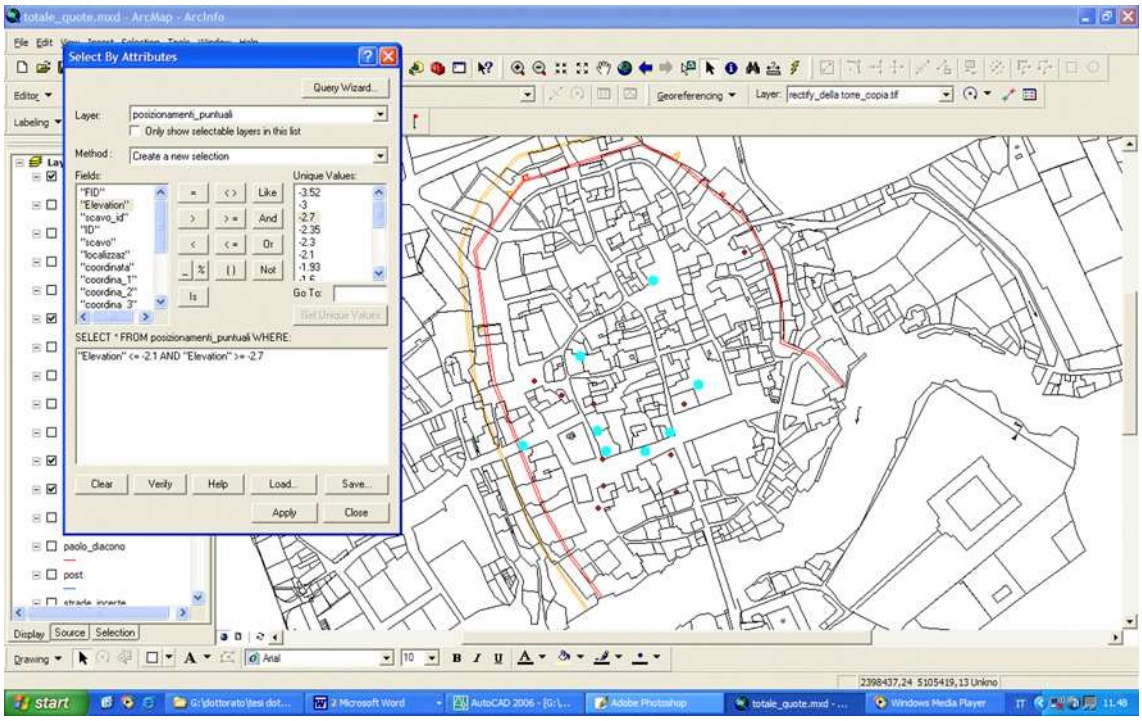


Fig. 14 – Example of query.

The data transmission

As a fulfillment of the GIS, for the city of Cividale del Friuli was created in agreement with the Superintendence a multimedia workspace based on a cd that collects information on the most significant finds in the history of the city at various stages of life.

The internal organization of the site has been set on the floor plans of the Palazzo dei Provveditori, base of the Archaeological Museum: in this way the visitor is free, with its own choice, to navigate inside the Museum and to select the parts that interests him the most or following his personal curiosity, but most of all has the information, thanks to the use of the archaeological map done with the GIS, necessary to see and understand the shape of the ancient city, rebuilt on the digital support and inserted in the multimedia cd as an image.

Fig. 15 – Navigation inside the Museum.

In this way the discoveries and the studies related to the ancient city can be made available to the public to facilitate the understanding of the ancient urban shape.

Second function, also connected to the one just described, is to allow the relocation of the finds in the place of discovery, to know the original purpose in the context of relevance. This prevents the possibility that the materials exposed remain only beautiful pieces of art and makes possible to understand, in addition to the typological and historical data, the topographic and functional relation with the areas or the structures that contained them in antiquity.

Conclusions

In conclusion, the creation of an archaeological map on digital support and the subsequent implementation of the GIS not only allowed the collection of heterogeneous data favoring the study and the research, but are a great tool for the realization of the archaeological risk map that can be called a forecast map because it provides data for a circumstantial protection, a tool that is constantly in development, that sums known data to hypothetical data, identifying the areas at risk of future archaeological finds.

The use of these tools by the local authorities, helps to preserve the archaeological heritage that has already been investigated and studied and the one that is still hidden beneath the modern city.

Fig. 16–17 – Moments of the topographic relieves.

Acknowledgments

The authors would like to thank Dr. Maselli Scotti, Dr. P. Ventura and Dr. S. Vitri of the Superintendence for Archaeological Heritage of Friuli Venezia Giulia for the possibility of reaching the data archive and professor G. Manzoni and C. Morselli of the University of Trieste for their collaboration during the PhD dissertations.

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Philadelphia, USA

The use of urban historical archaeology and digital technologies to interpret and better understand the birth of a nation

Glen MUSCHIO
Drexel University

Abstract: This report highlights 2 new media projects based on recent and current Philadelphia archaeological excavations. Computational analysis and GPS mobile technology are at the core of the two projects conducted at Independence National Historical Park, Philadelphia. The projects have implications for the way archaeology is conducted and for the image a nation holds of itself.

Keywords: computational analysis, public archaeology, GPS mobile tours, new media, virtual reconstruction.

Introduction

The creation of a national park located around Independence Hall in Philadelphia was authorized by an act of Congress in 1948 (GREIFF 1987: 68). Today, it is known as Independence National Historical Park (INHP), its mission is

> *… to preserve, manage, operate, maintain, protect and interpret park resources significantly associated with the American Revolution and the establishment of the United States of America in order to perpetuate these resources and to help all people understand the people, events, and ideas associated with the park's tangible resources* (INHP 2007: 10).

The Park contains national treasures considered by many as sacred symbols of liberty and democracy including the *Liberty Bell*, *Franklin Court,* the home of Benjamin Franklin, and *Independence Hall*, the site where the Declaration of Independence and the United States Constitution were signed. INHP is a popular tourist attraction, between July 2009 and June 2010 the 21 hectare park received 3.9 million visitors (IVCC 2010: 4). *Independence Hall* is recognized as an icon of democracy around the world and was inscribed as a World Cultural Heritage site in 1979 by the United Nations (UNESCO (n.d)).

In the late 18th century, when the Declaration of Independence was signed and the American Revolutionary War was fought, Philadelphia was the largest city of Britain's North American colonies. In the post colonial period, the city grew to be an industrial powerhouse, but by the mid 20th century it was in decline and when the INHP was authorized many buildings not associated with either the American Colonial era, or the period immediately following the Revolutionary War, were razed. Limited archaeology was conducted at the time the Park was established and the information gleaned did influence early planning and interpretive decisions for the Park, however many of the remains of demolished buildings and artifacts associated with them, as well as the remains of earlier buildings, which were not excavated, were left in place and covered over (COTTER et al. 1993: 74–78).

Fig. 1 – Looking south at Independence Hall, located on Independence Mall, Independence National Historical Park, Philadelphia. To the left of Independence Hall is the building where the Supreme Court met, to the right, is the building that housed the US Congress. Opposite Congressional Hall is the Visitor’s Center and to its north is the new Liberty Bell pavilion (Photo courtesy of James Powers [flickr Wind Watcher]).

Since 2000, there have been several major construction projects on INHP grounds including a Visitor’s Centered opened in 2001, a new pavilion for the Liberty Bell and the National Constitution Center both opened in 2003 (INHP 2007: 2–3) and the President’s House dedicated in December 2010. Archaeologists and historians have used these opportunities to excavate, examine, interpret and reinterpret these old sites with dramatic and far reaching implications. Some of the analysis is being conducted in multidisciplinary teams aided by the latest computer technologies, other work is being done at the persistence of concerned citizens and sometimes directly under the gaze of a public eager for information about existing social conditions that have long been ignored in the founding narrative of American democracy. In the two cases presented below, the archaeology being conducted is not only changing the face of archaeology, it is changing the narrative about the founding of a nation.

The National Constitution Center archaeology site

In 2001–2003, prior to the construction of the National Constitution Center (NCC), built on the northern end of Independence Mall and dedicated to the study of the United States Constitution, archaeological investigation revealed the richest American Colonial era site unearthed in an urban area. Nearly 1 million artifacts were recovered including Native-American pre contact artifacts, as well as 18th, 19th and early 20th century artifacts. Food remains were also recovered, shedding light on daily diet. Over 600,000 ceramic shards were recovered, many from the 18th and 19th centuries. The rich collection of ceramics includes many objects imported from England and China as well as domestic ceramics produced in Philadelphia. The

collection sheds light on the diffusion of early manufactured goods, and the beginnings of industrial capitalism.[1]

The 3D Colonial Philadelphia Project – Digital Restoration of Thin-Shell Objects for Historical Archaeological Research and Interpretation is a National Science Foundation supported research project comprised of an interdisciplinary team of Drexel University faculty, graduate and undergraduate students in Electrical Engineering, Computer Science and Digital Media and area archaeologists and archaeologists from Independence National Historical Park, working to develop computer-imaging techniques that will automate the virtual reconstruction of ceramic shards recovered from NCC archaeological excavations. At present, archaeological analysis and interpretation of ceramics involve a painstakingly slow process of reconstructing vessels from shards recovered at a dig. Using temporary glue, shards are assembled by hand. The reconstructed artifacts are photographed, then disassembled and placed in storage. While ceramics are often valuable sources of information, the stored objects are not readily accessible to researchers for further study and interpretation, nor are they available to a public curious about the past. Working with 3D scans the project seeks to automate the virtual assembly process which would greatly expedite the reconstruction, interpretation, and cataloging tasks that now consume so much research time (COHEN et al. 2008). Furthermore, digitizing ceramic shards has the advantage of facilitating data access for other researchers as well as museum curators and non-experts. Our NSF project, if successful, will provide opportunities to offer the public engaging new ways to better understand daily life in historical periods providing perspectives missing, overlooked or ignored in more conventional approaches to understanding the past. The recent historical archaeology conducted at INHP is not only fueling multidisciplinary research methods, including computational analysis that will impact archaeology technique and interpretation, the archaeology is largely responsible for the Park's telling of new stories about life and times in Colonial and early post Colonial Philadelphia. Many of these new stories address the issue of slavery and its legacy.

Historical research conducted in Philadelphia city, church and institutional archives, inspired by information gleaned from the archaeological remains recovered from the NCC site, revealed that by the 1790s, three individuals, once slaves, had become influential members in Philadelphia's emerging free black community. The three individuals resided in houses built along one street in the area now known as "Block 3" on Independence Mall (SALISBURY 2008). One individual, James Oronoco Dexter, was manumitted in 1767 (TOOGOOD 2003), his house served as a meeting place for the planning of the African Episcopal Church of St. Thomas, established in 1794, it is one of the first two black churches founded in Philadelphia (EYRING and WOODFORD 2004).

[1] I would like to thank Jed Levin, Chief Historian, Independence National Historical Park and Archeologist, who supervised the archaeology projects at the National Constitution Center and President's House sites and Douglas B. Mooney, Senior Archaeologist URS Corporation, Inc. Field Director at the two sites, and Patrice L. Jeppson, Historical Archaeologist, West Chester University and Cheyney University of Pennsylvania and CoPI on NSF Award Number 0803670 *The 3D Colonial Philadelphia Project – Digital Restoration of Thin-Shell Objects for Historical Archeological Research and Interpretation* for sharing their insights, experiences and observations regarding INHP archaeology and interpretation, without their generous assistance and guidance the works described in this paper would not have been possible.

Fig. 2 – Electrical Engineering graduate student Zexi Liu,(left) and Ezgi Taslidere, Post Ph.D. (center) with Digital Media undergraduate, Girish Balakrishnan (right) digitizing ceramic shards recovered from the NCC site.

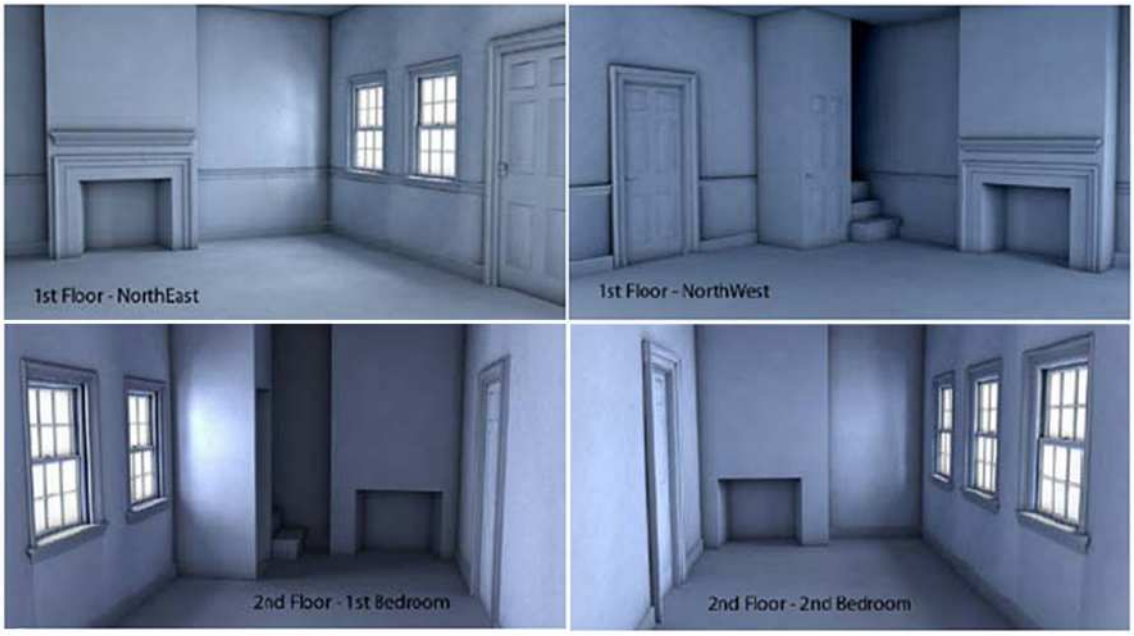

Fig. 3 – Interpretive 3D digital models produced by *Christine Adams, Agastya Arya, Jake Nichols, and Zexi Liu* in the NSF supported class, *Computational Archaeology*.

As part of our NSF grant, we conducted an interdisciplinary class composed of graduate and senior undergraduate students at Drexel University. The idea was to bring students with backgrounds in Electrical Engineering, Computer Science and Digital Media together, familiarize them with our NSF research, and offer opportunities to explore the use of computer technology in analyzing archaeological data and distributing archaeological knowledge. One group of students worked with INHP Chief Curator, Karie Diethorn, and Chief Historian, and Archaeologist Jed Levin, URS Corporation Senior Archaeologist, Douglas Mooney and CoPI NSF researcher Dr. Patrice Jeppson. Together they reviewed historical records of the Dexter House, and a 3D digital exterior model of the house previously produced based on the archaeologically revealed footprint of the building. Students also recorded measurements of stairs and woodwork from the *Todd House,* a period residential house standing on INHP grounds regarded as possessing similar attributes to the Dexter House. Based on this information, a preliminary 3D digital model of what the Dexter House interior may have looked like was produced. The intention is to virtually furnish the house with historically accurate furnishings including ceramics and other artifacts recovered from the

archaeological excavation and believed to have been associated with Dexter's occupation of the house. The virtual environment will be used as an educational tool to explain what archaeologist do, and how we can learn about cultural heritage and the lives lived by everyday people from archaeological evidence and interpretation.

The President's House

Philadelphia served as the National capital of the United States of America from 1790–1800. George Washington, the first President, illegally housed slaves in Philadelphia during his term in office. *The President's House* commemorates the site of the house occupied by the first two Presidents and acknowledges slave labor as an integral component of the social fabric in the founding of the nation. It is the nation's first acknowledgement of slavery in a National Park. A pamphlet distributed by INHP at the exhibit's dedication ceremony in December 2010 notes:

> *This exhibit is the result of an eight-year collaboration between the National Park Service and the City of Philadelphia. The partnership was advised by an oversight committee that brought local community groups together to help shape the content of this exhibit* (INHP 2010).

The INHP's description puts a happy face on a passionate and turbulent process well chronicled in the *Philadelphia Inquirer* by "Culture Writer," Stephan Salisbury (2010)[2] and on the web page of *Avenging the Ancestors Coalition* (ATAC), a non-profit group describing itself as a "… broad-based coalition of historians, activists, attorneys, elected officials, religious leaders, media personalities, and other tax-paying voters – descendants of the victims of the greatest holocaust in the history of humankind" (ATAC 2007–2011). According to the group's website, "In order to expose the truth, Avenging The Ancestors Coalition (ATAC) was founded in 2002 & led the successful 8 year battle for a slavery memorial at the site" (Ibid).

In January 2002, Edward Lawler Jr. published, *The President's House in Philadelphia: The Rediscovery of a Lost Landmark* in which he describes slave quarters built by Washington to house his slaves brought to Philadelphia from his Mount Vernon plantation. Lawler also points out that the Liberty Bell, which had become an important symbol for abolitionists in the 1840's, was about to be placed in a new pavilion that would stand adjacent to the spot where Washington built his slave quarters. Lawler writes:

> *The Liberty Bell became then the powerful rallying symbol of the struggle to end slavery in America. This ancient meaning will echo as one approaches the new building on Independence Mall. The last thing that a visitor will walk across or pass before entering the Liberty Bell Center will be the slave quarters that George Washington ordered added to the President's House* (2002).

In 2007, archaeological excavation of the President's House revealed portions of its foundation, as well as support buildings and passageways connecting them. The archaeology was conducted in front of a review stand from which some 300,000 visitors came to see "evidence of slavery and freedom side by side at the birth of a nation" (JEPPSON 2011). The impact of the archaeological evidence documenting social

[2] For a more complete bibliography of Philadelphia Inquirer articles including the writings of Stephan Salisbury see *Special Reports, The President's House.* Available at http://www.philly.com/philly/news/special_packages/inquirer/7496306.html. For additional historical articles regarding the President's House see *The President's House in The News*. Available at http://www.ushistory.org/presidentshouse/news/index.htm.

contradictions was so profound that there was a public outcry to redesign the planned exhibit to accommodate the archaeological findings. A glass structure enabling visitors to see a section of the house foundation became the focal point of the redesigned exhibit. The exhibit makes use of partial walls and window frames, but no roof, nor doors, it suggests the presence of the mansion, but does not attempt to replicate it. The names of the nine slaves Washington kept in his household, have been engraved on a wall. Video displays show reenactors giving first person accounts of their experiences as slaves. The narrative of the exhibit, which grapples with many contradictions, has been criticized for lacking “both intellectual coherence and emotional power” (ROTHSTEIN 2010). It has also been praised as “True history” (JOHN-HALL 2010).

Fig. 4 – The photo taken May 17, 2008 shows a view looking north on Independence Mall. The Liberty Bell pavilion is in the lower left. The ground markings in front of the pavilion show the foundation lines of the President’s House. The small structure is the public reviewing stand built in the 2007 for observing the archaeological excavation of the President’s House. The white building in the distance is the National Constitution Center and forms the Mall’s most northern boundary. (Photo courtesy of James Powers [flickr Wind Watcher]).

Once built, traditional brick and mortar exhibits like the President’s House become difficult to modify. A group of Digital Media and Computer Science seniors[3] collaborating with area and Park archaeologists, historians and curators are working to produce digital solutions for enhancing visitor experiences to IHNP. They have produced a smartphone prototype GPS self-guided walking tour of the Park dubbed, *The Instant Navigator.* The smartphone application features information on the *Dexter House, Franklin Court*, and *The President’s House*. All 3 exhibits are based on information gathered from archaeological explorations. The latter includes

[3] *The Instant Navigator Project* was produced as a joint Senior Design Project by Computer Science seniors Bradford Dorman, Chris Fagan, Scott Dorman and Alejando Valdes and Digital Media Seniors Jeff Ginsburg and Dave Roy with Computer Science Faculty Dr. Jeff Salvage and Digital Media faculty Jervis Thompson, Ted Artz and Christopher Redmann.

a digital 3D model of the exterior of *The President's House* based on information obtained from a 3D scan of the archaeological excavation and historical etchings of the house.

Fig. 5 – Left. Archaeological excavation reveals the President's House foundation. The photo on the right shows the reviewing stand overlooking the archaeological excavation. The entrance to the Liberty Bell can be seen beyond the excavation pit. Independence Hall can be seen in the background (Photos courtesy of Anja Dalderup).

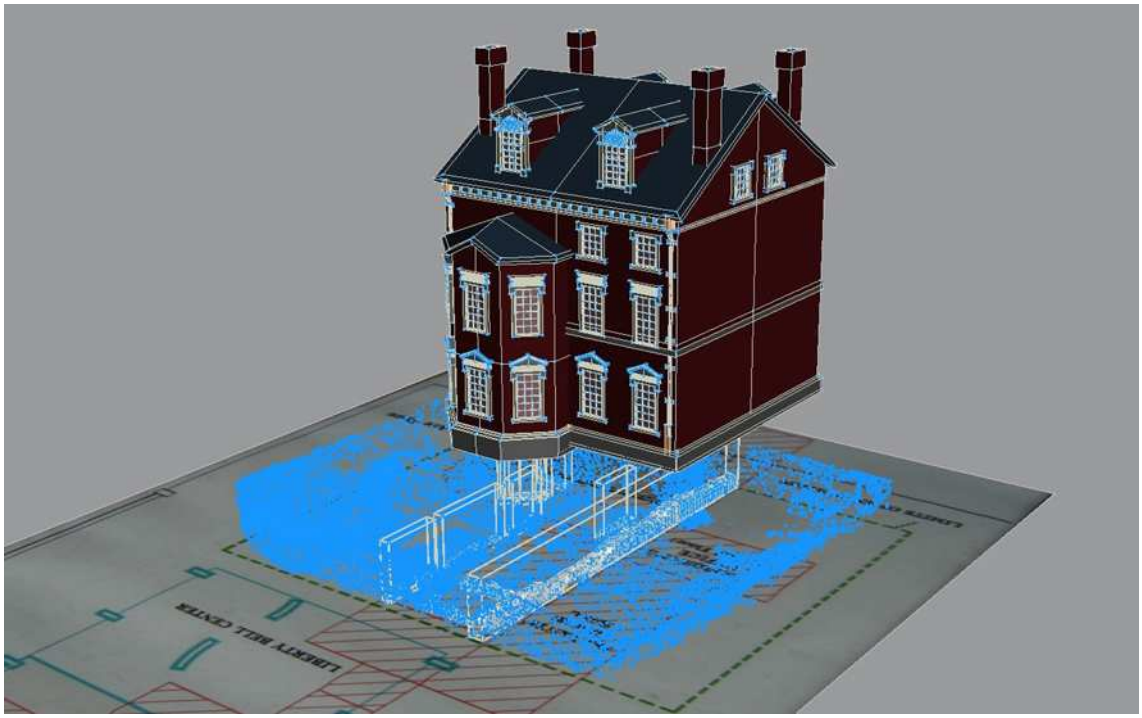

Fig. 6 – This 3D model is based on point cloud data collected by Erdman Anthony Engineering during the archaeological excavation of the President's House. The model is currently being developed by Digital Media MS candidate Peter Stratton.

Virtual tours of the sort being developed have the advantage of easily being updated and enhanced as additional information becomes available and as historical interests shift. Virtual tours can also link users to resources off site. For example, visiting the *President's House*, a visitor may be directed to institutions or libraries that contain related relevant information. Through prior agreements, it may be possible to provide visitors with access to digital information directly through the smartphone connection, or a user may elect to have the information emailed to a home computer for later consideration. Through the use of digital

technology, a visitor can extend the visit by beginning the learning experience at the site and continuing it with information acquired digitally at the time of the visit and deferred for considered to a later time and place.

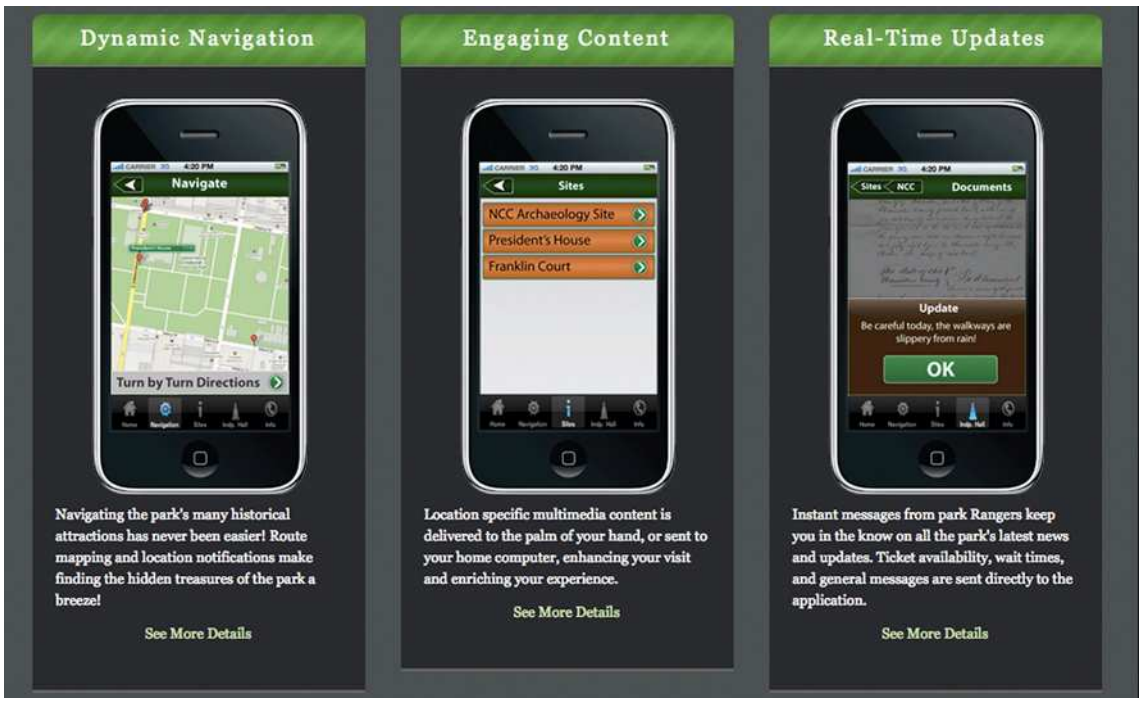

Fig. 7 – Navigation screens from *The Instant Navigator* prototype.

Concluding Remarks

The two ongoing interdisciplinary case studies help illustrate the use and impact of historical archaeology in reinterpreting the history of a nation. The use and development of new technologies to expedite research and to disseminate cultural heritage information demonstrate the impact digital technology is having on our ways of learning and teaching.

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The Role of the Venetian Cities in the Evolution of the Modern Urban Centers of Crete

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Abstract: The particular study aims to examine the interplay of the archaeological monuments in the evolution of the urban centers of the three main cities of Crete (Herakleion, Rethymnon, Chania). To achieve the particular goals a wealth of information retrieved from historical maps, modern statistical and cadastral databases has been fused together through various geo-information technologies. Bibliographic references were able to compose a database from where timelines of city-growth were extracted making feasible the comparison of the cities from Venetian times through their present layout, manifesting the changes of the urban matrix of the different cities in Crete. Thus it was also possible to examine the residues of the original Venetian architecture that remains intact until today and how the roles of the cities changed over time.
In this process, new technologies like AutoCAD, GIS, and ADOBE applications contributed accordingly to fully understand and visualize how these cities were and how they were transformed until today. The evolution of the Venetian cities was based on the densification and expansion of the original city centers, consisting of public and private buildings, public spaces, military facilities and free surface. It became obvious that although the three cities followed a similar trajectory of evolution, complementing each other in the relatively even distribution of population and civil roles, their current situation has been differentiated with direct consequences to the promotion of the Venetian architectural monuments. More specifically, with the pass of time, Chania and Rethymnon preserved their historical city centers and are still functioning as open-air museums, while Herakleion suffered a radical change in its urban planning, representing a more typical example of a “transformed archaeological city”.
Finally, with this analytical approach conclusions can be extracted that allow to propose a specific non-aggressive urban planning, regeneration of public spaces and conservation of the remaining architectural heritage to improve its present status of the main cities of Crete.

Keywords: urban evolution, venetian centers, Crete, GIS, CAD.

Introduction

The preservation of monuments in historical centers has played a crucial role in the evolution of the modern urban cities. The architectural monuments have become landmarks for the citizens and attractions for the tourists, capturing the attention of visitors with direct consequences in the economic and cultural activities of a city. On the other hand, the need for preservation of the monuments has created a number of obstacles in the free growth and expansion of the cities themselves. In order to comprehend today's situation and the plan of these metropolitan (in local scale) centers that enclose a historical dimension in their expansion, it is

important to study the past parameters that allowed the evolution of these centers and their transformation in larger urbanized clusters.

The concept of urbanization can be approached through a number of methods, but still it is significant to establish the relation of the expansion of the urban centers with their past in terms of the evidence provided through the standing monuments, excavations and the study of ancient sources and maps. The decoding and evaluation of historical documentation is critical for the examination of the evolution of the urban design at different time frameworks. It is the only way that we could try to understand how historical centers have affected the actual development of the cities and how they could become a motor for their further development, allowing an innovation or regeneration of the urban centers.

Historical Remarks. The Cities of Crete

The major cities of Crete evolved in a complementary way since from the time of their establishment they followed a common trajectory. The strategic geographical location of the particular settlements has been manifested even from prehistoric times and continued to play a critical role in the following historical periods. Following the Classical and Roman periods, the island of Crete went under the Byzantine control which was interrupted for a small period during the Arab occupation. The establishment of the Venetians came in the early 13th century, fusing the Byzantine Mediterranean traditions with the Western culture of the Renaissance. The Venetians followed a similar direction for the establishment of their centers that acted as satellites under the authoritative power of Venice (GRATZIOU 2010, GEORGOPOULOU 2001).

Venetian Candia (now Herakleion), became the capital of Crete (named also Candia as a whole island) during the Venetian period, remaining the political, military, commercial, social and intellectual centre throughout the five centuries of Venetian rule and one of the most important urban centers of the Eastern Mediterranean. This kind of prosperity gave rise to the development of a Veneto-Cretan urban society that promoted arts and was responsible for the Cretan Renaissance of the 16th century. Venice introduced also architectural elements of metropolitan character as it is obvious from both public buildings (such as Ducal Palace, Loggia, Basilica of Saint Mark) and private houses. This kind of prosperity attracted more population and increased the size of the city. In 1462 and under the threat of the Ottomans, a new fortification wall was constructed according to the principles of the bastion front system to provide defense to the expanded suburbs of the city and the harbor installations were reinforced. The city fell to the Ottoman Turks in 1669 after 22 years of siege, who demolished part of the walls to enter a ruined city that had been severely damaged by cannon shots. Partial restoration of the Venetian public buildings and transformation of the city's identity followed, accompanied by a socio-economic decay. After the deliberation of the island of Crete, Herakleion suffered more damages by a strong earthquake in 1856 and the German bombardment during the Battle of Crete (1941) which caused great destruction to the city (about a third of it was destroyed during the bombardments) and had to be rebuilt to a great extent. Herakleion became the capital of Crete in 1971.

Chania followed a similar course of expansion. By the time that Chania was liberated in 961 AD by the Byzantines, fortifications were constructed around Kastelli Hill, close to the harbor. Today only the western part of the Byzantine walls remains, along with a small section in Sifakas Street. In 1204 the Venetians annexed Crete and by 1252 they decided to reinforce the fortification walls using four bastions, towers and

an outer moat. At the same time they also constructed shipyards (arsenals) and improved the harbor, which was used as a first stop before reaching Candia. A construction of aqueduct and cisterns contributed to sustain the rising population of the city which has risen to 8,000 citizens. In this way, Chania became an important commercial center, adopting a number of Venetian architectural elements. A large section of the Venetian city was destroyed after its fall to the Ottoman Turks in 1645. The Venetian walls were reinforced and the architecture adopted the new customs of the east converting churches into mosques with tall minarets, while baths and fountains were also constructed. After the liberation of Crete in 1898, a major destruction of the city came from regular bombardments of the German Luftwaffe, which fortunately was not able to destroy completely the nucleus of the old city. Contrary to Herakleion, only small sections of the Venetian walls are preserved today, although the Venetian town plan is much better retained. Initially, after the deliberation of Crete, Chania became the capital of Crete until 1971, when the administrative power was reassigned to Herakleion.

Squeezed in between Herakleion and Chania, Rethymno began its period of growth when the Venetian authority of the island decided to establish an intermediate commercial base station that could facilitate the need of the island also in the mainland. Similarly to the rest of the cities, the flourishing conditions helped to attract more population and necessitated the construction of new fortifications around the venetian castle (Fortezza). The Venetian castle, together with other public architectural buildings (e.g. the Great Gate (megali porta, Porta Guora), the Piazza Rimondi (Rimondi square) and the Venetian Loggia) are well preserved even today. Most of the Venetian town plan of the 16th century, consisting of arched doorways, stone staircases, the small Venetian harbor and narrow streets, is still preserved in the city of Rethymno.

Historical Transformations – Methodological Tools

Historical monuments play a critical role in the evolution of the urban centers of the cities. Their preservation constitutes a living archive of memories and testimonies. They evolve to landmarks for the domestic life of the citizens and through them the past becomes alive. On the other hand, the way and degree of preservation of the historical monuments influences the general evolution of the city. There are cases, like Venice, where the historical landscape is almost completely preserved and the past architecture is used even today for the present activities of the citizens. In the particular case, a new city was constructed outside the limits of the older, having no interaction or relation with the past architectural monuments. In contrast, the cities of Crete evolved within and around the historical centers, as it has happened with most European cities. Part of the Venetian architecture was destroyed, other buildings were preserved, while others were transformed to new modern constructions. Whatever the case, the old centers did not remain static or "frozen", but instead they evolved to entities that could facilitate the needs of the modern citizens and at the same time they also preserved part of their historical features that could provide a different way of development through tourism and the organization of cultural events. Most important of all is also the modification of old architecture in order to adopt modern activities. In this way, consciously or unconsciously, the cities transformed their entity depending on the needs of the citizens and the cultural values of its period. In order to examine the transformation of the cities a number of resources have been used. The location of the survived archaeological monuments were revealed either from the partially preserved monuments or the

information exposed by old maps and archives. Reconnaissance and salvage excavations have also brought to light a number of monuments, some of which have been either retained or they have been covered again in order to proceed with the construction works. Other times, the use of geophysical prospection methods has made possible to map the underlying monuments or find the extension of already preserved monuments (PAPADOPOULOS and SARRIS 2010, PAPADOPOULOS et al. 2009). All the above information has been employed in order to create a geographical database that can indicate the evolution of the historical centers through a time line. A series of more than 25 maps and plots (e.g. BOSCHINI 1651, MEISNER 1642, DE WIT 1620, HOMANN 1716, a.o.) depicting the outline of the architectural features and the expansion of the cities through different periods has been scanned, georeferenced to the today's plan of the cities and digitized in thematic layers that represent different categories of urban space (Fig. 1). The importance of using different historical maps underlies in the fact that the various cartographers gave attention and emphasized different kinds of details. Having the different layers of geographic information, it was possible to investigate the transformation of the cities in various periods in terms of their extension, the density and function of buildings with respect to their location, and examine the way they exploited the landscape (Fig. 2). In this way, it was possible to deviate from static models that are usually employed for capturing the past settings of the urban environments (Fig. 3 & 4). Geographical Information Systems were employed for studying the temporal changes of space and its architectural elements (either being preserved or brought to light by geophysical prospection techniques and subsequent excavations). Virtual reconstructions of buildings, even with low rendering, became capable of providing a more realistic representation of the changes and transformations of the urban matrix. The information of old maps can augment our understanding of the historical development of the towns and cities across many urban details, in a way that written history alone cannot do.

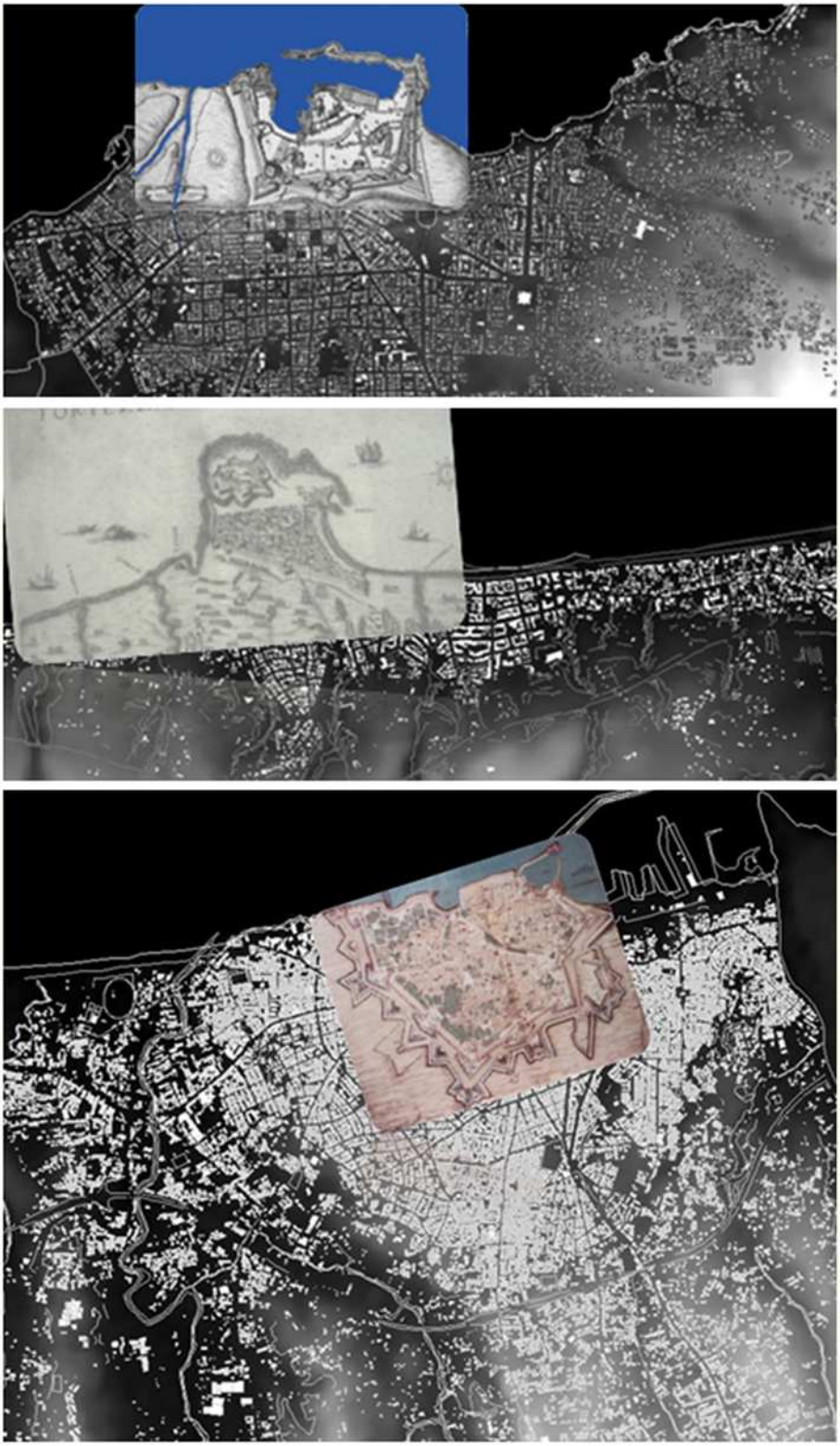

Fig. 1 – Superposition of georeferenced historical maps on the modern cadastral plan of the cities of Chania (up), Rethymno (middle) and Herakleion (down). The process was repeated for a series of maps of different periods and digitization of the most prominent monuments and architectural features followed in order to indicate the changes in the usage of space along the various historical periods compared to today.

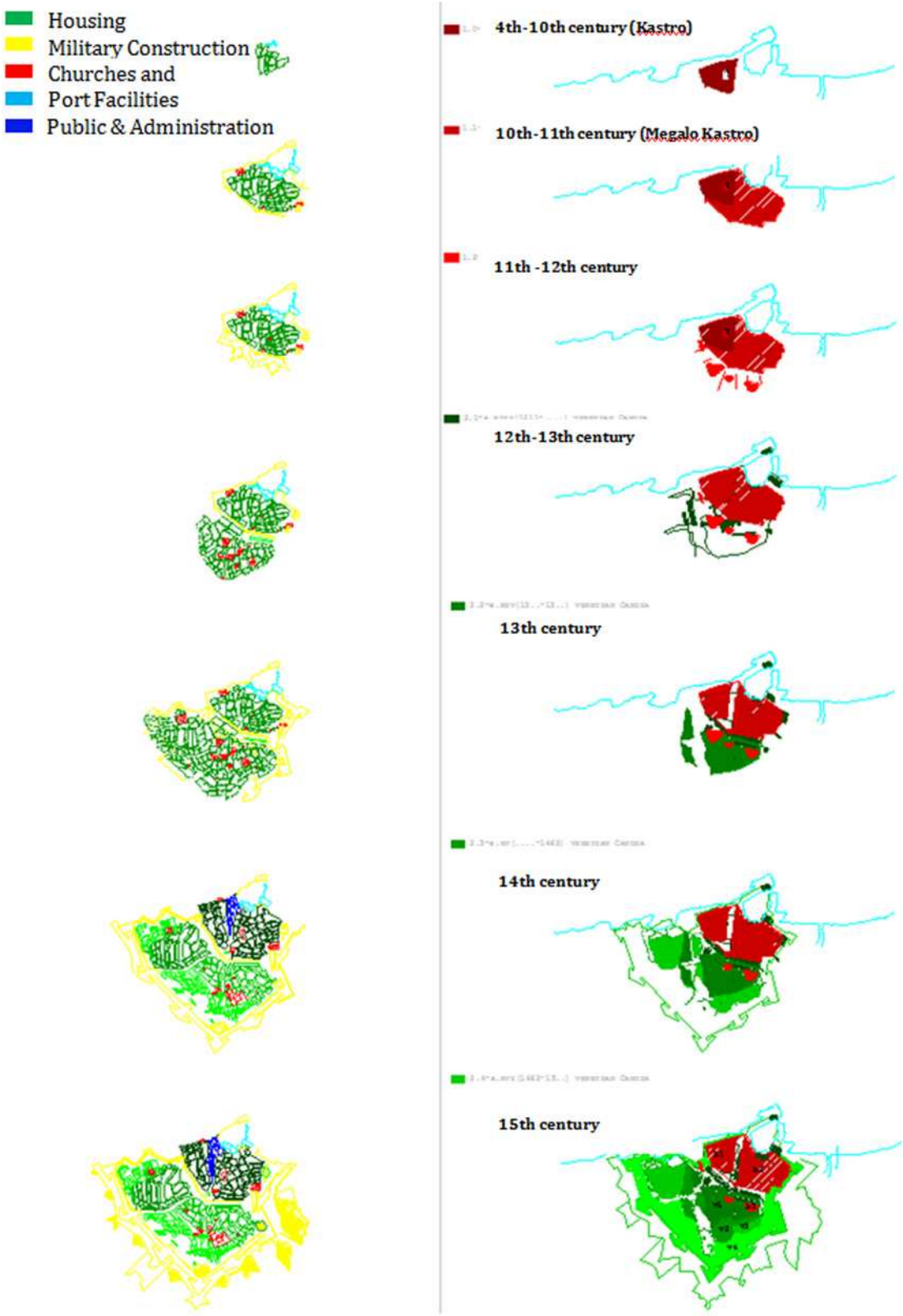

Fig. 2 – Time line evolution of the expansion of the city of Candia (Herakleion) from the 9th to the 15th century A.D., indicating also the differentiation of the function of the buildings.

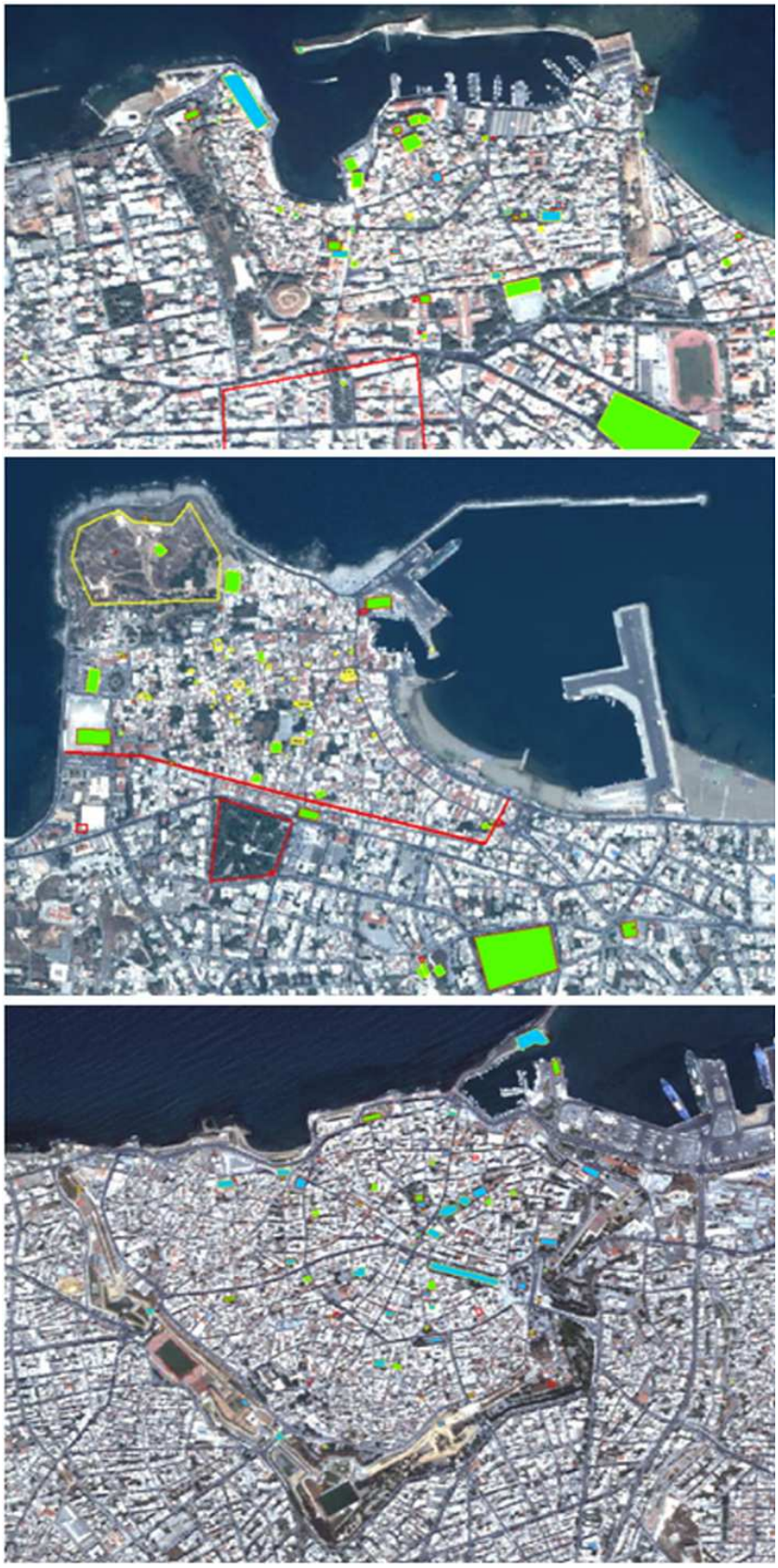

Fig. 3 – Preserved monuments of the Venetian and Ottoman period in the historical centers of Chania (above), Rethymno (middle) and Herakleion (below). A lot of the monuments of the Venetian period (blue & yellow) were reused during the Ottoman period (green). A few of them were also destroyed (red) in the latest phase of urbanization of the cities. The Venetian walls are well preserved in Chania and Herakleion. On the other hand, the Venetian city plan is still preserved in the historical center of Rethymno. The above maps are accessible at the portal: *digitalcrete.ims.forth.gr*.

Fig. 4 – Above: A model of the mid 17th ce. Venetian Candia existing at the Historical Museum of Crete at Herakleion (http://www.historical-museum.gr/en/index.html). Middle: Partial 3D reconstruction of historical buildings at the center of Rethymno, overlaid on the recent layout of the Old city. Below: Part of the monuments exposed across the St. Peter Basilica at the coastal front of Herakleion (Sof. Venizelou Avenue), following the results of the geophysical investigations.

Analysis Results

A complementary character of the urban evolution was followed in all three cities of Crete, using similar construction elements. The cities evolved and expanded in a proportional scale but in a different way. Clearly, the layout and plan of the cities influenced their future evolution.

The main roads of Herakleion followed either a curvature similar to the one of the fortification walls or they were constructed with a direction outwards the shoreline (Fig. 3 & 4). Similar was the situation with Chania, but still there were a number of streets that were running in a parallel direction with the coastline. On the other hand, the main transportation corridors for Rethymno were parallel to the coastline. The particular road plan continued even today as it is reflected from the whole development of the cities, even outside the historical centers. In Herakleion, the old town was facing inland and not towards the sea for reasons of defense. Even today, modern Herakleion is the only city that has turned its back to the sea. In contrast, Chania and even more Rethymno were directly linked to the sea, since the nucleus of their defense was constructed upon hills (Kastelli and Fortezza correspondingly) close to the coast. Even today they have exploited fully the seafront with most of the tourist activities and shops located along it.

As a capital of Crete, Herakleion experienced a large scale expansion and concentrated a large portion of the population within its municipal layout. The city expanded around the venetian fortifications without planning and increased in size through the centuries. The 114 ha Candia of the 17th century expanded over an area of ca. 24 ha in 2010, increasing its population from 34,000 to about 125,000 people. Similar was the growth of Chania and Rethymno which extended over an area of 38ha and 30ha correspondingly hosting a population of 8,000 and 5,200 people accordingly in the late 17th century. In all historical periods, expansion of the cities was around the Venetian walls that acted as a pole of attraction for the whole population and administration purposes. It was only during the last century, that population pressure lead to a more disperse expansion of the urban fabric.

Normalizing all data to the smaller values of Rethymno, the analogies that existed in the late Venetian period seem to have been maintained even today reflecting the complementary role of the three cities (Table 1). On the other hand, small variations of these ratios are representative of the evolutionary differentiations that each city has followed. For example, in terms of the extension of the city plan it seems that Herakleion, followed by Chania, pursued a more accelerated pace than Rethymno (a ratio of 1:2:5 in 2010 compared to 1:1.5:4 in the 17th century). Similar are the analogies in the variation of the population in the three cities for the two different chronological periods. Furthermore, as a consequence of the urban spatial inflation, the nuclear character of the Venetian cities became looser today. Even if the historical centers of all cities are densely populated, the total built surface as a percentage of the total area coverage decreased in all cases: From 33%, 42%, 39% --> 24%, 30%, 21% for Rethymno, Chania and Herakleion correspondingly. However this is not a reflection of the situation within the historical centers of the three cities, since the city with the least preserved monuments (Herakleion) is much more densely constructed than the rest of the cities where there is a larger number of preserved monuments.

17th century	Extension	Free space	Built surface
Rethymno	30 Ha	20 Ha	10 Ha
Chania	38 Ha	22 Ha	16 Ha
Herakleio	114 Ha	69 Ha	45 Ha

2010	Extension	Free space	Built surface
Rethymno	531 Ha	401 Ha	130 Ha
Chania	1083Ha	757Ha	326 Ha
Herakleio	2389Ha	1873Ha	516 Ha

Ratios	Extension	Built Space
Venetian Period (17th ce.)	1 : 1.5 : 4	1 : 1.5 : 4.5
Today	1 : 2 : 5	1 : 2.5 : 4

Table 1 – Data concerning the extension, free space and built surface of the three main cities of Crete in the Venetian (17th ce.) period and today (2010).

The preservation of the Venetian and Ottoman architectural monuments created a number of open areas that today constitute the lung of the cities. It is the places that comprise some of the most well known landmarks of the cities, meeting places, parks, areas of green (e.g. the walls of Herakleion, the castles of Fortezza and Firka at Rethymno and Chania correspondingly, a.o.) or even areas that are under protection from modern development plans, where citizens and tourists gather on purpose to avoid the usual traffic and noise of the modern city. Just to focus to the city of Rethymno, whose historical center remains one of the best preserved compared to the rest of the cities, fusing at the same time the Venetian, Ottoman and Cretan architectural influences. The small Venetian harbour of Rethymnon, with its 13th century Venetian mole and the Ottoman lighthouse, is still one of the main attractions of the city. It was still in use up to a few decades ago and today hosts a number of tourist stores that draw the attention of the visitors. The Rimondi Fountain, constructed in 1626, is located in the heart of the old town of Rethymno and it is still in operation and constitutes the center of the activities of the old center. The Venetian Loggia, today hosting the Archaeological Receipts Fund of the Ministry of Culture, is one of the most well preserved venetian buildings of the 16th century that used to be a meeting place for the Venetian mobility. A church of the Augustinian Priory, dedicated to the Virgin, was converted to Nerantze Mosque, which today hosts the Municipal Odeon. The one-aisled basilica of Saint Frangiskos church, built in the Venetian period, was converted to a poorhouse during the Ottoman period and most of the complex has been destroyed. Although there are no detailed plans of the basilica, geophysical investigations (ERT and GPR) that were carried out in the area (currently the yard of the old Turkish school that still operates as a primary school) outlined the extent of the complex and its compartments (PAPADOPOULOS et al. 2008). Following the geophysical investigations and

excavations in the particular area which is next to the Nerantze Mosque, the largest section of the yard became one of the new large squares of the old center of Rethymno and the point of reference for a number of cultural events. Finally, the Great Gate, being the main entrance to the old city and almost the only remaining feature of the venetian walls that were demolished after the Ottomans took over the city, leads to the central Four Martyrs square of modern Rethymno.

Final Remarks

Today the roles of the cities of Crete have changed completely compared to that of the past, but the influence of the monuments has been cumulative. However, the expansion of the cities followed a parallel direction through all the periods, and in cases where the old center remained as much intact from modern interventions, it retained its attraction not only in the tourist period but also in everyday life activities. The extensions of the cities tried to keep apart the old and new sections of them, especially in Rethymno and Chania, where the old centers were retained to a large degree. On the other hand, in Herakleion the new architecture invaded the old neighborhoods and hided to a large degree the isolated monuments (Fig. 5).
The architectural losses that the Cretan cities suffered were not the same in the three cities. As a result the perception of them is totally different in each one of them. The strategic location of Herakleion in Crete and also in the central Aegean promoted it to one of the largest cities of Greece (the fourth in population). Unfortunately, the city's monuments and artistic heritage were severely damaged by natural disasters and wars, more than the cases of Chania and Rethymno. As a consequence of this and the absence of planning in the post-2nd WW period, the reconstruction of Herakleion was carried out without following the main plans of the Venetian center, but instead it followed an anarchist plan with constructions erected both within the historical center and around the venetian walls. Soon, the brutal wave of the expansion of the city had to face the trend of rediscovering the old values of the city that were hinted in the surviving monuments and architecture.
Still, the adoption of the historical architecture and monuments in the modern activities of the cities has played a essential role in the perception of the monuments from the citizens themselves. Even in Herakleion, the fortification walls are hosting main roads (Fig. 5), museums and tourist points, sport centers, new public buildings, a.o. Large venetian houses are hosting cultural centers, administration departments or commercial facilities. Most important of all, the existing monuments provide free open space for the citizens to move and for the city to breath.
Having gone through a number of historical phases, the cities of Crete did not remain intact. Some monuments were destroyed, other were preserved or renovated. Monuments were transformed to satisfy the present needs. Generally speaking, the cities did not remain in a "frozen" state, but instead they evolved using the modern architectural trends (even sometimes without a precise design planning), adopting at the same time, consciously or unconsciously, the retained historical architecture. This allowed a free expression of the evolution of the city, keeping in its own way the continuity and ties with the past.
The problem of fusion between the modern architecture and the historical monuments has been the subject of numerous discussions, without however to be possible to conclude on a single direction of action (HORLER 1975). Progress against tradition? Construction works and innovative architecture against

protection of the monuments? The past against the present and the future? These kind of dilemmas are actually fake as we realize that they are not contradictory to each other since they mark continuation in time and space. The presence of monuments and historical architecture does not merely reflects the links with the past, but it also demarcates the continuity of a living organism, in which citizens coexist and constitute basic elements of it. Monuments need not to be isolated, but instead to become an integral part of everyday life activities. Neither to exist in frozen districts and/or be unreachable to the citizens. Bringing monuments and historical buildings close to the people is possible to revitalize not only whole sectors of a city, but alter the general character of it, as well as the attitude of the citizens. In this way, monuments will not be considered as an obstacle to development, but instead as the motor for a more holistic promotion of the urban environment.

"*In vain, great-hearted Kublai, shall I attempt to describe Zaira, city of high bastions. I could tell you how many steps make up the streets rising like stairways, and the degree of the arcades' curves, and what kind of zinc scales cover the roofs; but I already know this would be the same as telling you nothing. The city does not consist of this, but of relationships between the measurements of its space and the events of its past … As this wave from memories flows in, the city soaks it up like a sponge and expands. A description of Zaira as it is today should contain all Zaira's past. The city, however, does not tell its past, but contains it like the lines of a hand, written in the corners of the streets, the gratings of the windows, …"* Italo Calvino, Invisible Cities.

Fig. 5 – Details from a number of preserved Venetian monuments that exist around the city of Herakleion. Apart from isolated private houses (left), there are also monumental structures such as the fortification walls (upper right) and the port facilities (lower right). It is monuments like this that provide the character and identity of the city.

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S.I.T.A.R. – Sistema Informativo Territoriale Archeologico di Roma

A repository of archaeological data for conservation of cultural heritage and town planning

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Abstract: Beginning in 2008, the Soprintendenza Speciale per i Beni Archeologici di Roma launched the S.I.T.A.R., the territorial information system dedicated to recording archaeological data of the *Urbs*.
S.I.T.A.R. meets the primary needs of the Soprintendenza: protection, development and preservation of the exceptionally rich archaeological heritage of Rome. The system is a complex tool for the organization of the available data from the whole of the urban area, and it provides invaluable support in the process of urban planning.
The project follows the guidelines of INSPIRE, Infrastructure for Spatial Information in the European Community, set by the European Parliament and European Council (Dir. 2007/2/CEE of 14 March 2007).
The system manages very diverse types of data sets, ranging from large monumental contexts to single archaeological features found in rescue excavations; it also records all of the scientific data deriving from the entirety of the investigations (both salvage ones and planned ones) carried out in the territory of the Soprintendenza.
In the future, the system will function as the information center and general repository for all of the results of the various research projects carried out by the different offices involved in the preservation of the archaeological and historical heritage of Rome. Because of its modular logical architecture, the system is highly adaptable and will allow for interaction and exchange with new or existing public information systems that will become available to the offices working in the territory of Rome; this, in turn, will lead to the mutual utilization of the archaeological data and the integrated management of the recorded archaeological resources.
The overall goal of the S.I.T.A.R. project is to publish the recorded and interpreted data using the standards and technologies of WFS and WMS, in order to share the descriptive and spatial databases with the other offices that deal with town planning; this will also foster interaction and encourage the use of new methods for the spread of knowledge and the exploitation of the urban archaeological heritage.
The various aspects of the project are presented in posters illustrating the details of the methodology used in data acquisition and elaboration, the implementation of the webgis, and the experimentation with the use of the available three-dimensional data to reconstruct the morphology of the territory in different time periods.

Keywords: Roma, IDT, Webgis, Open-source, Urban archeology and town planning.

S.I.T.A.R. – Sistema Informativo Territoriale Archeologico di Roma: A repository of archaeological data for conservation of cultural heritage and town planning

SITAR is a project launched by the Soprintendenza Speciale per i Beni Archeologici di Roma (the acronym of which is SSBAR) aimed at recording archaeological data. Following the the European Parliament and European Council INSPIRE structure, Infrastructure for Spatial Information in the European Community, and the technological Guide lines of the Italian Ministry of Cultural Heritage, SITAR will be able to meet the scientific research requirements as well as those of the institutions in charge of city planning, by recording all the administrative and scientific data deriving from the whole range of the investigations and sharing it using a web-publishing platform based on OGC standards, also WFS and WMS technology, with the institutions in charge of city planning.

Fig. 1 – An example of actual relationships between the ancient Urbs and the contemporary City (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

Day by day, Rome – like all other western metropolitan cities – lives a divide between its quick developing rhythm (Fig. 1) and the eternal question on how much its historical skylines must be preserved and how much the new contemporary architectures should shadow the ancient ones. Rome has probably a bigger responsibility than all the other cities of the world, not because wants to maintain a Rome-centred vision of history or because, as it is often mistakenly said, Italy has 50%?, 60%?, 70% or 80%? (… these are just numbers, for us …) of the world heritage monuments, but because in Italy there has been a widespread culture of ruins’ conservation since the XVI (sixteenth) century (Fig. 2).

Fig. 2 – An historical view of the mausoleo of Cecilia Metella along the ancient via Appia, one of the most popular roman age monuments of Rome (Copyright (c) Davis Museum and Cultural Center, Wellesley College 2010).

Fig. 3 – “Via dell’Impero. Nascita di una strada” (Copyright: www.museicapitolini.org).

There were law-constraints established in the so called STATUTI for the preservation of ancient monuments a long time before the Italian unification of 1861. But it is in 1939 that the first national legislation about heritage landmarks was promulgated. It was an extraordinary law both for the historical context in which it was promulgated and for the modernity and actuality of the principles it established.
The ruins, the churches, the medieval castles, or the aristocratic palaces of the modern age are integral parts of many towns, they are the identity system of the nation, and everybody, from any cultural background, gives them a huge value; they are the country main patrimony.
Although Rome‘s conservation is extraordinary, the town was not exempted from some of the crucial passages of the post-war urban spread (Fig. 3) which have deeply marked and in some cases scarred the town.
Many public or private transformations, restorations, change of use acts or building of new areas have pierced Rome above or underground, in the historical centre and in the suburbs (Fig. 4).

Fig. 4 – Contemporary archaeological surveies in the developing Suburbs of Rome (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

As Prof. David Bibby says “Whatever the viewpoint, the special challenge presented by archaeology in an urban environment has become a motor, an impulse-giver, for development and innovation – in project design, excavation philosophy and technology. The insight into the material culture of historical towns and cities provided by urban archaeology has augmented our understanding of their historical development across all social classes”.
In the last few years an important role has been played by Urban Archaeology even though it isn’t always gone hands by hands with the methods of archaeological evaluation and the new technological devices from nearby scientific fields.

Even though Rome has developed a sophisticated Urban Archaeology using modern technology and the synergy of professional people and universities, yet it has not a social mission and it has not designed its deep hermeneutical function.

This is the background against which the Soprintendenza Speciale per i Beni Archeologici di Roma, one of territorial Offices of italian Ministry for Cultural Heritage, deals with its institutional mission. It guarantees the safeguard of the archaeological heritage of the city and its metropolitan territory and it participates, because of its primary function, to the planning of the urban and architectonical evolution of the historical centre and the suburbs.

This is also the background for the governance of the territory against which the Soprintendenza of Rome started the SITAR Project to carry out the first Geographic Archaeological Information System of Rome. The first project aim is to digitize all scientific and administrative data stored in the office paper archives and produced daily during the archaeological and geological researches.

On an operative point of view, we must remember that the archaeological information is very complex. We need to know it, manage it and communicate it. For this reasons we need all new web-based technologies, possibly open-source, which can achieve well built and flexible information architectures. The web-applications, like a webgis for example, guarantee an implementation and quick update of the system functions and they don't require special hardware and software equipments.

So beginning in 2008 the SSBAR launched the S.I.T.A.R., a Project for recording, managing, archiving, using and exchanging archaeological territorial data.

As a project and a System created and developed by SSBAR itself, S.I.T.A.R. meets the primary needs of the Soprintendenza: protection, development and preservation of the exceptionally rich archaeological heritage of Rome.

SITAR 's main goal is to provide invaluable support in the process of urban co-planning, shared with the others public Administrations.

The Project SITAR follows the guidelines of INSPIRE, Infrastructure for Spatial Information in the European Community, set by the European Parliament and European Council (Dir. 2007/2/CEE of 14 March 2007), and the national standards issued by italian Ministry of Cultural Heritage for codifing public GIS projects and the new approches to the analisys of archaeological heritage (in example, the recent guidelines for the Archaelogical evaluation or for the study and control of Seismic Risk on archaeological buildings).

The SITAR will function as the information center and general repository for all of the results of the various research projects carried out by the different offices involved in the preservation of the archaeological and historical heritage of Rome.

Because of its modular logical architecture, the system is highly adaptable and will allow for interoperability and data exchange with new and up-to-date systems that will become available to the offices working in the territory; this, in turn, will lead to the mutual utilization of the archaeological data and the integrated management of the recorded archaeological resources.

In details, the SITAR is a unique, multi-tasking tool for the organization of the available scientific and administrative data from the whole of the urban area of Rome.

As an Information System, SITAR brings together many various types of data sets, ranging from large monumental contexts to single archaeological features found in rescue excavations done in the territory of Rome.

The overall goal of the S.I.T.A.R. project is to publish the recorded and interpreted data using the standards and technologies OGC compliant, as the WFS and WMS standards, in order to share the descriptive and cartographic databases with the other offices that deal with town planning. This will also foster a true interaction with others public Information Systems and encourage the search, study and use of new analitics methods for the spread of knowledge and the exploitation of the urban archaeological heritage.

The various aspects of the SITAR are presented in two posters (Fig. 5):

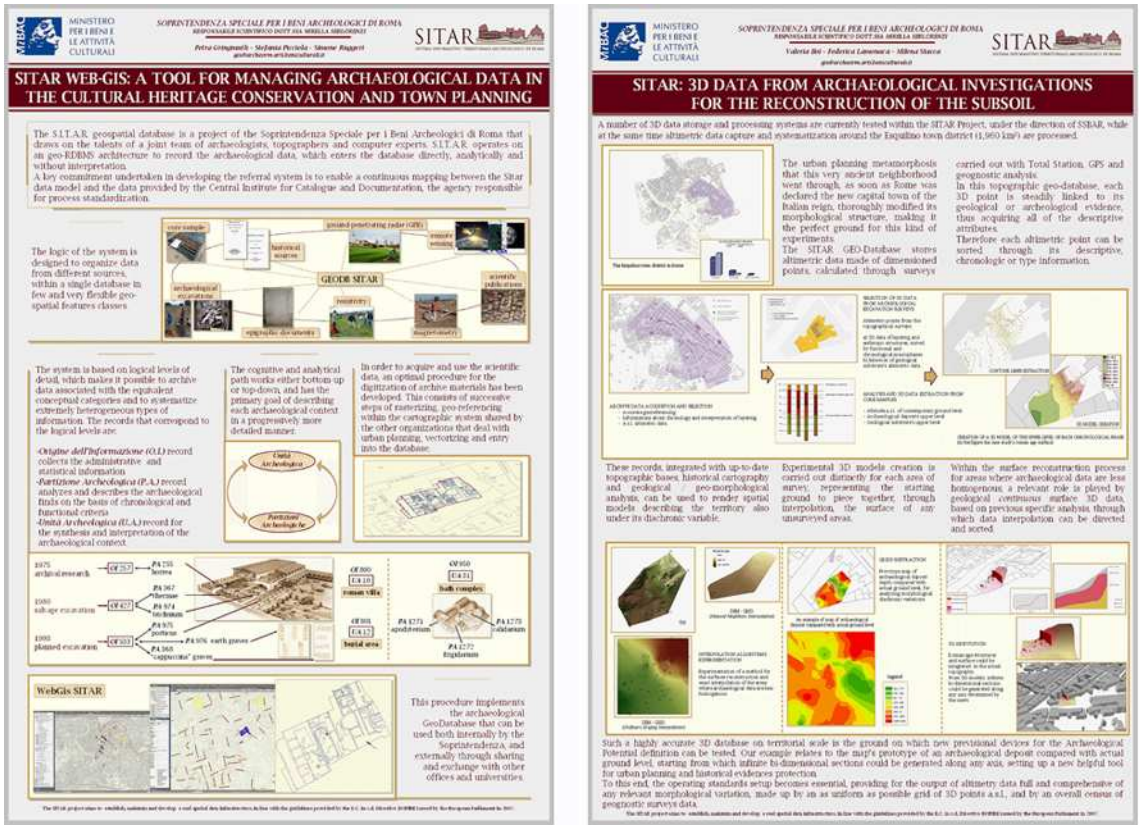

Fig. 5.1 and 5.2 – The two SITAR posters presented at the 15th International Conference on Cultural Heritage and new Technologies – 2010 (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

The first one, edited by Petra Gringmuth, Stefania Picciola and Simone Ruggeri (see their contribute in this publication) illustrates the details of the methodology used in data retreival, acquisition and digitization, while the second one edited by Valeria Boi, Federica Lamonaca and Milena Stacca (see their contribute in this publication), illustrates our first experimentations with the use of the available three-dimensional data to reconstruct the morphology of the territory in different time periods.

The logic of SITAR is based on 4 primary information layers and a fifth still in development (pay attention to the fact we don’t give the translation of italian definitions of our geospatial features classes, but we try just to explain them briefly) (Fig. 6):

NAME OF THE RECORD	DATA PROCESSING	RESULTS
Origine dell'informazione	Information	Data Origin
Partizione Archeologica	Description	Data Analysis
Unità Archeologica	Interpretation	Data Synthesis
Vincolo Archeologico	Contextualizing UA	Punctual Preservation
Potenziale Archeologico	Estimation	Project

Fig. 6 – Logical schema of primary five levels of SITAR (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma).

– the s.c. ORIGINI DELL'INFORMAZIONE: the administrative and scientific information of every single archaeological digging or geophisical/geological survey (in others words the sources of information);
– the s.c. PARTIZIONI ARCHEOLOGICHE: the scientific description of the archaeological findings even if fragmentary, following the chronological or functional criteria;
– the s.c. UNITÀ ARCHEOLOGICHE: derived by the logical union of more 'partizioni archeologiche' which together makes an archaeological complex (for example a specific building);
– the s.c. DISPOSITIVI DI VINCOLO: the law-constraints which punctually preserve the important monuments but not their contexts;
– finally, the s.c. POTENZIALE ARCHEOLOGICO (we try to translate it with "archaeological potential"): it is generated by the logic union and super-interpretation of the base layers. Local authorities and institutional bodies must bear the 'potenziale archeologico' map in mind when working on the urban development of a territory.

In the SITAR information architecture the four primary levels correspond to well structured archives which includes all corresponding spatial data shown in the map of the various features classes.

The archive of 'ORIGINI INFORMATIVE' guarantees the fundamental data recording of every single research intervention, or preservation or study carried out on Rome's territory.

The archive of 'PARTIZIONI ARCHEOLOGICHE' is a kind of Cadastre database finalized to the census of the archaeological and historical presences in the territory of Rome. As said, it uses all types of data and it allows we to quickly record different types of information.

The 'UNITÀ ARCHEOLOGICHE' correspond to the textual and spatial descriptions of the whole monument, its peculiarities and details. They show their actual and original dimensions.

The 'UNITÀ ARCHEOLOGICHE' become the new conceptual detail from which we can move towards the topographical reconstruction of the ancient settlements, also to allow the new town to respect the old settlement and create an innovative relationship with it.

The 'UNITÀ ARCHEOLOGICHE' will become the basis for the analysis of the archaeological evaluations which are a predictive tools to plan both the preserving of ancient deposits and the co-planning of new

settlements. Bringing together the old and the new data on the same map will give city planners a deeper knowledge of the urban territory.

After two years of work, most of which spent on planning the system, the SITAR workgroup has digitized about 10.000 records. We are now recording a new set of data coming from an exchange with the University of Roma-Sapienza and this exchange project shows us how to optimize human and financial resources (Fig. 7).

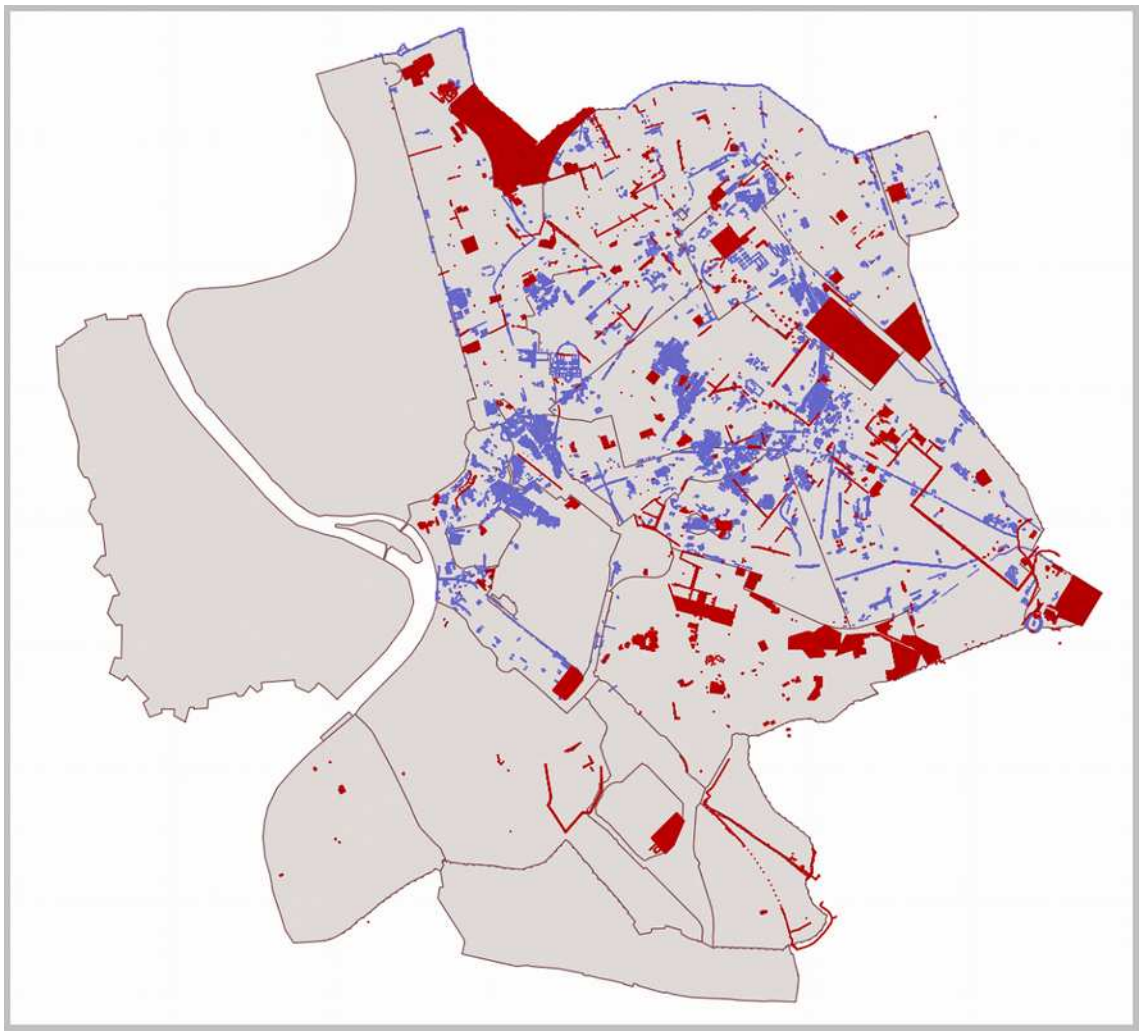

Fig. 7 – An example of interoperability between the SSBAR' SITAR Project and the Atlante of Ancient Rome edited by University "Sapienza" of Rome – Cattedra di Archeologia e Storia dell'Arte Greca, Prof. A. Carandini. An overview of the urban center in roman age, inside the Aurelian walls (Copyright: MiBAC – Soprintendenza Speciale per i Beni Archeologici di Roma | University "Sapienza" of Rome – Cattedra di Archeologia e Storia dell'Arte Greca, Prof. A. Carandini).

The SSBAR has now established new graphic standard criteria which must be followed also by each independent researcher on the territory of Rome. The data collected and sent to the Soprintendenza will automatically feed the system.

Today the information technology science develops very quickly and to keep the pace our system should be aligned progressively with the concept of the over and over self-expanding ‘cloud computing’.

We also need to develop the extraordinary potentials of 3-D informations which many dedicated softwares already support and that we think will be the near future of GIS.

We also think that the future of the systems will be tied to the new forms of geo-social networking developed thanks to the huge investments made by the giants of global communication (such as Google, Microsoft, etc.) (Fig. 8).

Fig. 8 – An idealization of the SITAR' idea of geo-socialnetworking: working and thinking both individually and toghether, but in the same framework (Copyright: http://lavitadellalavandaia.splinder.com).

The general public is fascinated by the huge amount of geographical, cultural and commercial informations it can retrieve from the web and the social networking, because it satisfies its need to individually process public data.

So the new frontier of urban archaeology is also to become a social network capable of being again a cultural element of great appeal and capable to educate the Citizens in order to share the destiny of our cultural heritage.

We believe that this is the only way to really preserve the historical landscapes because it will be the same people to want it.

We want to thanks all Persons that every day work with us at the SITAR project and, like us, are thinking that … (Fig. 9):

Fig. 9 – The Wiener Secession building (Copyright: http://www.panoramio.com).

Acknowledgement

This contribute is due to a large Workgroup, or better a *Family*, that corresponds at the name of SITAR. This Workgroup has been represented at the 15th Conference on Urban Archaeology at Vienna, by our dear Collegues Valeria Boi, Petra Gringmuth, Federica Lamonaca, Stefania Picciola Milena Stacca and Simone Ruggeri, sharing with us that important event, but all the Others Collegues were virtually present to substain the common SITAR’ philosophy.

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Links

SITAR: http://www.commissario-archeologiaroma.it/opencms/export/CommissarioAR/sito-CommissarioAR/Strumenti/Cartografia/index.html

Soprintendenza Speciale per i Beni Archeologici di Roma: http://archeoroma.beniculturali.it/

Program of the first convention on SITAR – Roma, Palazzo Massimo 26. 10. 2010: http://lnx.aiac.org/agenda/2010/Allegati_2010/locandina%20sitar.pdf

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Strategies and new technologies for urban archaeology: Matera, a town of UNESCO World Heritage

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Abstract: In the frame of the three last decades of experience in Italian urban archaeology, we are working to reconsiderate the dynamics of growth/development/fall of urban sites in south Italy, in particular in the region of Basilicata. The history of ancient towns in this area has been characterized by a low number of urban settlement in ancient greek and roman period, in which we are able to recognize the topographical transformation through late antiquity until the middle age, due to archaeological investigations. The majority of ancient towns has been abandoned, and the new towns were located just close to the old ones, so we can talk about “archaeology of towns”, but a very particular situation is represented by the town of Matera, one of the most famous rupestrian settlement of the Mediterranean basin, mentioned in the UNESCO World Heritage List. This is a “archaeology in town” case of study in which we are applying a multidisciplinary approach to reconstruct the history of this particular case of urban settlement. The use of data coming from stratigraphic excavations, archives, written sources, maps and ancient cartography, archaeobotanical and anthropological studies, geoarchaeology is focused to realize an archaeological and historical Map as a tool for the local bodies, the scholars and the public and to give contents for a project dedicated to the realization of the virtual museum of the town.

Keywords: Urban Archaeology, Matera, UNESCO, GIS, Antiquity, Middle Age.

Urban Archaeology in Italy

Italy is characterized by a significant imprint of the ancient civilization and therefore represents a privileged observatory to investigate the issues relating to the history of urban transformations through the centuries, particularly complex during the transition between Antiquity and Middle Ages, in which there have been significant cultural changes that have shaped the topography of towns.

The archaeological survey in urban areas has answered many questions related to major changes that the crisis of ancient society has resulted in the organization in urban centres, from transformations of urban models to the displacement of inhabited settlements between plains and entrenched positions, from the function and the transformation of the city walls and public Romans monuments, and their reuse, to the location of worship places and cathedrals.

Assuming that the Italian towns, in most cases, are characterized by a substantial continuity of settlement from ancient times to the present day, we consider, under the definition of urban archaeology, the study of multilayered urban subsoil deposits, integrated by the stratigraphic analysis of ancient buildings, aimed to the reconstruction of the topography of the different urban life periods.

We have to introduce some words on the current situation of Urban Archaeology in Italy (BROGIOLO 2010). From the first experiences during the Eighties in Lombardia, north of Italy, many others were following in Tuscany, Latium, Veneto and Emilia Romagna. We remember here the Project C.A.R.T. (Archaeological and Landscape risk Map) of Modena, the Archaeological potentiality Map of Faenza, the Archeological Map of Como, the Archaeological Map of the Region of Veneto, the Archaeological Maps of Naples and Rome, the Map of Cultural Heritage of Apulia. In these last decades the debate have been hugely increased by the analysis of late antique and medieval towns in the south of Italy (Campania, Apulia, Calabria), where archaeological excavations and historical studies has offered a new perspective to considerate the transformation of urban landscapes (for a synthesis: SOGLIANI 2010; VOLPE 2010; VOLPE and GIULIANI 2010).

Due to these important Projects, it is now well known as the instrument of the Archaeological Map, with its double meaning of Map of the archaeological potential and map of archaeological risk, reveals its fundamental role in modern urban planning.

The Map is useful for the preservation of the archaeological heritage and the development of enhancement programs of sites and of cultural heritage, while providing aid to effective territorial management, through the development of planning, in terms of protecting the common cultural heritage, the infrastructure economy and the highlighting of historical landscapes. Moreover its scientific goals are manifested in the possibility of reaching an optimum knowledge of the area, both urban and suburban, which allows us to understand the articulation of the settlement choices made in the past, functional to the needs and the potential of specific areas.

The implementation of an archaeological and historical Map restricted to urban reality is without doubt a considerable effort, especially when you are faced with a paucity of data collected during unsystematic investigations or at least not conducted according to modern methodologies of study. But we are convinced that it must be the basis both for archaeological investigation and for safeguard intervention of cultural heritage, particularly in urban areas, where many changes through the centuries and the reuse of buildings and plans produced a massive cultural stratification, very difficult to understand, if not dealt with specific tools to coordinate the investigation.

Actually in Italy, the realization of this kind of tools is a compulsory contribution in the frame of the recent law on Preventive Archaeology, essential when the development of a site may alter or destroy valuable archaeological deposits (AA.VV. 2010; MALNATI 2005; D'ANDREA and GUERMANDI 2008). Preventive archaeology brings the great advantage of nationwide coverage and the accumulation and study of detailed results from these last years of preventive archaeology have dramatically renewed and reshaped our understanding of the past. Finally, after nearly one and a half centuries of radical territory transformations without a proper conservative policy, there came a definition of a preliminary approach to archaeological issues. In the frame of Preventive Archaeology, the data coming from urban archaeology investigation, processed on GIS platforms, and composed inside the archaeological risk Map of towns, represents a compulsory instrument to reach scientific, urban planning and cultural needs of the civil modern communities.

Moreover, these actions are compliant to the European standards already formulated in 1992 within the European Convention on the Protection of the Archaeological Heritage of Malta – La Valletta, involving the

application of laws, aimed at reconciling aspects of the archaeological and monumental heritage conservation and those of economic development.

In the frame of this methodological approach, in these last years we afforded the archaeological study of urban centres in the Region of Basilicata (South Italy) (Fig. 1), through an interdisciplinary approach based on studies of historical documentation; digitization of ancient maps and cartography; study of archaeological materials coming from old and recent excavations; stratigraphical excavations; study of building techniques; spatial analysis; geoarchaeology; archaeobotanical and anthropological inventories; geomorphology; databases compliant to GIS 3D and laser scanning technologies for archaeological heritage recording.

Fig. 1 – The geographical map of the region of Basilicata and the location of the town of Matera (D. Roubis).

The case-study of Matera

The case-study of the town of Matera (Fig. 2) reveals a particular interest, both for its geomorphologic characteristic and its urban development from antiquity to modern time.

Fig. 2 – Matera, a view of the old town from the Gravina (photo Authors).

Fig. 3 – Matera. The slopes of the Civita (left); a view of the Civita from the Gravina (right) (photo Authors).

The Sassi district, basically the major part of the historic town of Matera, is probably one of the most clear cases of the persistence of rock cave dwelling practices up to modern times. Recently a series of researches and efforts allowed for the admission of Matera into the UNESCO World Heritage sites list and caused the following rehabilitation of many areas, since their forced abandonment in the Fifties of last century (http://whc.unesco.org/en/list/670). The case of Matera has shown that the settlements of the Sassi district has been developed over a long span of time defining technical solutions, living practices, therefore civilizations, that are directly linked with the human knowledge and experiences in transforming the natural landscape. Such patrimony is in between the monumental architecture and the urban landscape feature as none of the buildings can be considered *per se* but the whole makes the difference. Matera (Fig. 3) could be

considered the paradigm of *negative architecture*, typical of rupestrian settlement, where it is possible to observe a very particular stratigraphy of empty hypogeous built-spaces, with building *sub-divo* on top; in this way the rocky bank is both the basis for built structures and the reservoir supply of the raw material for constructions.

This study is part of a bigger ongoing Research Project on the Historical and Archaeological Map of the town (COLUCCI et al. 2008; SOGLIANI 2010), aimed to recognize the development of the town between the first settlement to the reinforcement of the urban physiognomy during the Middle Ages. We try to address our attention to build a core group of knowledge that represents the first synthesis of the studies that have analyzed the urban evolution, on the base of old archaeological investigations, recent archaeological data and of the conservation of urban stratification. This approach wants to be useful to a preventive evaluation of the potential impact of building work on the archaeological and architectural ancient urban heritage and to the consequent planning of structural works and infrastructure projects. Moreover the increasing of recent urban intervention for public works in the frame of urban refurbishment projects, are coming to interest some important monuments and parts of the town, as the Civita, with the Cathedral, or some residential and others religious area of the medieval town. Consequently it is fundamental to supports these actions with a correct archaeological investigation plus a complete registration of data on GIS repository (Fig. 4). Concerning the archaeological reconstruction of the town of Matera from antiquity to late Middle Age we compose all the data inside a GIS System to indicate the density of archaeological and monumental evidences through the centuries.

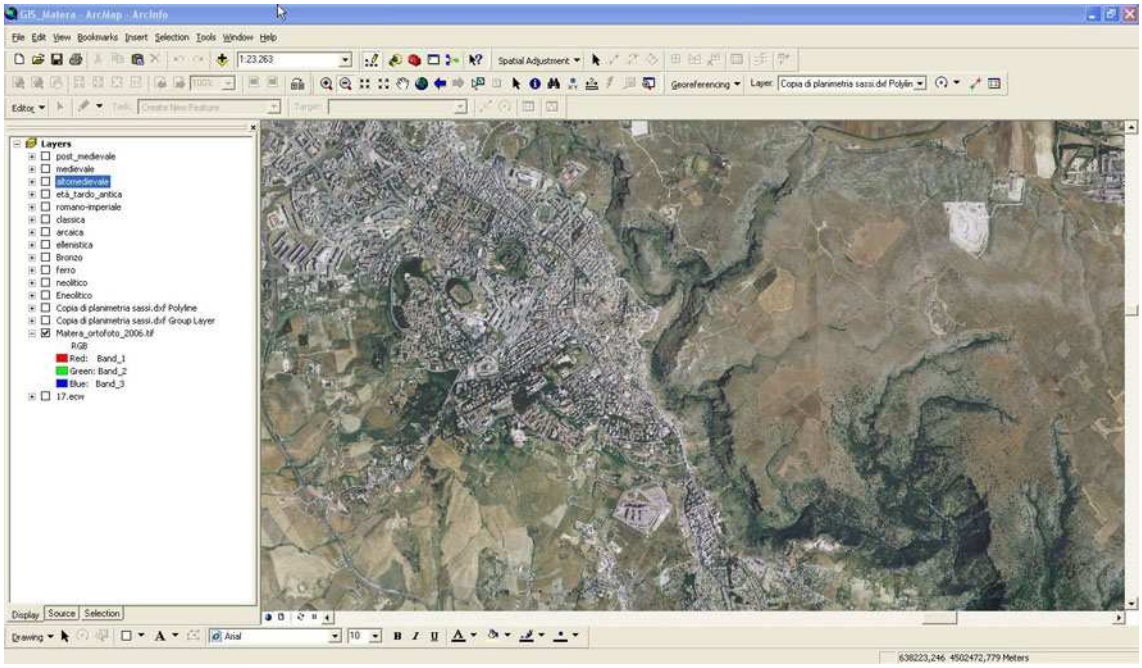

Fig. 4 – Matera. The GIS layer with the ortophotografic plan of the town.

The results

The area occupied by the ancient settlement is located on the hilltop of the Civita (400 m asl) (Fig. 5), which rises to divide two natural valleys, to the north the Sasso Barisano and to the south the Sasso Caveoso. The

area has been inhabited dating back to the Bronze Age, attested in the area of the Civita and its surrounding and subsequently during the Iron Age.

Fig. 5 – Matera. The aerial photo of the town (1989) (FONSECA et al. 1999).

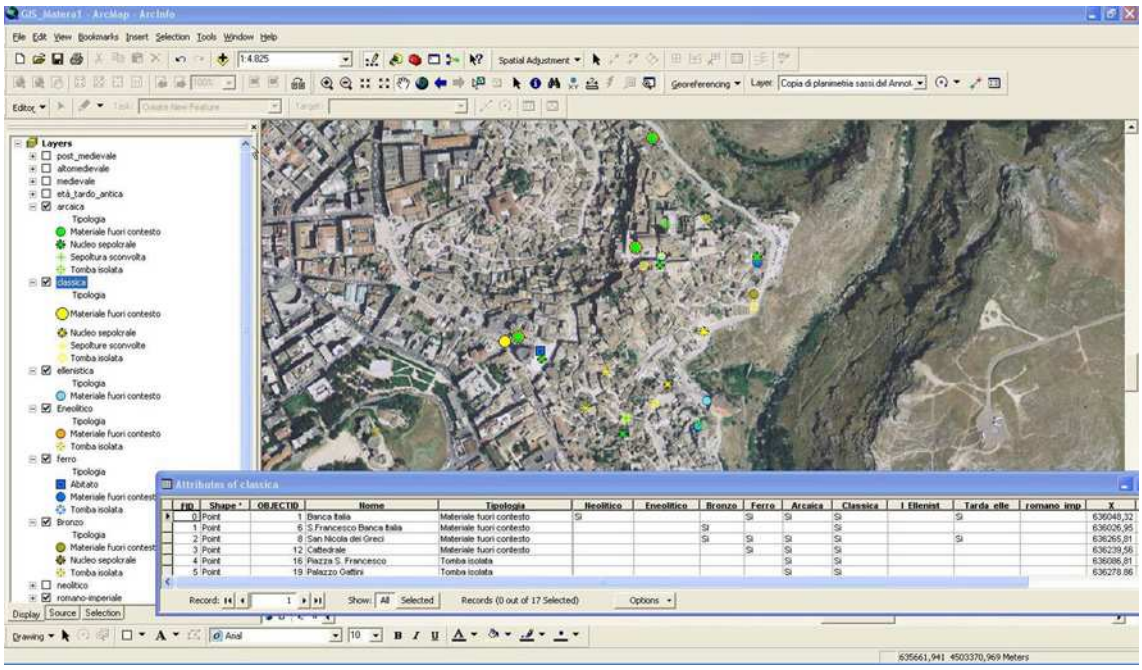

Fig. 6 – Matera. The GIS layer for the classical period.

The permanent settlement seems to continue, despite a scarcity of evidences, including greek and roman period, which appear as the most critical stages in the understanding of the settlements development. The paucity of ceramic and epigraphical evidences and overall their decontextualization doesn’t support effective topographical reconstruction of the *forma urbis* in roman period (Fig. 6). The same is for late antiquity, considering the lack of previous urbanistic character of the settlement and the very particular orographic configuration of the site, which are conditioning the comprehension of topographical transformation.
Items such as "multilayered urban site", but even more "orthogonal plan", "public spaces and residential areas", used as keywords to recognize urban transformation for most of the cities in which it was revealed the significant legacy of the urban classical age, in this case should be reformulated, taking into account the limits established by the very few written records on late ancient and early medieval age and the rare archaeological interventions.
The location of Matera, yet in the first Byzantine era, was not totally peripherical, due to the connection with the *via Appia* through secondary routes, which allowed, during high medieval period, the communications with the region of Apulia. In the “Itinerary of Guidone” (beginning of the 12th century) (Fig. 7), on the base of the “Cosmographia of Anonimo Ravennate” (7th century), Matera is part of a journey that from Oria ended in *Grumentum*, passing through Taranto, Mottola, Castellaneta, Montescaglioso, Gravina, Banzi, Acerenza and Muro (DALENA 2006).

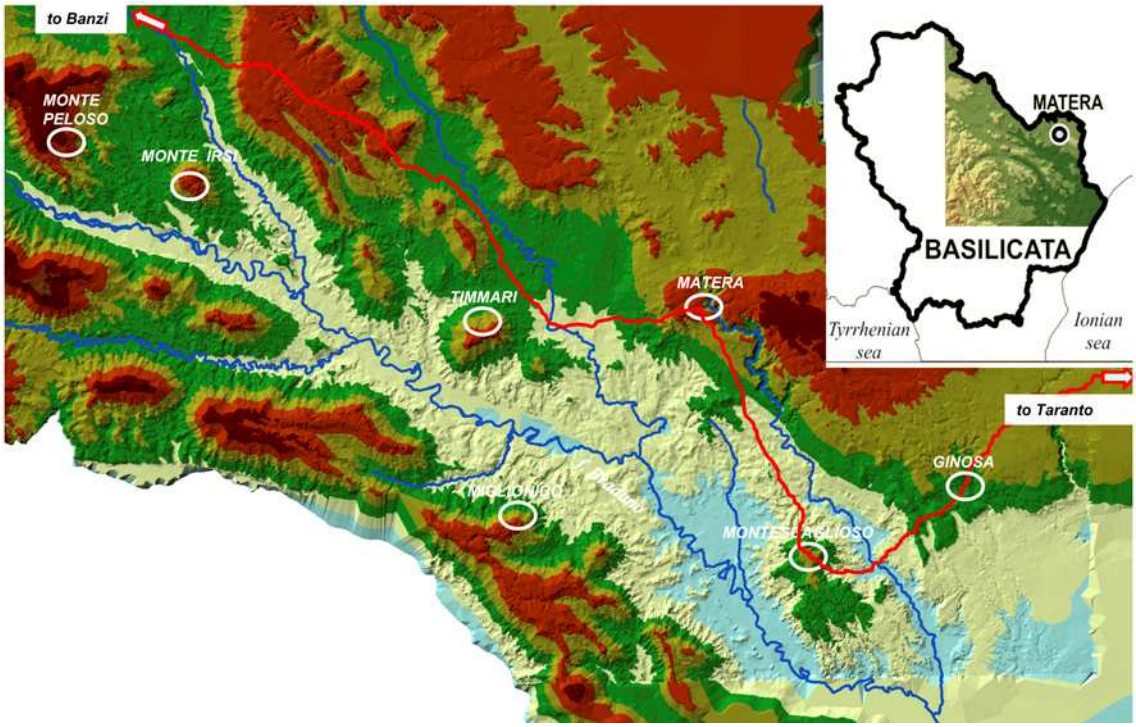

Fig. 7 – The itinerary from Oria to Banzi, Acerenza and Muro by Guidone (D. Roubis).

Some material evidences, although very weak, are related to a proto-Byzantine phase, as the discovery of some fragments of late antique pottery (TSA) in the Civita, some roman coins (late imperial age) and one *pentanummo* of the emperor Justinian the first (553–565).

At the middle of the 8th c. Matera belong to the Lombard Duchy of Benevento and, after the *Divisio Ducatus* (849 and 860), to the Principality of Salerno, as part of the *gastaldato* of Acerenza. But from the last decades of the 9th c., the town gradually moved towards a stronger Byzantine political control. The increased weight of imperial power is also manifested in the religious sphere: in 968 Polieucto, Patriarch of Constantinople, submits Matera, as suffraganean Diocese, to the metropolitan seat of Otranto. In the mid 9th c., an imperial "protospatario" (DEMETRIO 2009), as well as imperial officers and military garrisons lived in the town: a very strong evidence for a well defined administrative and military rule of the site, to which should have corresponded physical places and buildings, suitable to carry out all the activities of the civil power. The discover in the area of the Cathedral of a consisting nucleus of Byzantine coins, consisting of 320 pieces, dated continuously between 829 and 11th c., with a peak quantity (228 coins) referring to the type of Constantine the VII with his mother Zoe (913–919), could refers to a physical place of absolute primacy of Byzantine power *in urbe* (SALVATORE 1986; SOGLIANI 2010).
The material sign of those aspects, is once more evident in the cemeteries, interested by archaeological investigation, extended on wide areas of the town (Fig. 8) (St. Francesco Square, St. Lucia to Malve, Madonna de Idris, St. Nicholas of the Greeks, St. Mary de Armenis, St. Barbara), around churches and monastic buildings arising both in the upper part of Matera – the Civita –, and on the slopes of the height, whose type is generally comparable to rock settlement, generating concentrations of population.

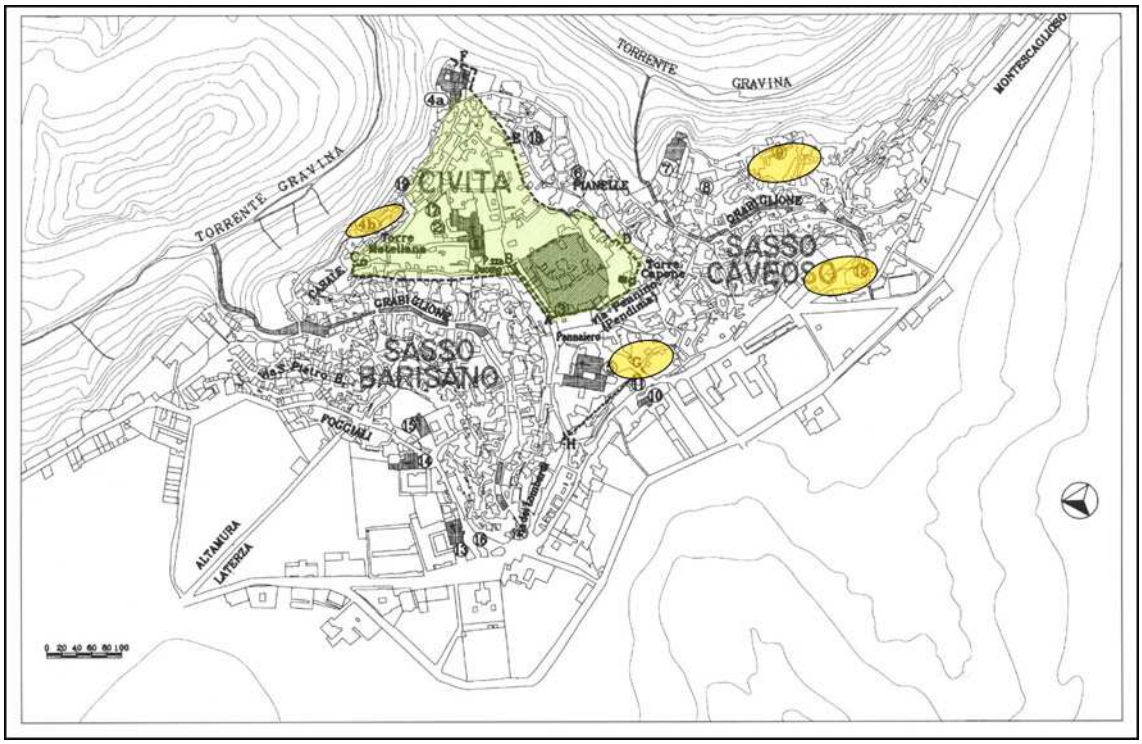

Fig. 8 – Matera. The Map of the town with distribution of early medieval cemeteries (FONSECA et al. 1999, revised by the Authors).

All the cemeteries are characterized by very strong similarities: they are interested by rock-cut graves, with anthropoid or rectangular shape, goods free, except few cases. The chronology have been fixed to 8th–9th c., on the basis of archaeometric analysis (BORGOGNINI TARLI and GIUSTI 1986) (Figg. 9, 10).

Fig. 9 – Matera. The cemetery of St. Francesco square (left); the cemetery of Rione Malve (right) (FONSECA et al. 1999).

Fig. 10 – Matera. The church of St. Lucia alle Malve (left), the cemetery on the top (right) (photo Authors).

The cataloguing actions realized for the archaeological map allowed us to fix inside the urban landscape and in the surroundings, the location of the huge number of rock churches (Rupestrian church of Canarino, of Vitisciulo, Madonna della Croce, St. Falcione, St. Giovanni in Monterrone, St. Luca alla Selva, St. Nicola al Saraceno, St. Nicola dei Greci, St. Nicola sulla Via Appia, St. Vito alla Murgia, St. Barbara, St. Lucia al Bradano, St. Lucia alle Malve, St. Stasio, Crypt della Scaletta, Crypt of Pandora, Rupestrian monastery of Cappuccino Vecchio, Rupestrian monastery of San Nicola all'Annunziata, St. Maria de Idris, St. Maria de’ Armenis, Monastery of St. Maria della Vaglia, Monastic church of St. Eustachio, Saints Pietro e Paolo, Church and monastery of Madonna delle Virtù) (Figg. 11, 12, 13).

The thickening of the religious foundations from the 13th c. is evident in the extension of the settlement plan outside the ancient town enclosed by walls, which extends radially around the spur of the Civita.

Fig. 11 – Matera. The rupestrian churches of St. Maria de Idris and St. Giovanni in Monterrone (photo Authors).

Fig. 12 – Matera. The rupestrian churches on the Gravina (photo Authors).

Fig. 13 – Matera. The rupestrian churches of St. Eustachio (left) and St. Barbara (right) (photo Authors).

The need therefore to think of an efficient tool for research, for the territorial cataloguing and for the planning of a proper urban development, in compliance with the requirements of the protection of cultural heritage, has continued to formulate more technical levels, such as analyzing risk factors, the drafting of the spatial constraints Map, the cooperation in the activities of urban planning and actions for the protection and preservation, including the restoration and maintenance of monuments and sites. We planned the draft of the archaeogeological risk Map of the rock churches located along the slopes of the Gravina in front of the town, inside the Parco della Murgia Materana. The research has experimented a model of analysis validated for the area, which could be extended in others territorial districts. The methodology employed for the evaluation of geo-archaeological risk represents an intermediate solution between a purely quantitative approach and the realization of qualitative considerations on dangerous phenomena (erosion, decay, collapse) and their potential consequences for cultural heritage (Fig. 14).

Value of risk items

- importance of the church for its architectonical elements
- percentage of churches with the same chronology (century)
- state of conservation of pictorial cycles
- old damages to the structures

	0	1	2	3	4
Valore	nullo	bassissimo	basso	medio	alto

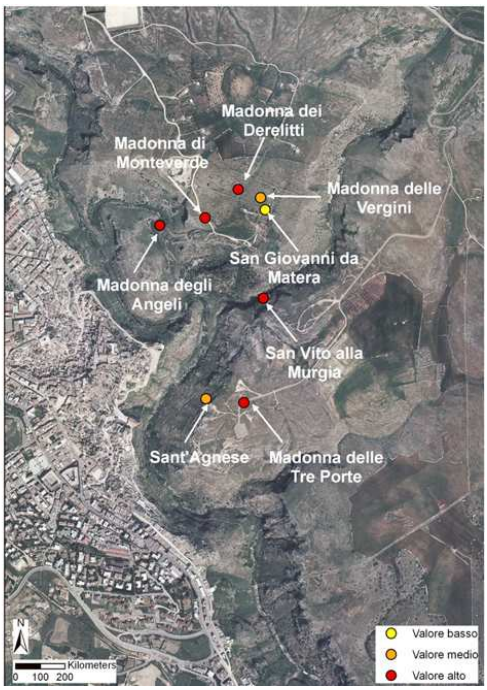

Fig. 14 – A scheme of some of the methodological parameters used in the archaeogeological risk map of the Rupestrian Churches Park of Murgia Materana (F. Sdao, M. A. Minopoli).

The draft of a Risk Map, offers information about the conservation and value of the archaeological heritage, and at the same time it is the necessary preliminary approach to the implementation of projects aimed at restoration, musealization and enhancement of the archaeological and monumental heritage.
Now, coming back to the urban context, it is clear that more evident transformation can be registered by religious and civil architectural evidences built up during middle age and some later on (Fig. 15).

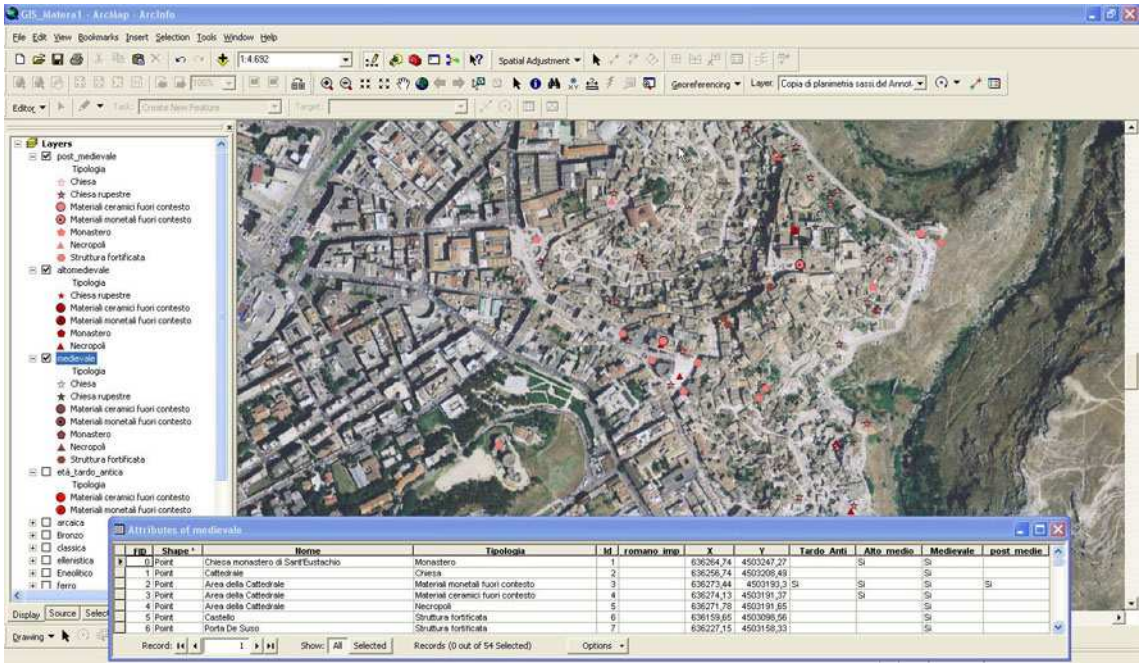

Fig. 15 – Matera. The GIS layer with medieval period.

Fig. 16 – Matera. Excavation of a medieval cemetery in the area of the church of St. Giovanni Battista (already entitled to St. Maria ai Foggiali) (photo I. Marchetta).

An important contribution for the enrichment of the historical and archaeological Map of the town has been the recent discovery of a huge cemetery, dated from XIII to XVIII century, in occasion of the first intervention of urban stratigraphic investigation in front of the church of S. Giovanni Battista, already entitled to S. Maria La Nova “ai foggiali” (silos for grain storage) (MARCHETTA 2008; SOGLIANI and MARCHETTA 2011). The intervention, realized on the occasion of public works for the refurbishment of the square paving (Fig. 16), allowed us to put another mark on the Map and to clarify the role of this side of the town, out of the medieval walls, both religious and funerary and for grain storage and welfare services to the civic community advantage.

Another topic component of the urban physiognomy is represented by fortifications, urban walls and castle. We scheduled the perimeter of the walls which are surrounding the hilltop of the Civita, with towers and gates and we are just begin the global relief and the study of building techniques of each single section of the entire curtain, to determine the chronological and constructive development (Fig. 17).

Fig. 17 – Matera. The medieval walls of the town on the south side of the spur of the Civita (on the left a polygonal tower) (photo Authors).

Written sources give evidence for existence of a first curtain in the second half of 10th c. (*Chronicon Casinense* and Erchemperto, year 967: “*munitissima civitas*”), but at the moment no archaeological data are available, even if it is certain a strategic role of Matera in the conflict between Byzantines, Lombards and Arabs for the supremacy on this territory. More detailed information and a material evidences are available for the 11th c., during the war between Byzantines and Normans, and in 12th c. when also the castle is mentioned (Fig. 18).

Fig. 18 – Matera. The medieval walls of the town on the west side of the spur of the Civita (the circular tower known as “Metellana”) (photo L. De Franco).

The grow up of the building inside the Civita have cancelled during the centuries the original shape of the area, originally interested by the medieval castle. The survival of the place name (Castelvecchio) in the area located next to the main entrance to the Civita, signed by the two gates Porta di Suso e Porta di Juso, and the information about the demolition of the castle after 1448 allowed us to locate it on the Map (Fig. 19), with the aim to indicate a site characterized by a high level of archaeological potential.

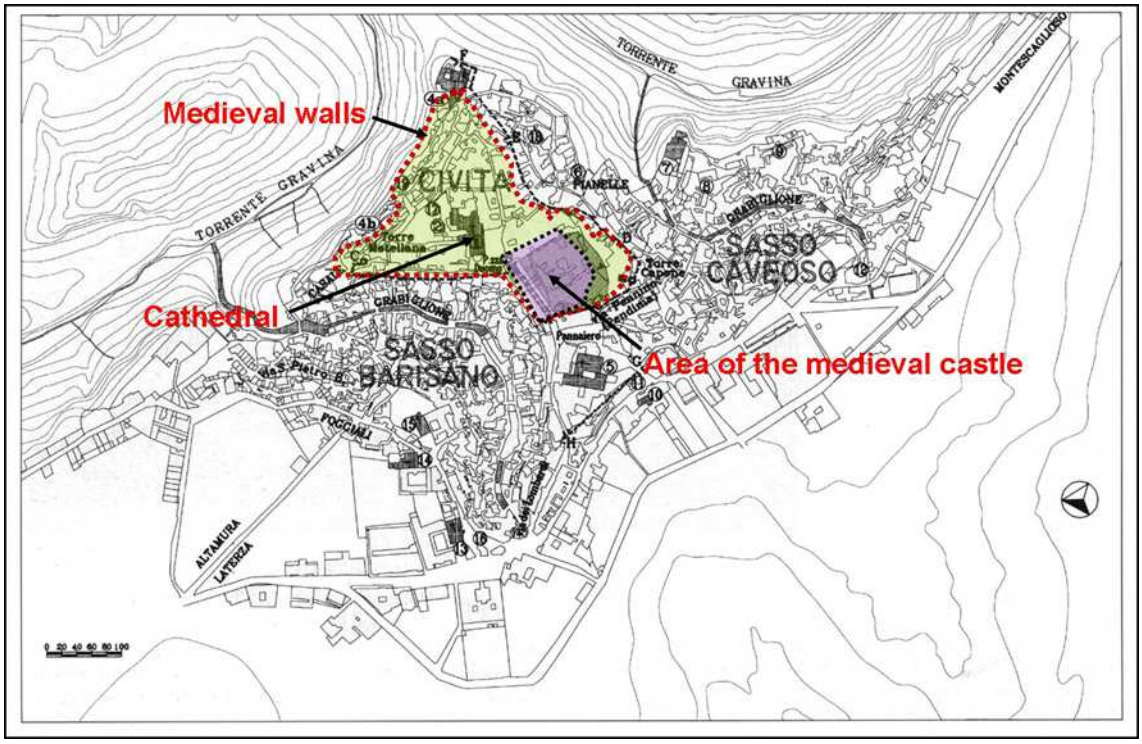

Fig. 19 – Matera. Plan of the medieval town with the location of the walls, the Cathedral and the old castle (FONSECA et al. 1999, revised by the Authors).

The fortification of the town developed from 14th and 15th c. in the plain around the Civita. At the end of 15th c. a new castle has been built on the hilltop besides the ancient town, as a sign of the new feudality power. At the end, we are looking for the complete integration between the basic archaeological research, scientifically validated, and the mapping on GIS of the data. The next steps of the research will product a web-gis, which could collect others important information layers, as the watershed system of the town, the water supply system (private and public cisterns), the food supply system, the historical cadastral maps and other thematics. All the information collected in the historical and archaeological Map of Matera are finally available for the spreading of cultural data, focused on the highlighting, management and enjoyment of cultural heritage in this so particular rupestrian urban area, using a multidisciplinary approach and ITC new tools. This will brings together actions to increase the value of this urban area like cultural resources Maps; Thematic urban itineraries; audio guides; development of on line and off line platforms for the remote use of Cultural Urban Heritage.

Moreover, from this last point of view, a specific attention has been put on the highlighting of one of the rock churches on the Gravina, the one of St. Maria delle Croci (Fig. 20).

Fig. 20 – Matera. Church of St. Maria delle Croci. Laser scanning representation of the interior of the rupestrian church (F. Gabellone).

In the frame of the EU Project Byherinet, dedicated to highlight the network of Byzantine cultural heritage in the Mediterranean basin, the staff of IBAM ITLab experimented the use of 3D laser scanning technique aimed to the documentation and the virtual enjoyment of one religious monument, particularly precious, but very difficult to reach.

At the end of this paper, all these archaeological and monumental evidences represents a very rich research agenda for the future, assuming that this study has shown just the first step of a bigger in-town urban archaeology project.

End note

The CAM Project (Historical and Archaeological Map of Matera) is due to a cooperation between the School of Specialization in Archaeology of Matera (University of Basilicata) and the Archaeological Superintendency of Basilicata, with the participation of the Institute of Archaeological and Monumental Heritage of CNR.
The archaeogeological risk Map Project has been realized in cooperation with the Department Structures, Geotechnical and Geology applied to Engineering of the University of Basilicata (prof. F. Sdao) and it has been the subject of a Dissertation at the School of Specialization in Archaeology of Matera of dott. M. A. Minopoli in the Academic years 2009–2010 (prof. F. Sogliani, prof. F. Sdao).

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Cryptoporticus: a hidden system under the skin of the ancient town

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Abstract: The Hadrian’s Villa can be read as a real urban settlement. The main objective of this project is the documentation and the investigation about a part of this settlement: the cryptoporticus. The reading of this system will be done according to four main development lines: the urban scale, the architectonic scale, the detail scale, and the confrontation scale. We applied our well proved procedures to obtain a detailed and accurate survey of the cryptoporticus network connecting it to our previous digital surveys in the Hadrian’s Villa; this was really powerful allowing a complete interpretation of the connections between the buildings and the underground. The use of a phase shift laserscan was a practical solution to produce high quality survey in small spaces reducing the overall scanning. The whole research was done working side by side with archaeologists to read and to interpret the traces and suggestions coming from this detailed documentation. The confrontation between the cryptoporticus in the Villa and other similar networks in the area allowed developing a better idea of the life inside the Hadrian’s Villa. The sizes, the sections, the “built-in” plants, the kind of floor and masonry are all witness of the use of this network, the confrontation of this clear aspects with the size and function of the vehicles, storage places, relationships with building functions allowed to interpret how this lively organism was capable to bear the whole Villa apparatus and keep each single function. The study of this network is not only useful for a better understanding of the Villa, but also to start a new reading of the large area of this monument where a lot is still to be said.

Keywords: Cryptoporticus, Laserscan, documentation, architecture, survey.

The Hadrian’s Villa

The construction of the Villa began in 118 a.C. after the proclamation of Emperor Hadrian. The use to have marvelous residence out of Rome became a common behavior for the Roman Emperors starting from Tiberio (27 a.C.). Various scholars place the main phases of the Villa's construction as connected to the travels of the Emperor along the Empire boundaries.

The knowledge of the world acquired by Hadrian, and the culture imported from the Empire, influenced the architecture of the Villa. There is no doubts about the fact that the Villa shows echoes of many different architectural orders, mostly Greek and Egyptian.

The construction works continued almost with no stops for twenty years until the Hadrian's death in 138 a.C. The Villa, even if not completed, was used by Hadrian's various successors. During the decline of the Roman Empire the Villa fell into disuse being abandoned to its own fate and a long age of decay started to bring down to ruins the whole area. The remains of the monument were discovered again during the Renaissance. According to the contemporary state of knowledge the Hadrian's villa is a great complex of over 30 buildings grouped in numerous pavilions scattered in a very large area covering about 300 acres.

A system of construction of this size move the problems and the issue from the proper conditions of a building right to the urban scale, with specific problem of people and goods movement all around this huge settlement. The choice made by the Villa architects was to try creating an articulated network of connections completely independent and almost invisible from all the area of the Villa characterized by richness and luxury, this was done for two main purposes: avoid to have a direct view on the servants activities and create special spaces for walking and relax during the summer season to the emperor and his court.

Fig. 1 – General plan of the main area of the Hadrian's Villa, development chronology and scheme of the main cryptoporticoes network.

In the Villa there are many types of connections partially or completely realized underground, some have been completely built, with the realization of a dig and then of vaults and other masonry works to integrate it to other constructions or back to the landscape, others were made simply digging tunnels into the tuff. The name used to indicate these structures is *Cryptoporticus*. The state of the knowledge about the *cryptoporticus* network documents a system articulated along almost five kilometers.

The Cryptoporticus network

The need of galleries was strictly linked to the mobility inside the Villa's area. A need similar to the current needs. In the complex of the Hadrian's Villa, cryptoporticus have very different characteristics, especially under the functional aspects. Often the function of a cryptoporticus changed over the years, adapting to specific needs. Generally (and often wrongly) some underground tunnels are defined cryptoporticus;cryptoporticus, in its standard definition, means a series of corridors partially buried, barrel-vaulted and lighted by small windows open on one side of the vault. Often the corridors are linked together according to a rectangular shape and are frequently placed under a peristyle. The cryptoporticus was generally used as a substructure, or to stabilize a steep terrain, or like a podium for other architectures. The network of underground paths of Hadrian's Villa can be classified according to some macro-categories:

- Classic cryptoporticus, for the imperial court, usually decorated.
- Link ambulacrum: are galleries connecting the different buildings, they were usually used by the crew of the villa.
- Underground carriageable roads: There is an extensive network of roads for the transport of supply and building materials.
- Hypogean elements of service: Like maintenance galleries, aqueducts, depots, and so on.

Fig. 2 – View of one of the most suggestive underground spaces in the Hadrian’s Villa: the structure called “building with fish pond”.

Inside the Hadrian’s Villa almost each building is composed and serviced by one or more covered path, just near or even combined in the structures.

Now it is worth to mention the fact that during the long centuries of abandon the Villa and Hadrian were not completely forgotten, during the middle age a legend about a local Saint, “Santa Sinforosa”, took place with a strong link to certain “underground” characteristic of the Villa. Probably, during the long abandon time of the Villa the presence of the large underground structures produced a valid support to legends about Saint Sinforosa’s martyrdom.

Fig. 3 – Various view from the cryptoporticoes in the Hadrian’s villa.

According to the main legend Hadrian send Sinforosa, a Christian roman woman, to death, the reason for this was the refuse of the woman to renounce to her religion. As a following punishment for his bad act, after the death of the Saint, Hadrian is persecuted by her spirit and by a strong remorse. So he decide to go living

underground to avoid the sunlight and to expiate. It is possible to imagine this legend as a direct explanation of the strange and huge underground network the people from the middle age found in the Hadrian's Villa, probably the idea of living far from light was suggestive enough to need some strong and complex legend like this one to be justified. Visiting this huge "invisible" town, it comes immediately clear where the legend finds its roots.

Documentation through digital survey

A so rich and articulated network deserve a better documentation then the one available now a day. It's not only a matter of having a map; it is quite clear that this is almost one of the better technological efforts in urban mobility for that time, with a strict correlation to all the buildings, a detailed map can give interesting indications about the way the whole area was built. It is a complex subject but the large number of openings and the continuous integration with all the ground constructions make this subject an ideal ground were the use of digital survey will give the better benefits.

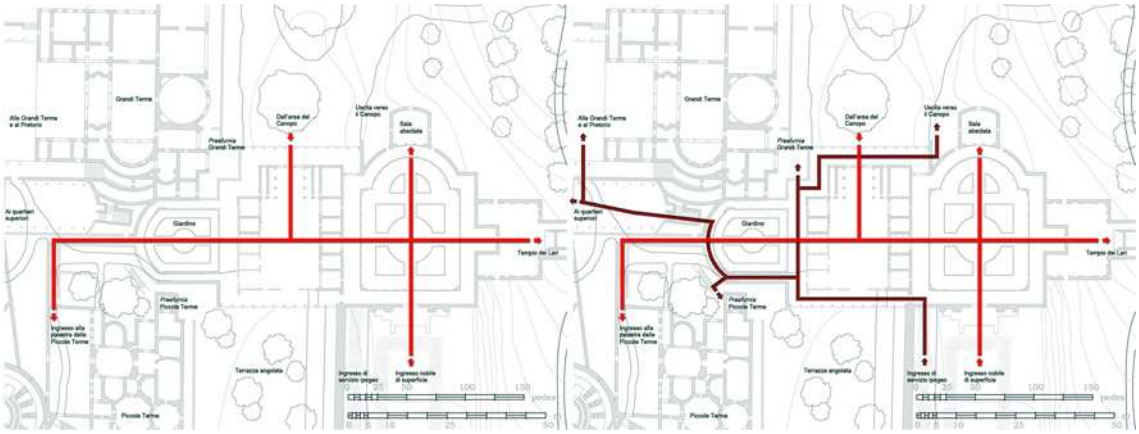

Fig. 4 – The cryptoporticus between the small and the great baths, overground and overground paths.

To start the approach to this subject we decide to operate where we have yet completed over ground digital survey. The area between the Small and the Great Baths was the ideal starting point for this documentation work. The whole survey of both the baths was completed: the Great baths and the Great Vestibule were surveyed in 2004 while the Small baths were surveyed in 2008 and 2009. The new survey campaign started in 2009 was aimed to the underground area between the two baths. In the whole area the over ground paths scheme is quite simple, it consists of lines of distribution straight and perpendicular to each other. At the same time the underground paths follow the shape of buildings foundations. Some exits are close to service areas (like the boiler rooms of the two baths).

The overall model of the area was obtained from the pointcloud models created by the integration of the two digital surveys made in 2004 and 2009.

The main characteristic and the main novelty in this composed survey was the fact that for the first time it was possible to see clearly the overlap of ground's architectures and subterranean galleries.

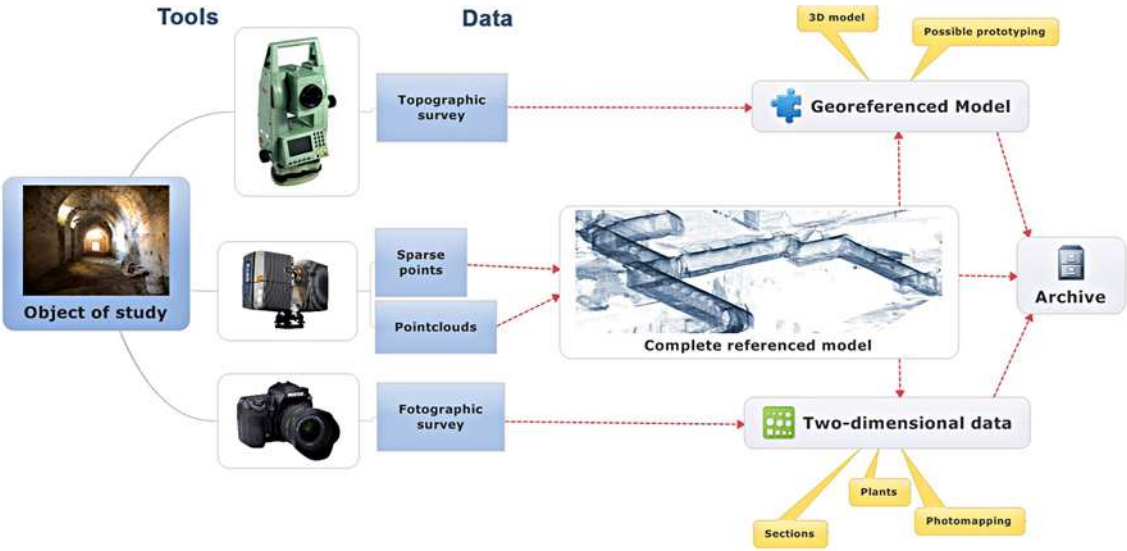

Fig. 5 – The main workflow used for the digital survey of the cryptoporticoes between the small and great baths.

The survey of this underground network was done with a phase shift laser scanner, a Cam2 Faro Photon 120, as is well known each station taken by this panoramic measurement tool create a portion of the digital three dimensional model based on a very dense pointcloud.

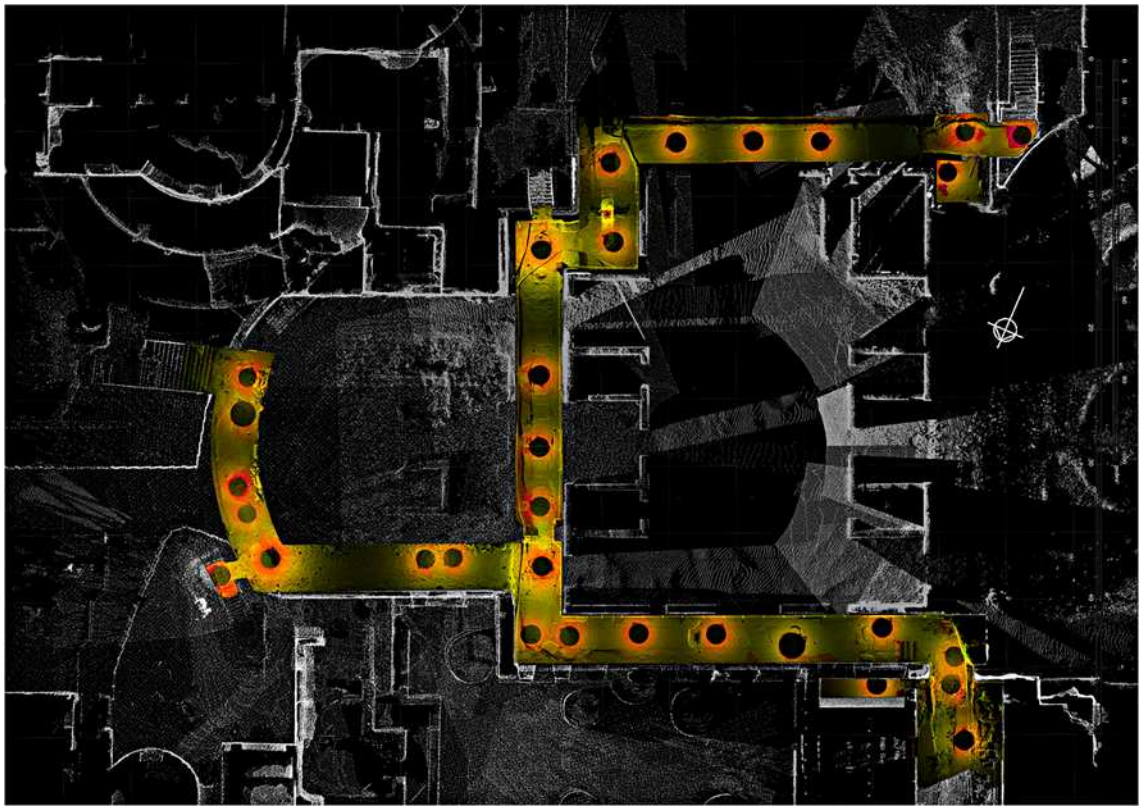

Fig. 6 – Plant of the cryptoporticoes. The scanning stations inside galleries are clearly visible (dark spots). The white plant represents the overground external environment.

To allow composing each single scan in a complete, descriptive model, a specific network of targets was deployed all along the *cryptoporticus*; both flat and spherical targets were used.

The spherical targets (identified as corresponding points from any position of the laserscan unit) were placed with the main aim to allow all the single scans to be assembled into the main pointcloud model, the flat targets were used to consolidate the registration process but more than any other reason to allow the linking of the underground survey to the geo-referenced topographic survey done on the entire area of the Villa. In facts, since the first survey in the Hadrian's Villa, in 2004, we had consolidated a topographical network all around the West part of the archaeological area, to allow the progressive growing of the whole survey and to bring each new scan to a global, common, reference system.

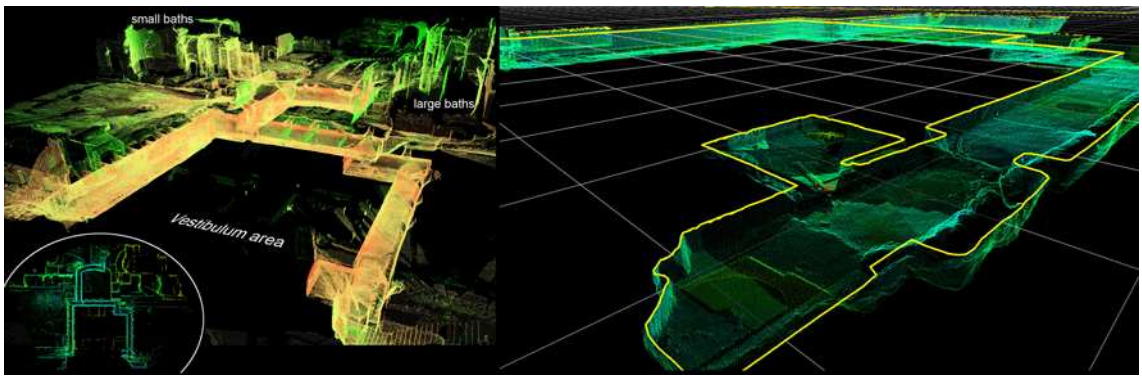

Fig. 7 – Pointcloud model of cryptoporticoes and external environment, on the right the pointcloud is properly cut by cutplanes for generating plants and sections.

In this way the overall pointcloud model is a solid, well referenced, system. This kind of data can be considered as the ideal starting point for any further post processing. So it is ready to be used in different ways: for example to create 3D surface and textured models, to develop Virtual tours, to prepare models for rapid 3D prototyping, etc… According to the procedures and the experience we gained during the years the first step to take with this kind of archaeological subjects is to extract a good series of 2D drawings out of the pointcloud. So the model was simply dissected in all directions for the creation of traditional drawings as plans and sections. These drawings were integrated with data from the photographic survey for the photomapping; this was done to produce an high quality, near to real, not deformed, image of the *cryptoporticus* using a graphical language near to the traditional one, capable to be inserted in well consolidated reading and interpretation procedures. Obviously each single scan made with FARO Photon 120 Phase-Shift Based Laser Scanner can be used to get a lot of information out of the scanned part, but only a complete, well covered, overall survey allows a clear readability of the whole system.
The result obtained is based on 46 referenced scans needed to survey the whole *cryptoporticus* under the Central *Vestibulum*. Almost all the ground survey scans come from previous laserscan survey, combined with the new part according to the well consolidated topographical network. All subsequent processing were created starting from this assembled digital three dimensional model.
The level of details of the overall result is quite high, with minimal occlusion spaces, when it was possible, some addiction scans was taken, like for the sewer channels running along the center line of the whole network, when there was some covering stone missing and enough space the scanner has been lowered in the hole to capture some samples of the duct.

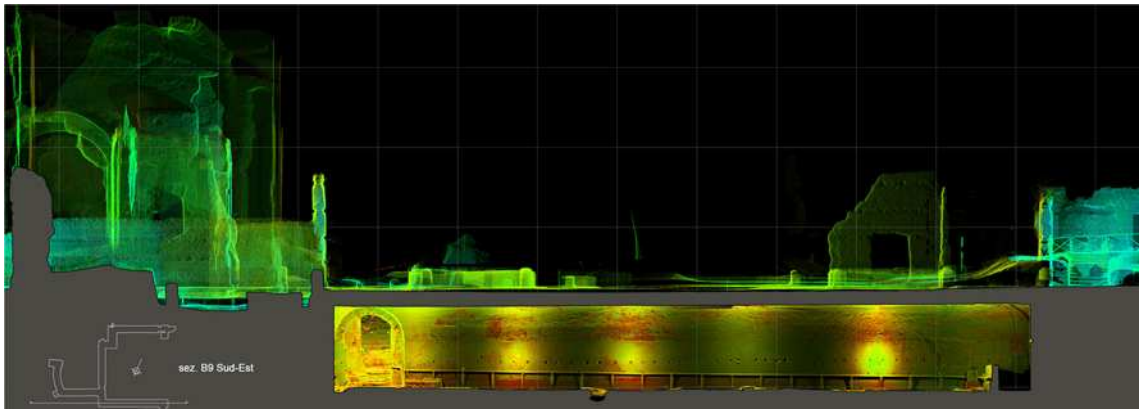

Fig. 8 – One of the sections extracted from the registered pointcloud, all the parts from the ground buildings comes from the previous survey realized in 2004, 2008.

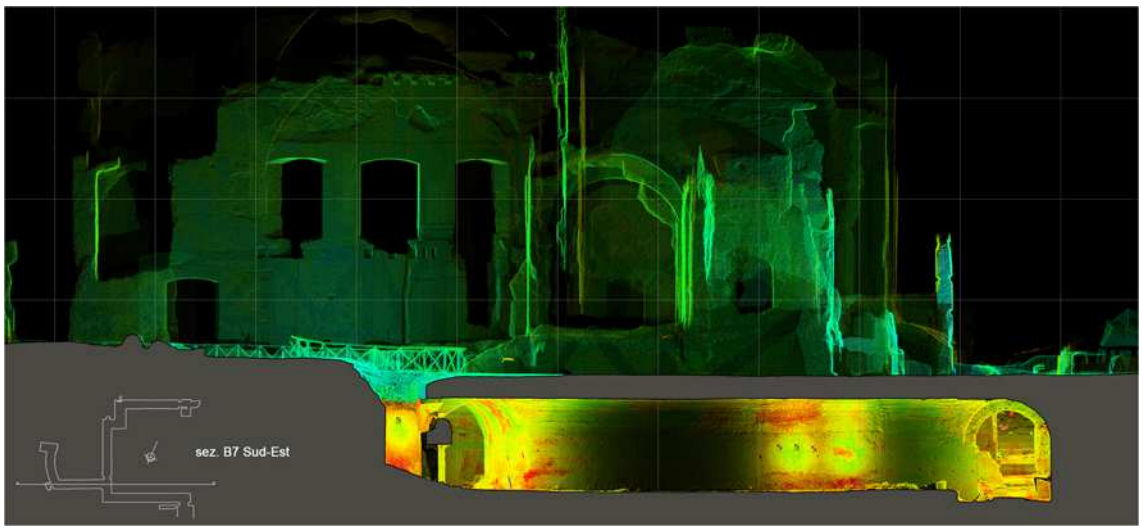

Fig. 9 – Another section extracted from the registered pointcloud. The front in the background shows the Great Baths North side.

The overall model clearly shows all the details from the galleries along the perimeter of the vestibule, and between the two baths with all the openings, the stairs and the connections to the ground.

The registered pointcloud show all the gathered points according to a colors or grays palette. It is well known that the color variations are the effect of different reflectance values recorded by the scanner. But even if this feature is useful to identify different materials in the analyzed surface and allows a good reading of shapes and elements, it is quite clear that this give a limited image of the real when used for presenting bidimensional drawings. For this reason a complete photoplan of the whole galleries was done, it was highly preferable not to base the color remapping on a camera mounted on the scanner, this mainly for two reason: the light conditions were too complicated, the risk of flares and other parasite issue was quite high. So a separated, optimized, high quality, photographic campaign was done. Using a digital SRL camera with super wideangle zoom lens it was possible to calibrate each shot and take it in the more convenient hour, when the lighting was right for that part of the wall. In a couple of days the whole work was done, then when the fronts extracted from the pointcloud has been ready, all the shots were calibrated and digitally corrected over using the pointcloud as reference base.

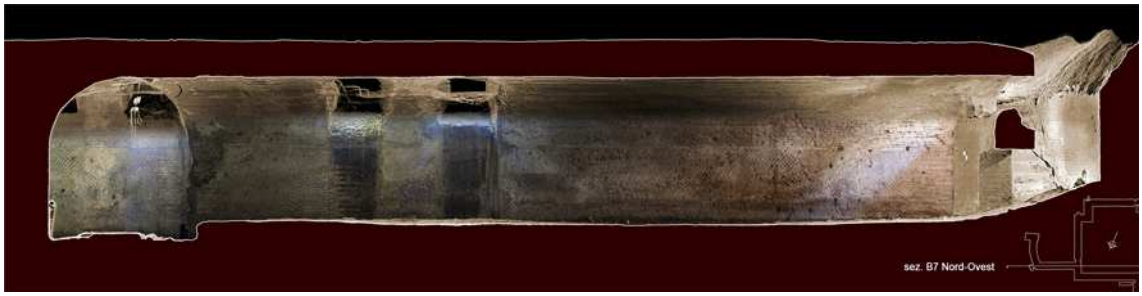

Fig. 10 – Cryptoporticus section with the photoplan applied.

Fig. 11 – Cryptoporticus section with the photoplan applied, on the right the staircase to the overground.

To produce the photoplans it was necessary to make a series of shots moving parallel along the walls of the galleries, using artificial lights where necessary. Because of limited space it was necessary to use a lens with very short focal, and this has inevitably caused the presence of some spherical aberrations on each image. The fix of geometric distortion was made using a specific software that, due to the optical datasheet of the lens, is able to apply a kind of "reverse spherical aberration", and to correct the geometric errors of each shot taken with that lens.

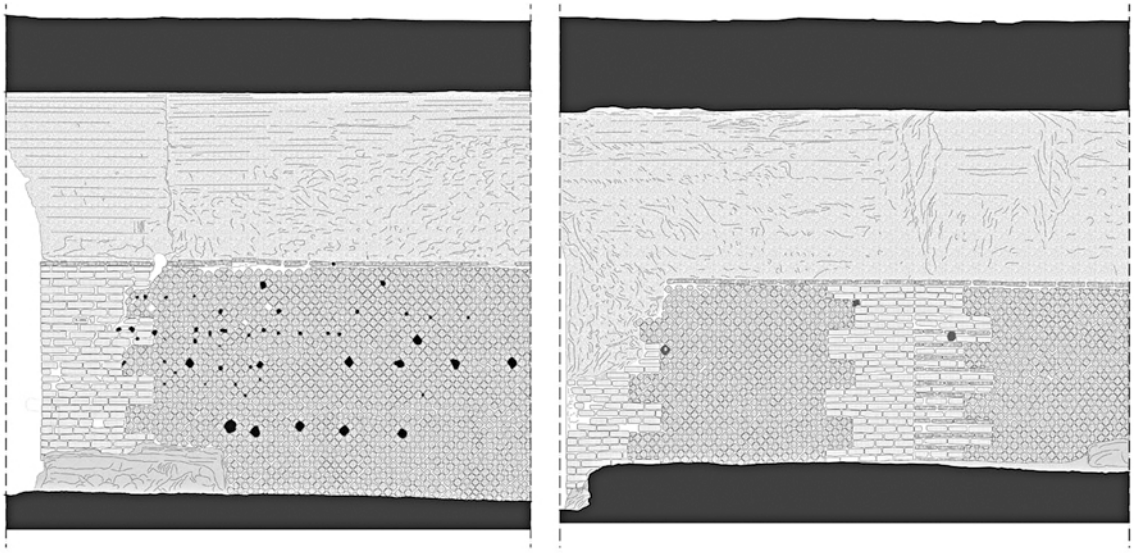

Fig. 12 – Details from cryptoporticoes sections. Extraction of traditional bidimensional drawings to bring to a common level of readings the information from the laserscan data. The drawing is done by common CAD techniques.

At this point it was possible to automatically assemble the images with a stitching software which allow the processing of a series of pictures taken with a linear motion of the optical nodal point of the camera.
The photoplan obtained in this way can be adapted very simply on the pointcloud sections, the result is an hi-res photographic image, geometrically accurate of the cryptoporticoes.
The enhancement of the overall result is quite clear looking at the final drawings.
The pointcloud was processed to produce 24 sections all around the underground network, but, if needed any other section can be extracted out of the referenced model and can benefit from the rich gathered level of details. The detailed sections allow to clearly read all the aspect of the masonry, and this can be very useful even for redrawing purposes, a clear set of bases like these offer an easy starting point for any vector drawing, giving the opportunity to measure and quantify the characteristic of the surfaces, from the type of masonry to the state of decay.

The reasons to digitally investigate and survey the cryptoporticus network

First of all the clear documentation of the underground area in itself should be a good reason to operate and archive this work, it is the contemporary way of archiving the state of a place and a rich monument like this really deserve this approach.
Because of the very complex architectonical situation this is, with no doubts, the best way to read the relationship between overground and underground parts. The precision of the whole result allow to consider all the alignments as sure and any further study can clearly identify where are the more interesting points to focus the attention.
According to this survey a study of the paths and of the levels can be started, because of the rich surfaces description, it is now possible to evaluate the directions, the inclinations, the changes in levels and the changing applied to the sections of the whole network, this is extremely meaningful for the understanding of the whole architectural work.
As a consequence there is the right knowledge about the “health” of the monument. The three dimensional model and the post processed section give a clear, accurate description of the state of the monument, any further transformation can be monitored. Monitoring the condition of a monument means two main things: safety for the visitors and safety from losing an important piece of Cultural Heritage; a large, massive, extended and complex like the Hadrian’s Villa is not easy to control in its transformations, but they go on whatever is done to take a look to them or not. An year by year digital survey, based on a solid reference system, can allow to preserve the monument from disasters, giving useful information about the shape transformations in time, something far behind the level of details a mind or a simple photography can memorize. And if need the 2009 survey bases can be better base for a restoration process, this network is not safe enough to allow visitors and tourists to freely go around it, but some kind of restoration process sooner or later must be considered to allow access or at least to allow the preservation of this meaningful part of architecture.

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The survey of the cryptoporticus, the small baths, the great baths are researches between the main "Hadrian's Villa" research project of the *Dipartimento di Architettura Disegno Storia Progetto, Firenze*. Scientific responsible: prof. Giorgio Verdiani, the survey team who operated in 2009 during the cryptoporticus survey was composed by G. Verdiani, F. Tioli, A. Peruzzi, M. Pucci, A. Blanco, G. Corsaro, A. Mariani. The 2009 survey campaign was done in collaboration with Area3D s.r.l. Livorno.
All the survey and operations were conducted thanks to the collaboration of the *Soprintendenza Archeologica del Lazio* under the supervision of dott.sa Benedetta Adembri. The whole “Hadrian’s Villa” research is developed in collaboration with the *Premio Piranesi International Workshop* and *Accademia Adrianea* under the supervision of prof. Pierfederico Caliari.

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SESSIONS

Lost Cities

Reconstruction of the urban landscape of an ancient metropolis in Asia Minor: integration of 2D and 3D technologies and methodologies in Hierapolis of Phrygia (Turkey)

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Abstract: The paper concerns methodologies and technologies applied to the reconstructive study of the urban layout and landscape of Hierapolis in Phrygia (south-western Turkey), a Hellenistic, Roman and Byzantine city in the valley of Çürüksu River (ancient Lykos River). The history of the city, founded in the 3rd century BC, was marked by destructive earthquakes, which have also determined the main phases of its urban development during the Roman and Early Byzantine periods, until the decline and the abandonment in the Middle Byzantine and Seljuk periods. Moreover, the western sector of the urban area is covered by white and thick calcareous formations, produced by the springs whose waters emerge from the central area of the city.

During the last eight years, a research project of CNR-IBAM, in collaboration with the Italian Archaeological Mission, was aimed at the reconstruction of urban layout and its transformation during centuries, by means integration of archaeological excavations and surveys, satellite and aerial remote sensed data, topographical surveys using differential GPS, Total Station, and Laser Scanner, and geophysical prospecting (GPR, Magnetometry, Electrical Tomography) of the areas covered by thick colluvial and alluvial deposits and by the calcareous formations that have incorporated ancient remains. The result was a digital archaeological map integrated in a GIS, in which all ancient monuments and remains are placed on a large-scale cartography and on DEMs with different geometric resolution. These map and DEMs constitute the base for the 3D reconstruction of some monuments and archaeological areas (such as the Frontinus Road, the North Agorà, the Nymphaeum of Tritons, the Theatre, the Martyrion of St. Philip, etc.), in a still in progress project aimed at the virtual reconstruction and restoration of Hierapolis, through integration of the 3D photo-modelling and laser scanning techniques and the archaeological and topographical data.

Keywords: Archaeology, Virtual Reality, Hierapolis of Phrygia, Archaeological Map, 3D Reconstruction.

Introduction

This work concerns the methodologies and technologies applied by the Institute for Archaeological and Monumental Heritage of the National Research Council of Italy finalized to the reconstruction of urban layout and ancient landscape of Hierapolis in Phrygia. It is a Hellenistic, Roman and Byzantine city in south-western Turkey, near the modern village of Pamukkale, in Denizli region, about 200 km East of Izmir (D’ANDRIA 2003; D’ANDRIA and CAGGIA 2007). The urban area of Hierapolis stretches over a travertine shelf looking onto the broad and fertile valley of the Çürüksu River, the ancient Lykos, one of the tributaries of the Meander River (Fig. 1). The steep slope is covered with white calcareous formations, produced by the

springs whose waters emerged uncontrolled from the central area of the city as a result of earthquakes in the medieval period.

Fig. 1 – Hierapolis of Phrygia on a travertine shelf looking onto the valley of the Çürüksu River, where is the modern village of Pamukkale; the steep slope is covered with white calcareous formations (DEM based on Shuttle Radar Topography Mission data and draped with a QuickBird-2 panchromatic image taken in 2005).

The history of Hierapolis, founded in the 3rd century BC, with an orthogonal road network, was marked by destructive seismic events, which have also determined the main phases of its urban development (D'ANDRIA, SCARDOZZI and SPANÒ 2007). After a devastating earthquake in 60 AD, there was an intense period of monument building which led to the expansion of the city during the Flavian age and again in the 2nd century AD and in the first half of the 3rd century AD: as result, in this period Hierapolis reached its maximum extension of about 72 hectares (Fig. 2). Another important building phase of the city again followed an earthquake in the middle of the 4th century AD, and led to the development of the Christian Hierapolis in the Early-Byzantine period, when it became a *metropolis* of the *Phrygia Pacatiana* and an important pilgrimage centre for the presence of the Sanctuary of St. Philip, built near the tomb of the Apostle: in this period, Hierapolis reduced its extension to 60 hectares and the city walls and numerous new religious buildings were built and others were restored. After a further earthquake in the middle of the 7th century AD, the city went into decline but it continued to survive until 13th–14th centuries, the period of the wars between Byzantines and Seljuk Turks for the control of Anatolian peninsula: the regular urban layout of the Hellenistic and Roman periods was not maintained due to the construction of houses on the ruins of the previous buildings and within the ancient roads, that were diverted. During the Middle-Byzantine and the Seljuk periods only few settlement sites were identified in the ancient urban area.

During the last eight years, a research project of CNR-IBAM, developed in collaboration with the Italian Archaeological Mission, was aimed at the reconstruction of urban layout and its transformation during centuries. It is based on integration of archaeological excavations and surveys, high resolution satellite and aerial remote sensed data, topographical surveys using differential GPS, Total Station, and Laser Scanner, and geophysical prospecting (GPR, Magnetometry, Electrical Tomography) of the areas covered by thick

colluvial and alluvial deposits and by the calcareous formations (thick until 3–4 m) that have incorporated ancient remains.

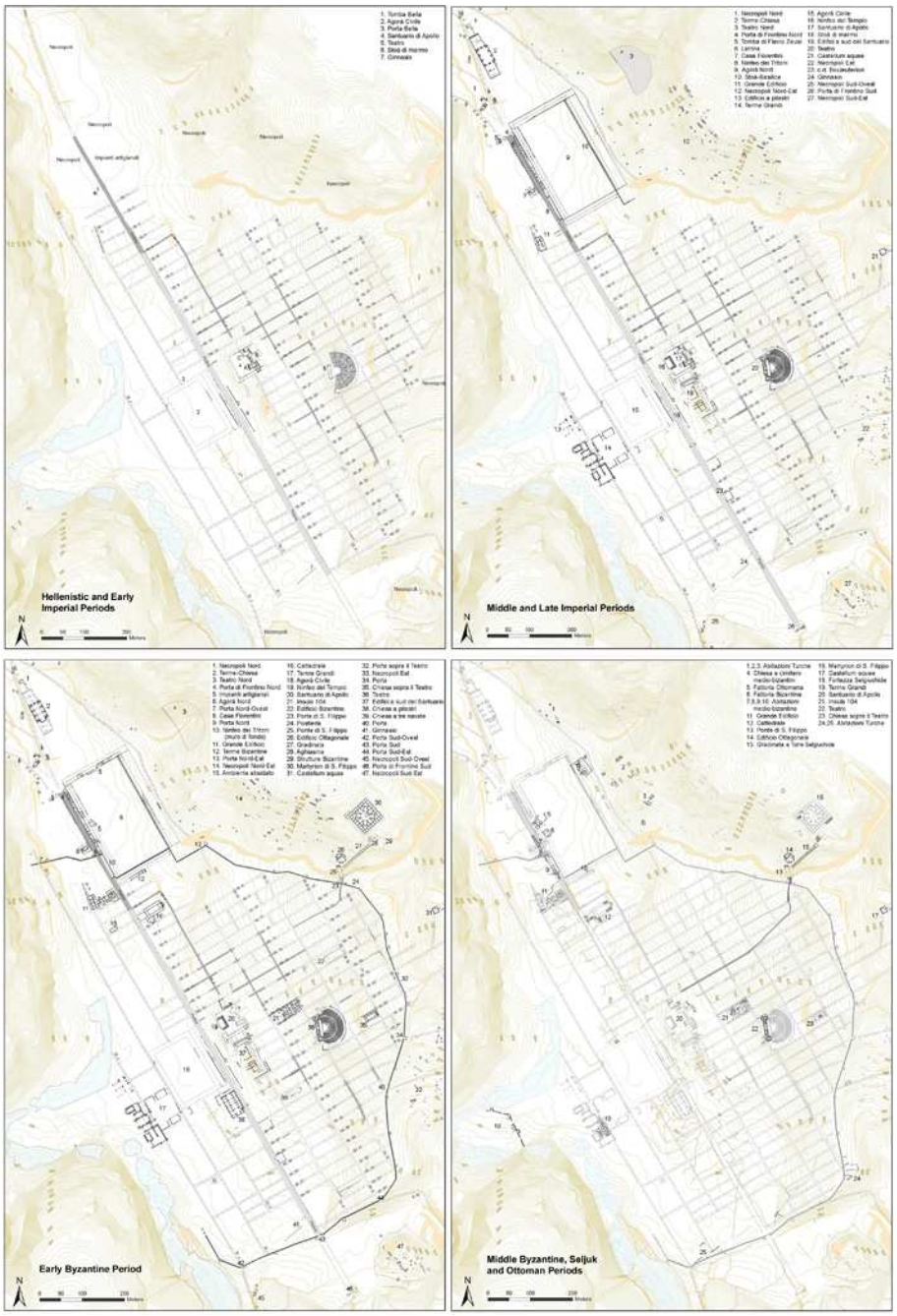

Fig. 2 – Main phases of Hierapolis urban development: 1. the Hellenistic and Early Imperial period (from the 3rd century BC to 60 AD); 2. the Middle and Late Imperial ages (from the Flavian period to the second half of the 4th century AD); 3. the Early Byzantine period (from the 5th century AD to the middle of the 7th century AD) and the Middle Byzantine; 4. Seljuk and Ottoman periods (from the middle of the 7th century AD to modern days).

The result was a digital archaeological map integrated in a GIS, in which all ancient monuments and remains are placed on a large-scale cartography and on DEMs with different geometric resolution, elaborated from cartographic data, through remote sensing data (radar, from SRTM, and optical from ASTER and Ikonos stereo pairs) and GPS surveys. These map and DEMs constitute the base for the 3D reconstruction of some

monuments and archaeological areas (such as the Frontinus Road, the North Agorà, the Nymphaeum of Tritons, the Theatre, the Martyrion of St. Philip, etc.), in a still in progress project, named “Virtual Hierapolis”, aimed at the virtual reconstruction and restoration of Hierapolis, through integration of the 3D photo-modelling and laser scanning techniques and the archaeological and topographical data.
So, the research activities of the Institute for Archaeological and Monumental Heritage in Hierapolis are returning a new life to a lost city, through the integration of 3D photo-modelling and laser scanning techniques and archaeological, topographical, architectural and remote sensed data. (G. S.)

Integrated methodologies and technologies for the archaeological map of Hierapolis

Since 2003 until 2010 the Institute for Archaeological and Monumental Heritage (in particular, the Ancient Topography, Archaeology and Remote Sensing Laboratory) performed archaeological surveys in the urban area and in the territory surrounding the ancient city, as part of the research activities of the Italian Archaeological Mission in Hierapolis, that since 1957 has been carrying out archaeological excavations and restorations in the city and in its necropolises (CASTRIANNI *et al.* 2008; D’ANDRIA, SCARDOZZI and SPANÒ 2008; SCARDOZZI 2008).
The archaeological and topographical systematic surveys conducted in the urban area of Hierapolis, integrated with the stratigraphic excavations, are finalized to the creation of a digital archaeological map of the city (Fig. 3), integrated in a GIS, and to the study of the urban layout and its transformation during centuries. The research is based on the integration of multidisciplinary methods and technologies to support archaeological surveys, with the aim to acquire as much data as possible on the ancient topography of Hierapolis, for the reconstruction of the “different cities” that have occurred in the site over the centuries. The archaeological layers in the map are very heterogeneous data and are based on different methods of investigation with different levels of reliability. The base of the archaeological map is a large-scale (1:1,000) digital cartography of the city, drawn by geomatic experts from the Faculty of Architecture at the Politecnico of Turin.
The systematic research and topographical surveys of all archaeological remains preserved in the urban area and in the necropolises were conducted using a robotic Total Station Sokkia SRX and a high precision differential GPS-GNSS Sokkia GSR 2700 ISX (Fig. 4). These were supported by low-altitude aerial photographs, taken from a tethered air balloon (Fig. 5) and by a radio controlled Cam Copter that can acquired also stereoscopic photos, and by the large use of multi-temporal high-resolution satellite images (both panchromatic and multispectral) taken by recent satellites for civil use (QuickBird-2 images of 2002, 2005, 2007 and 2009; Ikonos-2 image of 2004). Integration of air-photos and satellite remote sensing data (Fig. 6) was very useful to document archaeological areas and monuments, to understand their topographical context, and to detect traces and anomalies linked to ancient buried remains (SCARDOZZI 2010a). In particular, the contribution of the satellite images to the research has been very significant and they are used in all phases of the research, during field work and in the data processing and management in the GIS of Hierapolis, where ortho-images constitute raster layers for positioning archaeological features and for vectorization of traces and anomalies linked to ancient buried structures or paleo-enviromental elements.

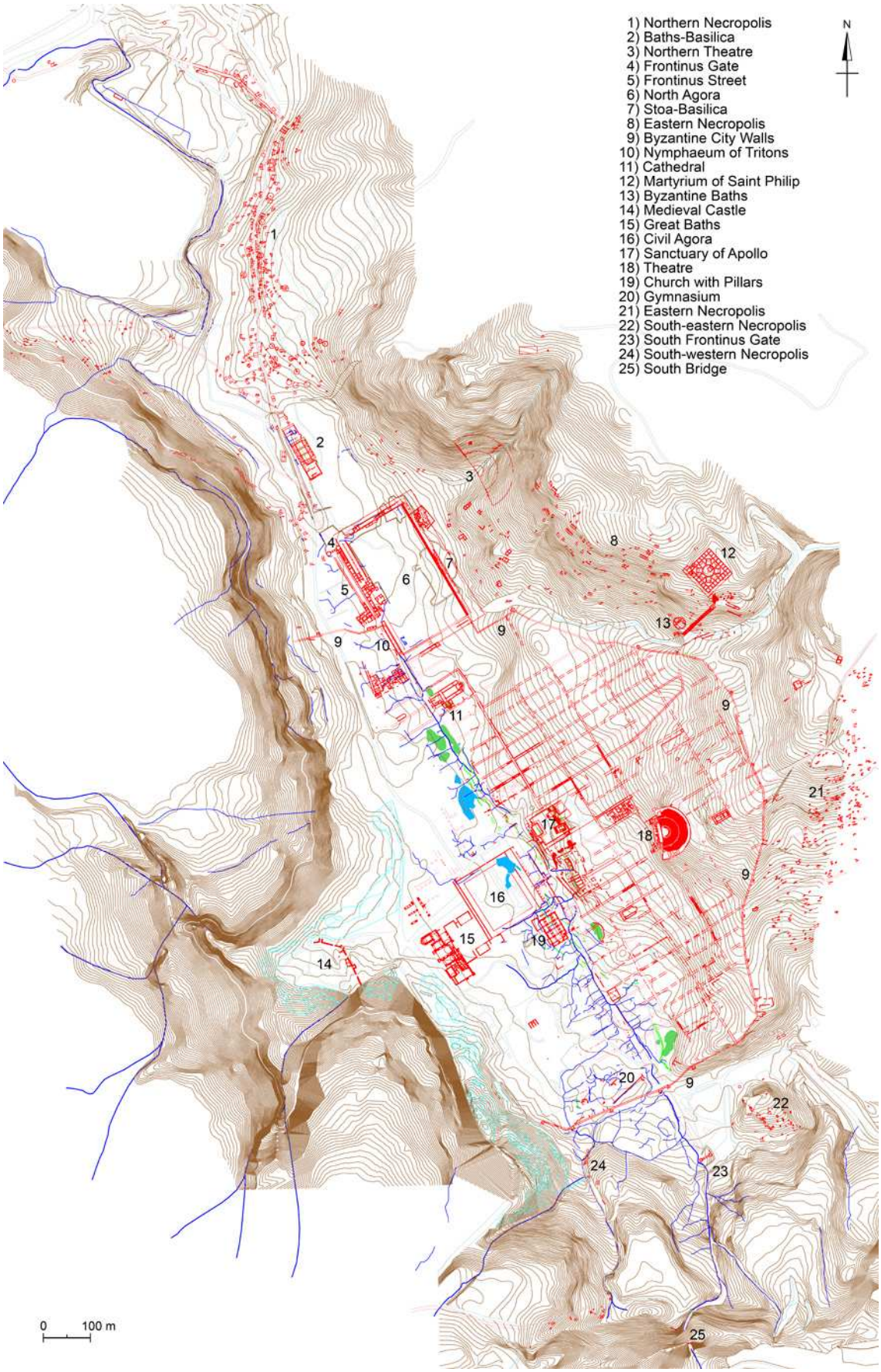

Fig. 3 – Archaeological digital map of Hierapolis (updated in 2010).

Fig. 4 – GPS survey of the ancient remains in the urban area.

Fig. 5 – Aerial photo of the northern sector of the urban area: remains of the regular urban layout are visible.

Fig. 6 – The central and northern sectors of Hierapolis in a panchromatic QuickBird-2 image of 2009. Some of the 3D reconstructed monuments are visible: 1, Frontinus Gate; 2, Frontinus Street; 3, Stoa-Basilica; 4, Nymphaeum of Tritons; 5, Martyrium of Saint Philip; 6, Theatre; 7, Marble Stoa.

The recent images, ortho-rectified, were also used for updating modern topography in the cartography that was used as base of the archaeological map. Moreover, the acquisition of space photos taken by US spy satellites in the years 1960s (in particular, a Corona KH-4A image of 1968) provide a multi-temporal documentation that allowed to acquire also very interesting data concerning the transformations of the archaeological area and of the surrounding territory during the last forty years; the main transformations and destructions were caused by the building of six hotels within the ancient urban area (which started at the end of the years 1960s), of a small barrack of Turkish Army, and of the structures of the two large northern and southern entrances, that have partially covered ancient roads and tombs (Fig. 7). The hotels were demolished in the last years 1990s, but their construction has, however, destroyed large sectors of the ancient city.

Very important data were also acquired by the old maps of Hierapolis drawn by scholars who visited the ruins of the city during the 19th century; in fact, these maps, that are closer to the ancient urban landscape, provide documentation of the last phase of the city and plans of structures now demolished.

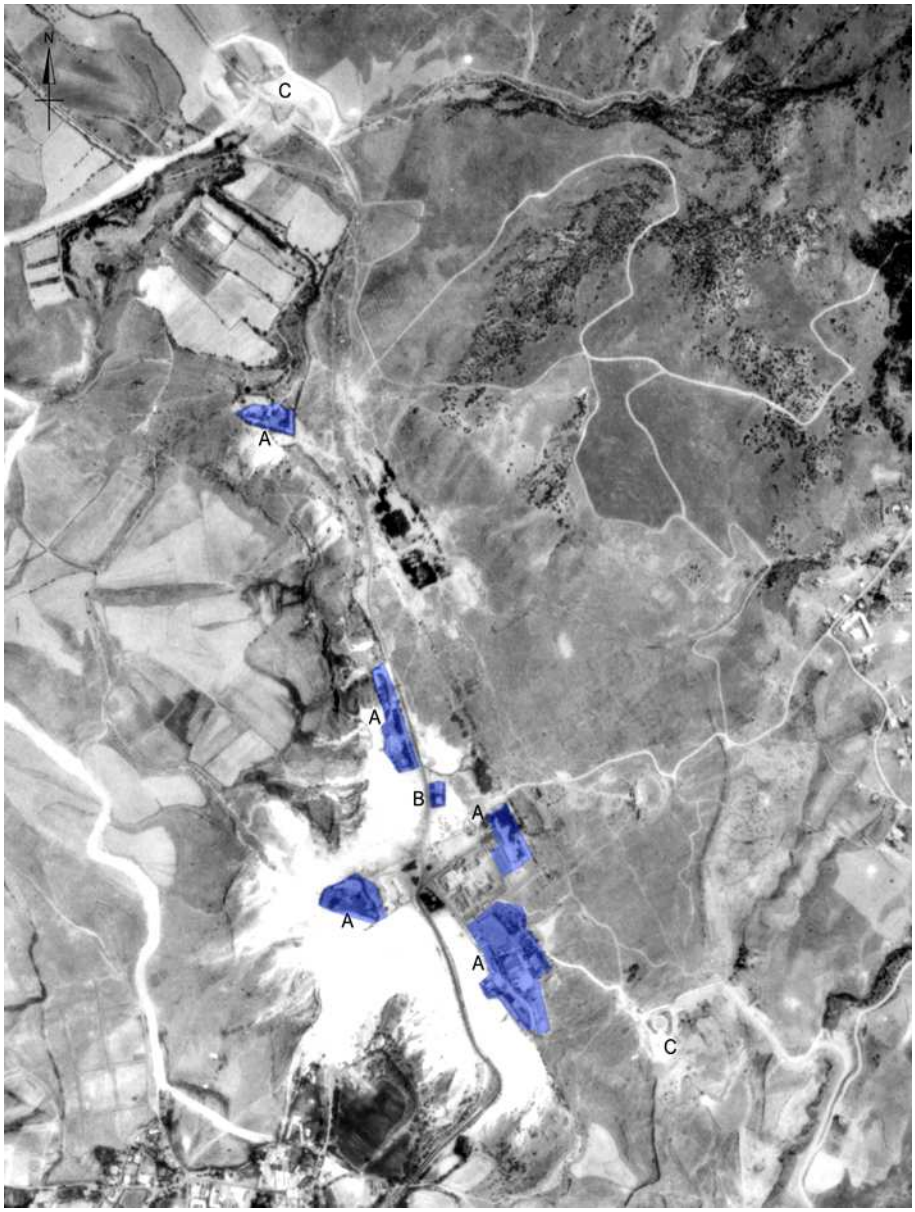

Fig. 7 – Aerial photo of the years 1990s where the areas occupied by the hotels (A), the barrack (B) and the building sites (C) of the northern and southern entrances.

In addition, given the presence in some areas of the city of colluvial and alluvial deposits (especially in the North Agora) and recent limestone formations that have covered and incorporated the ancient structures and are thick even 3–4 m, the research has been integrated with geophysical surveys (SCARDOZZI 2010b).
In particular, the layers of limestone have covered the western side of Hierapolis since the Medieval age and have been generated by the calcareous water from the thermal springs along the seismic fault that run through the ancient urban area. The integrated use of Ground Penetrating Radar, Magnetometry and Electrical Tomography, have allowed to document a lot of traces of buried walls and roads, that were georeferenced in the archeological map; an overall surface of 6 hectares was investigated with geomagnetic surveys and one of about 1 hectare by means of GPR (Figs. 8–9). In one case, geophysical measurements were verified through excavations, which clarified the causes of different anomalies.

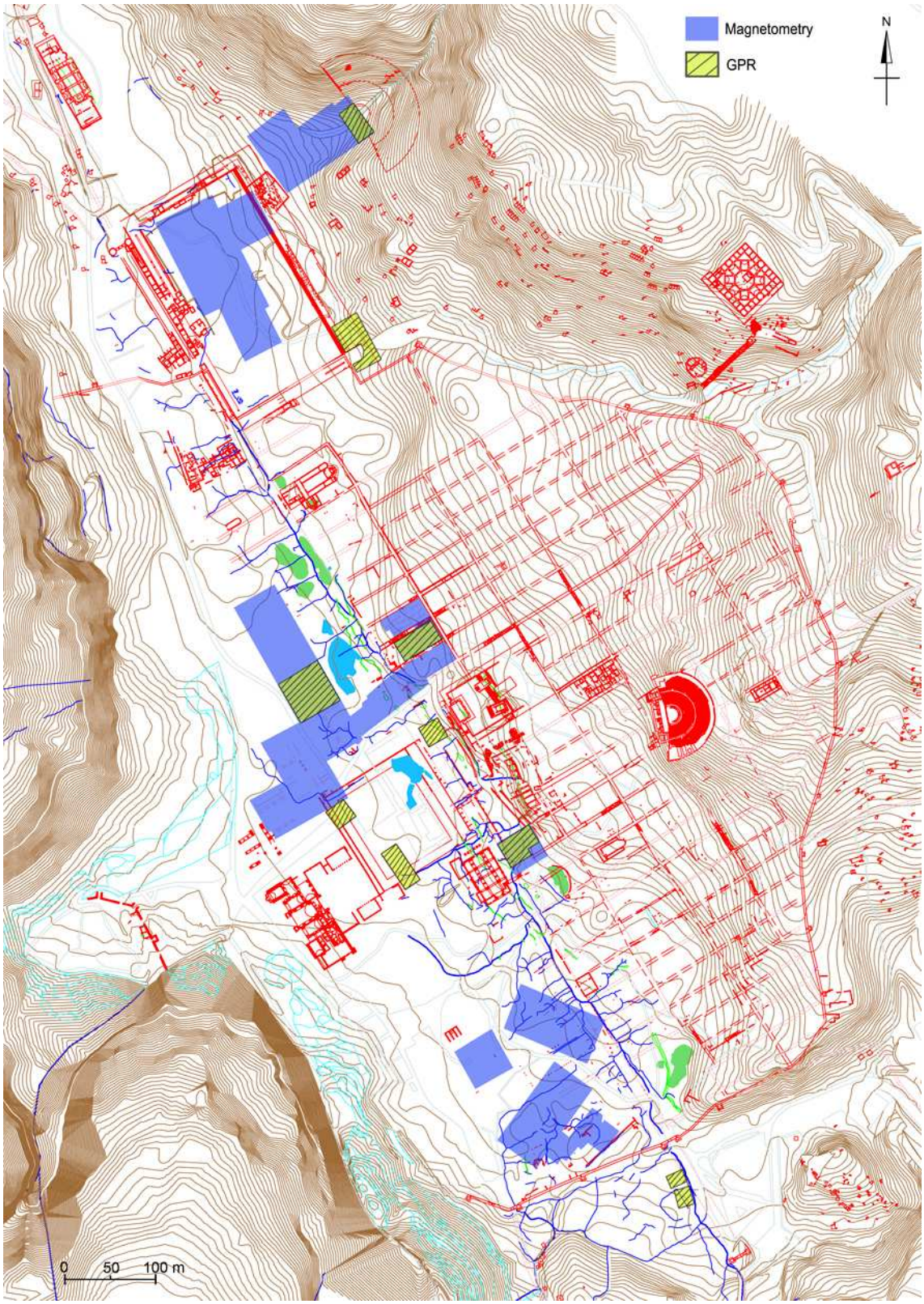

Fig. 8 – The sector of the urban area covered by geomagnetic and GPR surveys.

Fig. 9 – GPR measurements using together 200 mhz and 600 mhz antennas (2010).

The archaeological research has also taken account of the hydro-geological and seismic features which characterized Hierapolis and are closely connected to the ancient monuments (Fig. 10). Specifically, all the evidence regarding the seismic fault (fractures in the surface, from 50 cm to more than 1 m wide), which is still active, was documented and inserted into the archaeological map. Moreover, the thermal springs that well up from the subsoil through cracks in the surface along the fault and were closely connected with the sacred areas in the central sector of the city, have also been located on the archaeological map.

Fig. 10 – Aerial photo of the central area of Hierapolis: Byzantine channels (big arrows) and fractures on the surface (small arrows) are visible.

It also now shows the entire network of limestone channels that originated from these springs and characterised the city above all in the Middle-Byzantine and Ottoman periods. These channels, which were

often made using materials taken from previous constructions and lined with calcium carbonate deposited by the same waters, cross the central and western sectors of the city and were used for agricultural purposes, for livestock rearing and for the production of wool. In the Hellenistic and Roman-imperial periods, they flowed from the high plain of Hierapolis down into the fields of the Lykos valley below (Figs. 11–12), as Strabo (XIII, 4, 14) and Vitruvius (VIII, 3) both attest. Subsequently, after the earthquake of the mid 7th century AD, with the disappearance of an urban administration able to manage this water supply network in a unified way, the emergence of the waters was no longer controlled; the channels proliferated, following irregular routes through the streets and ruined monuments, to bring water to the various places in the ancient urban area that were still occupied.

Fig. 11 – Ancient channels that flowed from the high plain of Hierapolis down into the fields of the Lykos valley below.

A first result of this research was the *Atlas of Hierapolis*, published in 2008, which is a compendium on the knowledge of the city and its necropolises acquired during the first 50 years of work by the Italian Archaeological Mission; the maps of the *Atlas* showed the plans of all the monuments investigated and of the excavations areas. Instead, the research of the last three years is finalized to the creation of a digital archaeological map in 1:1,000 scale, which update the *Atlas* with new data from stratigraphic excavations, systematic archaeological and topographical surveys of the not-excavated areas and monuments, and with the data acquired thanks different remote sensing technologies (ground, aerial and satellite). The map is also characterized by new layers, the features of the seismic fault, the springs, the water channels and the detailed geological data concerning the urban area and its surroundings.

Fig. 12 – Aerial photo of the northern and central sectors of Hierapolis (1992), in which the traces and remains of the regular urban layout are visible (A); B, ancient channel that flowed down into the Lykos valley; C–F, hotels.

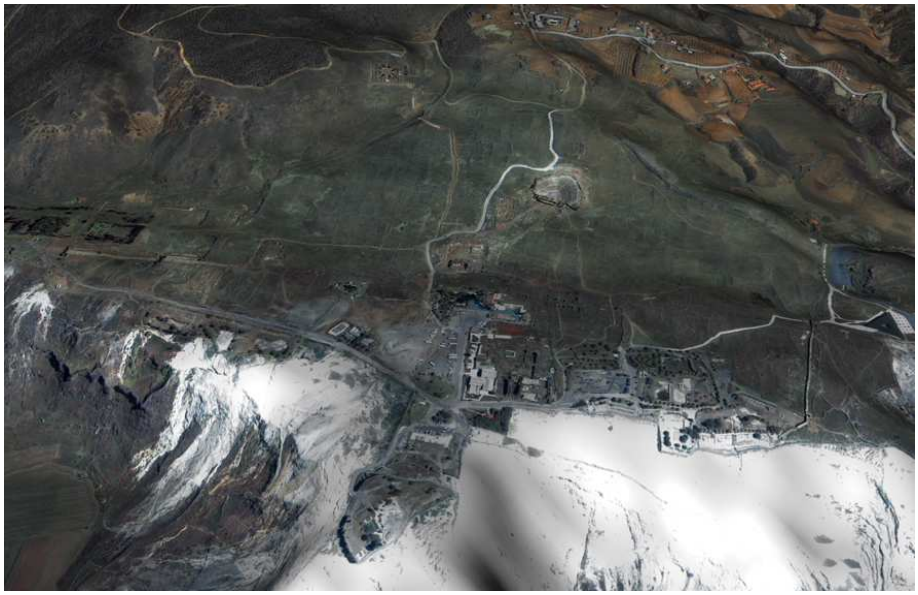

Fig. 13 – High resolution DEM extracted by an Ikonos-2 stereo-pair of 2004 and draped with a pan-sharpened image in real colours of the same satellite.

Moreover, the map is integrated with Digital Terrain Models and Digital Elevation Models charatcerized by different geometric resolution, elaborated from carthographic data and through GPS surveys and remote sensing data; in particular, DEMs processed starting from SRTM (Shuttle Radar Topography Mission) data and extracted from an Ikonos and an ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) stereo pairs, both acquired in 2004 (Fig. 13). (G. S.)

Methodology and 3D technologies in the “Virtual Hierapolis” project

The rich documentation collected during archaeological and topographical field works is the base for the 3D reconstruction of some monuments and archaeological areas of Hierapolis, which are performed by the Information Technologies Laboratory of the Institute for Archaeological and Monumental Heritage, as part of a project, still in progress, finalized to the virtual restoration and the three-dimensional restitution of ancient buildings of Hierapolis. The project, named “Virtual Hierapolis”, has been gradually articulated in the campaigns of excavation of the years 2007–2009 and developed from early experiences of Virtual Reality conducted on the same site during previous years (CAGGIA and ISMAELLI 2009; LIMONCELLI 2009; GABELLONE 2010a and 2010b). The activation of a specific research activity of Virtual Archaeology is certainly one of the most innovative aspects of the work conducted in recent years by the Italian Archaeological Mission. In effect, the recent developments of the information technologies have led to the emergence of new disciplines characterized by the union of methods and techniques specific of the “hard sciences” with the humanities sciences. These represent, especially in the field of archaeology and architecture, a significant update of the traditional studies on ancient buildings.

Within these new disciplines we introduce the Digital Restoration, based on a set of integrated methods of Computer Graphics, both bi-dimensional and three-dimensional, and aimed at restitution of artistic, archaeological or architectural heritage in its complete or almost integrity.

The second objective of this study is to create tools of communication that are easy to understand and can be used to develop narratives (storytelling) that describe, using the methods of Virtual Reality, the results of archaeological explorations. This objective was obtained with the use of ultra-realistic rendering. This is part of a tendency over the last few years, which have seen considerable progress and growth in the technologies used for the study and visualisation of ancient contexts. The specific solutions produced by software companies, in terms of both realism and real-time 3D applications, are being taken up by increasing numbers of archaeologists and historians. The use of Virtual Reality enables them to give their research and products a more interesting appearance and to provide non-expert users with communication tools that can have great emotional impact. This approach is not just about seeking the most technologically advanced solution, but is in line with current developments in entertainment and Cultural Heritage communications. Today representation has to aim at realism and the emotional involvement of the spectator, using the same techniques as modern cinematography. In the project presented here, the realism comes in the simple form of a video, which however has great value from both the emotional impact and the scientific point of view, making use of laser scanning, camera mapping, particle effects, new rendering engines, image-based modelling and other highly advanced modelling techniques. Communication in this case becomes “spectacular” and a vehicle for high-level content, suitable for all levels of user, but created with tools of great

scientific value, founded on interdisciplinary research and dialogue between different forms of knowledge. (F. G.)

The Theatre of Hierapolis: a holistic approach to reconstructive study

The Holistic philosophy is based on the idea that the properties of a system – any system, from microscopic particles to the most complex stellar systems – should be considered as a whole. In other words, they cannot be explained exclusively with reference to their individual components.

The specific nature of an object thus derives from the interaction and the relations between its parts. This interaction is synergistic and generates “emergent properties”, i.e. new possibilities and values that are not predictable from the characteristics of their separate parts. An example is steel, whose resistance to traction is far superior to the sum of the resistance of its components iron and nickel. Thus, concerning that which may be termed holistic, the functional sum of its parts is always greater (or at least different) to the sum of its parts. A typical example of a holistic structure is the biological organism, since a living being should always be considered as a single whole that cannot be expressed by the sum of its constituent parts. In recent times the conviction has developed that the study of Cultural Heritage is not a static subject: indeed, since the research evolves continuously with the discovery of new finds, scholars must regularly revise their past certainties. Thus Cultural Heritage can no longer be perceived as the sum of a number of individual objects, kept and catalogued in museums or collections, with no link to the historic and social context. The very mechanisms and evidence on which the proposed interpretation of a datum is based must be clearly described and presented to the wider public. In this way the research process is clearly defined and the public can be involved in the assessment and interpretation of an archaeological find and the relevant reconstruction. These considerations lead to a reflection on the study of ancient monuments, those complex and intricate creations that form the basis of a Cultural Heritage constructed by human beings by the addition of juxtaposed, connected elements. Such elements are organised in such a way as to give rise to “architectural organisms” which, just like organic forms, fall within this holistic vision.

We speak here obviously of cities, roads, monuments, houses and settlements in which the approaches to construction are repeated and are recognisable as belonging to a single domain. The city is clearly a “domain” in which a holistic vision finds full application: the construction of a building generates unique conditions that influence the adjacent and subsequent constructions. The basic architectural elements, such as cornices, capitals and columns, make reference to an overarching “idea of the city”. Thus the task of reconstructing an ancient building must necessarily encompass the interpretation and the study of the entire urban complex, and this entails identifying and representing the “idea of the city” of which the individual building is just a part. The results of this reconstructive study show that the Theatre of Hierapolis is highly representative of those expressive and historical features that we find in all the monuments of the city. Thus, together with the theatre, the overall physiognomy of the entire ancient context begins to take shape: “Virtual Hierapolis” is an interdisciplinary study and representation project based on Virtual Reality systems which includes the Stoa-Basilica (Figs. 14–16), the Frontinus Street and Gate (Fig. 17), the Nymphaeum of Tritons (Figs. 18–19), the Martyrium of Saint Philip, the Marble Stoa, etc.

Fig. 14 – 3D reconstruction of the Stoa-Basilica in the North Agora (2nd century AD).

Fig. 15 – Virtual reconstruction of the façade of the Stoa-Basilica.

The construction of a VR-based knowledge system assumes that the connections between items (in our case individual monuments) and their fundamental coherence will facilitate intelligent or cognition-based behaviour that enables even non-expert users to grasp the “idea of the city” and the cultural identity that the items reflect. The holistic approach, i.e. one that is based on an understanding of the monuments considered together, does not preclude however the possibility of using an inductive method, which proceeds from the detail to the general picture, to find solutions to specific interpretative problems. The reconstruction of the theatre, as described below, was accomplished by “digital anastylosis”. This involves the three-dimensional

restitution of the individual architectural and sculptural elements that are detectable. Each of these elements has been re-processed in three dimensions using NURBS modelling (*Non Uniform Rational Beta Spline*) and *Subdivision Surfaces*, starting from the detailed two-dimensional survey drawings.

Fig. 16 – Stoa-Basilica: a detail of the 3D reconstruction of the central sector of the façade.

Fig. 17 – Virtual reconstruction of the Frontinus Street and Gate (1st century AD).

In the case of the Theatre (Fig. 20), although the quantity of collapsed architectural elements is sufficient for the formulation of a plausible reconstructive hypothesis, the fragmentary nature of the surviving pieces and in some cases (fortunately rare) the total absence of the originals does constitute a problem. As always happens in the reconstruction of ancient contexts, the more or less fragmentary information concerning the original appearance of a monument can give rise to serious problems of reliability. For this reason, in addition

to the hyper-realistic reconstructive proposal, we have presented a correspondence model of the original elements, which will allow scholars to retrace the criteria used for the reconstruction and to formulate alternative proposals. Hopefully it will also help to soften the diffidence that is sometimes shown towards 3D technologies, which are frequently abused in reconstructive proposals. (F. G.)

Fig. 18 – The current situations of the Nymphaeum of Tritons (A) and its virtual reconstruction (B).

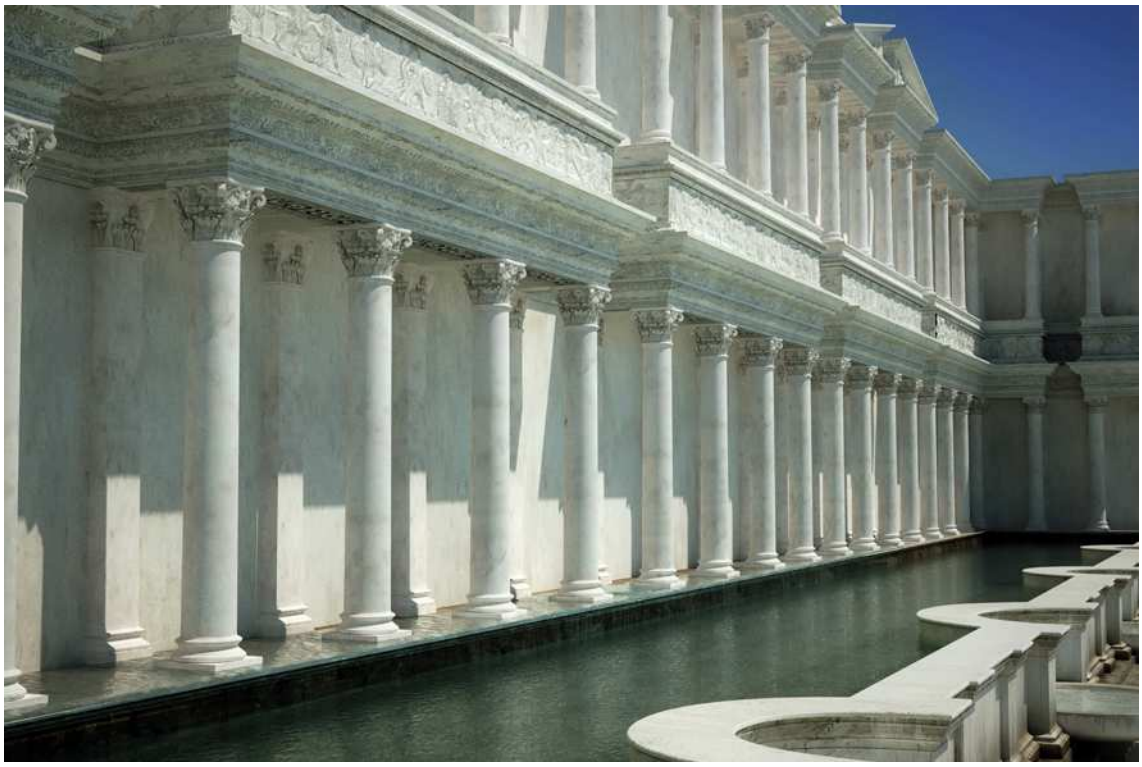

Fig. 19 – Nymphaeum of Tritons (3rd century AD): a detail of the 3D reconstruction of the façade.

Fig. 20 – Virtual reconstructions of the Severian three superimposed orders of the *scaena* of the Theatre.

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The archaeological research on the ancient topography of Hierapolis and the virtual reconstruction of its monuments are possible thanks to the constant support of Prof. Francesco D'Andria, Director of the Italian Archaeological Mission. Special thanks go to Drs. Laura Castrianni, Giacomo Di Giacomo, Imma Ditaranto and Veronica Randino of the IBAM-ANTARES Lab., which work at the archaeological map of Hierapolis, and

to Drs. Francesco Giuri, Ivan Ferrari and Massimo Limoncelli, research fellows of the IBAM-IT Lab, for their contribution to virtual reconstructions.
Until 2008, the digital archaeological map of Hierapolis was elaborated in cooperation with the Faculty of Architecture of the Polytechnic Institute in Turin (Drs. Antonia Spanò, Cristina Bonfanti, Filiberto Chiabrando). The reconstructive study of the Theatre of Hierapolis was conducted with the considerable study of Filippo Masino and Giorgio Sobrà (Polytechnic Institute in Turin).
Geo-physical surveys in Hierapolis are performed in 2007–2008 by Drs. Stefan Giese and Christian Hübner of the company GGH (Giese, Grubert & Hübner Gbr.) from Freiburg, and in 2010 by Drs. Gianni Leucci, Nicola Masini and Raffaele Persico of the CNR-IBAM.

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SESSIONS

A Critical View on Urban 3D Reconstruction Models

The printed legionary camp of Vindonissa

The development of a new digital and physical model of Vindonissa

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Abstract: Between 2008 and 2009 the Kantonsarchäolgoie Aargau and several external partners (University of Basel, University for applied sciences Northwester Switzerland, private companies) realized a new model of the legionary camp of Vindonissa (Windisch/Switzerland) and its surrounding civil settlements. On the base of substantiated scientific research it was possible to provide the model with a high level of detail, thus giving the reconstruction of the situation around 90 AD a maximum of plausibility. From the digital CAD data, the buildings were printed out directly by a 3D-printer. The model now shows well over 500 buildings on a surface of 3.2 × 2.32 m on the scale of 1:450 and is one of the new attractions of the Vindonissa-Museum in Brugg (Switzerland). Our aim was to realize a model of Vindonissa, which both satisfies the interests of a broader public as well as those of the archaeologists. Our work included not only the reconstruction of the buildings, but also the rendering of the natural setting with the hill-plateau of Windisch and the landscape with the rivers Aare and Reuss. Transfoming data from the digital world into reality as physical, 3D-printed buildings is a step which has not yet often been carried out in the context of archaeological museums and it provides us with much new information about such processes.

Keywords: Roman Legionary Camp, museum, 3D-model, 3D-print.

Vindonissa and its museum[1]

In the 1st century AD, the Roman army built and occupied a legionary camp at the confluence of the three rivers of Aare, Reuss and Limmat. In the past 100 years, research on this legionary camp and its civil settlements has been carried out in the region of the present-day town of Windisch[2]. In 1912, the initiative of the Gesellschaft Pro Vindonissa led to the construction of a museum – the Vindonissa Museum - in the town of Brugg near Windisch with the aim of presenting the substantial finds from the excavations to the wider public[3].

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[1] Sincere thanks are given to A. Lawrence (translation), E. Bleuer (permission to publish the following article), R. Zanini (model-constructor), D. Parry and Th. Schneider (3D-Print VDS Arlesheim), M. Rietmann, H. P. Wyss and R. Müller (Institute for 4D-Technologies i4DS at the University of Applied Sciences North-western Switzerland, Brugg), D. Berger, R. Bellettati, F. B. Maier, Ch. Meyer-Freuler and Th. Pauli-Gabi (Kantonsarchäologie Aargau).

[2] Actual overview over the state of archaeological research about Vindonissa in PAULI-GABI 2006. Summary of the history of archaeology in Vindonissa in the early 20th century in MEYER-FREULER 2010.

[3] Concerning the origin of the Museum cf. HEUBERGER 1913; recently published article concerning the origin of the museum: FELLMANN BROGLI and WERTENSCHLAG 2009.

The previous model

In 1957, on the occasion of an exhibition about roman Switzerland in Basel, R. Fellmann initiated a first model of the legionary camp in the scale of 1:200 based on the state of knowledge at that time (FELLMANN 1957/58; FELLMANN 1956/57). In the 1960ies and 1970ies, in the wake of large-scale excavations to the south and west of the legionary camp, certain building floor plans were added to the model (Fig. 1)[4].

Fig. 1 – The old model of 1957 with the groundplan-additions of the 1960ies and 1970ies in the Vindonissa-Museum in Brugg (B. A. Polyvás, Kantonsarchäologie Aargau).

The new model and its making

For over 50 years, situated on the ground floor of the Vindonissa Museum, the model rendered precious services valued by all visitors for the presentation of the Roman legionary camp; through this model, generations of visitors were introduced to the world of Vindonissa (Fig. 1). As our knowledge of the legionary camp and its surroundings has grown considerably in the last decades, the old model is now outdated in many aspects. As the integration of a scale model within the new permanent exhibition was judged a worthwhile investment, the wish was expressed to present and visually explain these many new results to

[4] Excavations of Windisch-Königsfelden 1961–1963 [V.61.1], published in WIEDEMER and SITTERDING 1961/62; WIEDEMER 1962; WIEDEMER and TOMAŠEVIC 1962; TOMAŠEVIC 1963, the excavations of Windisch-Windisch-Scheuerhof 1967 [V.67.1] and Windisch-Scheuerhof 1968 [V.68.1], published in MEYER-FREULER 1989, and the excavation of Windisch-Königsfelden [Feuerwehrmagazin] 1976 [V.76.3], published as MEYER-FREULER 1998.

the visitor in the form of a new model. Thus, within the scope of the re-conception of the permanent exhibition in 2008, a new model was commissioned.

Many decades of intensive excavation and research activity in Vindonissa have led to a growth in information not only on the legionary camp itself but also on the areas out with the camp walls[5]. Thus, one of the special features of the new model is that it portrays a comprehensive reconstruction of Vindonissa around 90 AD. This no longer “just” includes the legionary camp as in the previous model but also the civil settlements to the west[6], the south and to the east (Fig. 2).

Fig. 2 – Current state of knowledge of the roman settlement of Vindonissa with the size of the old model (blue) and the one of the new model (red). Size 1 to 5000 (R. Bellettati, Kantonsarchäologie Aargau, modified by the author).

Furthermore, the presentation of the natural topography with the plateau of Vindonissa framed by the rivers Aare and Reuss enables a better understanding of the unique location of this settlement.

[5] Cf. last published summary about the civil settlements of Vindonissa in HINTERMANN 2000.

[6] i.e. results from the excavations from the “Vision Mitte” project, current summary with links for further reading in SCHUCANY et al. 2009; SCHUCANY and WEY 2009.

The viewer can quickly get his bearings with the help of the depicted geography and the ruins still visible today, like the amphitheatre, the camp gates or the baths located in the cemetery of Windisch. Thus, the new model presents the legionary camp and its surrounding settlements within its natural environment and whilst providing the visitor with a comprehensive impression of the layout of a Roman landscape at the end of the 1st cent. AD.

As opposed to the previous model, the comprehensive design of the area on show (1.04 × 1.4 km) should not merely allude to any archaeological structures nor should it leave any questions open. Based on the status quo of the extent of the Roman settlement, a scenario has been designed where the camp of the 11th legion is situated in the centre of a three-part Roman town (*vici* in the south and the west, *canabae legionis* in the east). For the layout of the settlement of Vindonissa, a scale of 1:450 was chosen, leading to the dimensions 2.32 × 3.2 m in its final version. In accordance with the aesthetics of the new permanent exhibition, the model's colour scheme is reduced and details like vegetation, humans and animals etc are omitted (Fig. 9). As a compromise in the model's visualization, colour was added to the buildings tiled roofs (red), wood shingles (brown), the terrain (grey) and water (blue). The vegetation is depicted by schematic tree and shrub cut-outs and isn't highlighted from the terrain.

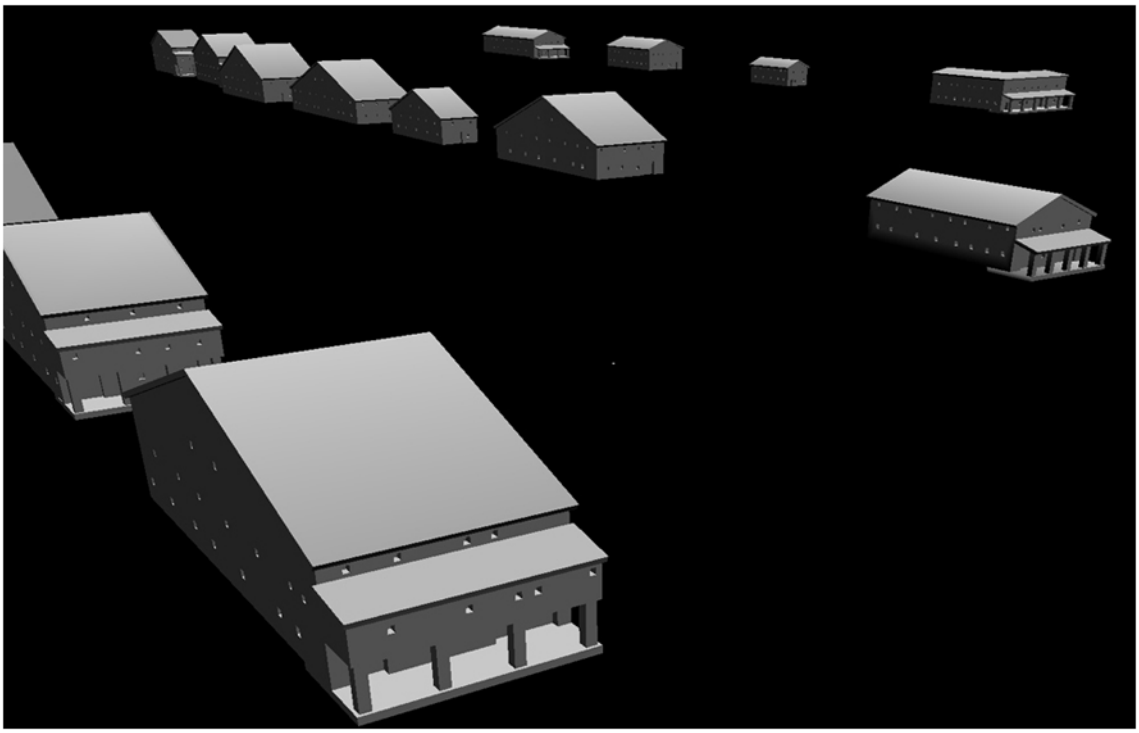

Fig. 3 – Screenshot of a part of 14 different types of civil settlement buildings (author, Kantonsarchäologie Aargau).

The reconstruction of the buildings

In a first project phase all available documents of the known building floor plans dating to the end of the 1st cent AD were collected and the reconstruction of the buildings was started on (Fig. 4–5). On one hand the existing reconstructions were incorporated and the buildings were reconstructed and compared to other examples from contemporary military camps.

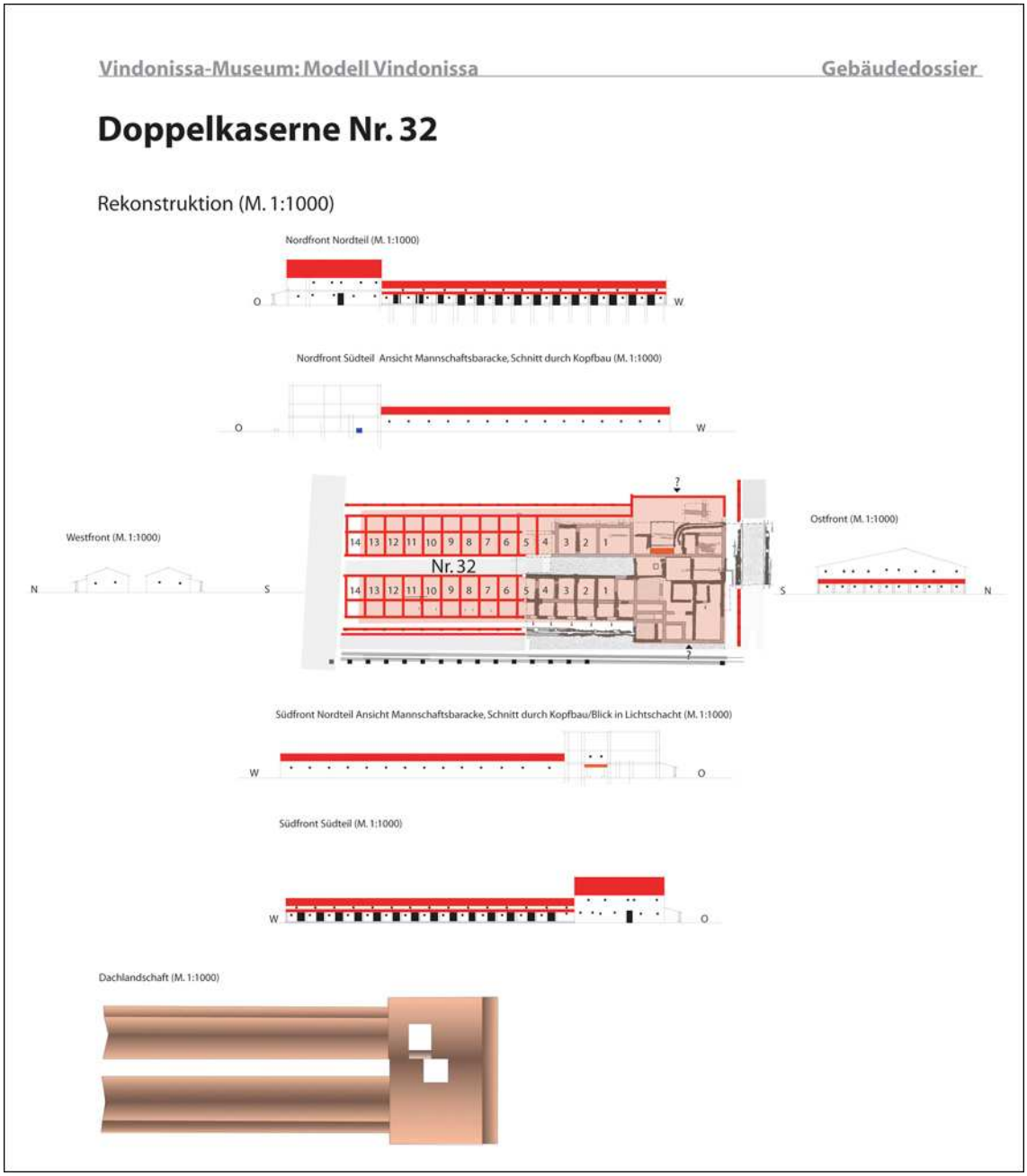

Fig. 4 – Screenshot of the digital plan of the reconstruction of a military barrack (excavation Windisch-Spillmannwiese 2003–2006 [V.003.1]) (author, Kantonsarchäologie Aargau).

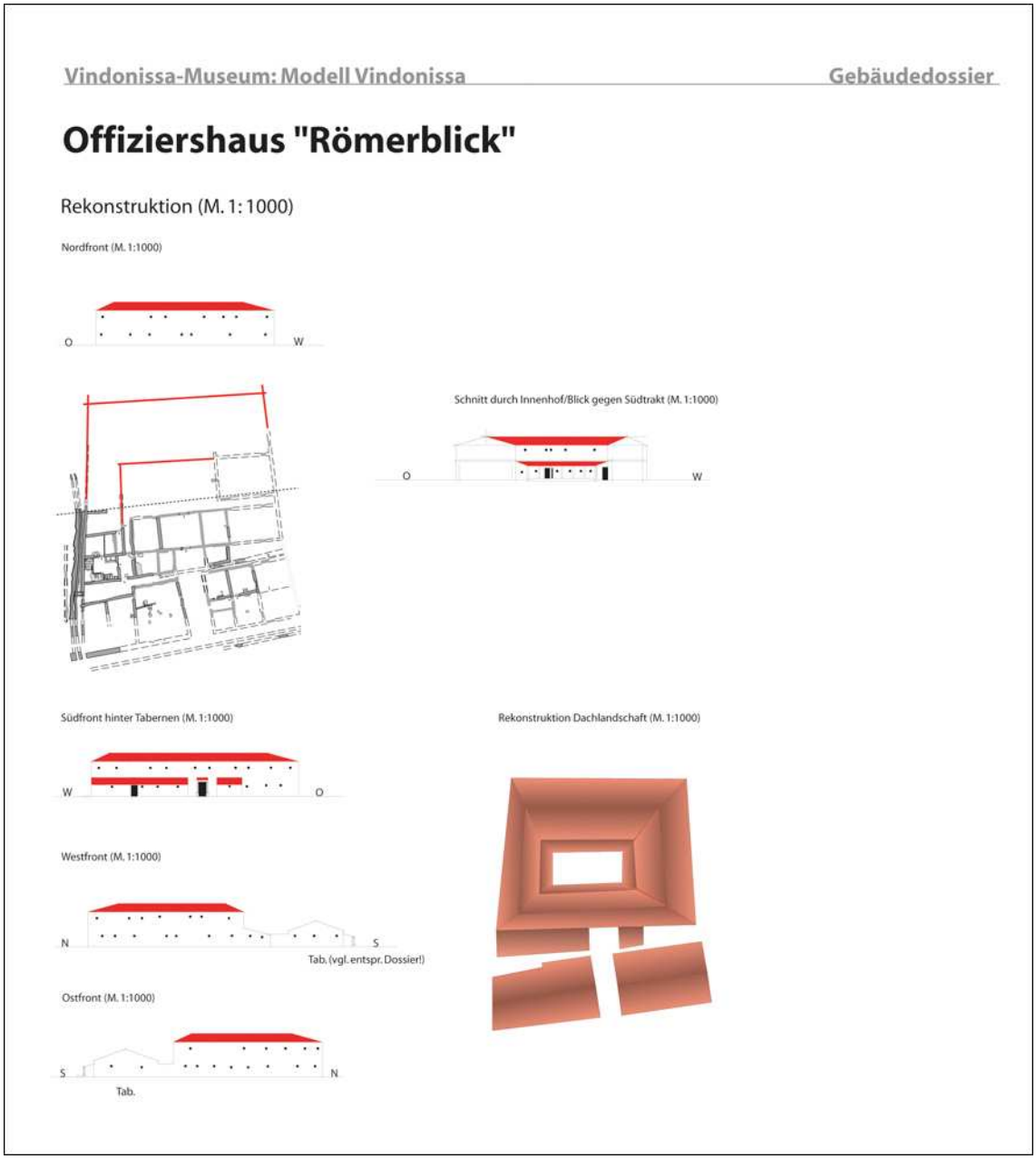

Fig. 5 – Screenshot of the digital plan of the reconstruction of an officer's building (excavation Windisch-Römerblick 2002–2004 [V.002.11]) (author, Kantonsarchäologie Aargau).

After this phase, the civil settlements in the east, south and west of the legionary camp were reconstructed, also using comparisons from other contemporary military camps. However, as the state of knowledge is very sparse in some cases, structures belonging to Roman towns *(vici)* dating to the late 1st cent AD were included (e.g Baden, Lenzburg, Oberwinterthur or the numerous *vici* in today southern Germany). Even if only a few floor plans are archeologically proven from the civil settlements, the functional character of the individual areas is still evident. The extensive excavations of the last years in the area of the western civil settlement have shown that a habitation consisting of strip-houses characterized by craft and trade installations was established along the important trunk roads leading to Augst *(Augusta Raurica)* and Avenches *(Aventicum)*. To the east of the legionary camp, quite a different type of settlement existed: Floor plans belonging to Mediterranean-style peristyle villas point to a settlement characterized by larger, somewhat more luxurious living quarters[7]; simple strip-houses were erected further afar, nearer the banks of the river Reuss. Structures belonging to road junctions, sanctuaries, large buildings such as the amphitheatre or the forum, baths, the harbour or cemeteries yield important information on the disposition, access, extent and infrastructure of the civil settlement. Based on the known strip-house floor plans from the western civil settlements and other known strip-house forms from the surrounding *vici*, 14 different types of civil settlement buildings were defined and, depending on the topographical conditions, were fitted into the uncharted road sections (Fig. 3). Scale plans of the buildings were drawn up as vector graphics and the corresponding faces of the buildings and their top views were reconstructed (Fig. 4–5). Where necessary, sections through the buildings were compiled. In June 2008, along with the final touches to the reconstructions, these drawings were then converted into printable 3D models (Fig. 6–7).

Fig. 6 – Section of the rendered 3D-model, part of the legionary camp and the civil settlements to the west and south of the camp (M. Rietmann, i4DS FHNW).

[7] Overview in HINTERMANN 2000: 16–23.

Fig. 7 – 3D-Print of the buildings of the model: the data of the buildings is send to the printer, the printer brings to life coloured buildings out of a powder of plaster, after printing the buildings have to be excavated, cleaned of remains of powder and then fixed additionally with epoxy (author, Kantonsarchäologie Aargau).

Terrain model

The terrain model was created simultaneously to the settlement buildings. The modern-day terrain model served as a point of departure and was then modified using historic maps and further illustrations to create an “antique” situation as possible. In order to obtain absolute values for the natural soil, measurements from excavations and exploratory trenches from the whole area were used. The spur of Windisch, which has undergone drastic transformations in modern times, especially posed some problems. For the reconstruction of the dump (Schutthügel) historic photographs and drawings are available depicting the dump before the railway was built at the beginning of the 20th cent. and before the large excavations in the 1950ies (Fig. 11). Furthermore, recent exploratory trenches to the north of the dump have yielded precise information on the extent of its northern perimeter (cf. PAULI-GABI 2005). The rendering of the riverscape was based on one hand on the earliest cartographic illustrations, on the other analogous, undeveloped river systems and the resulting alluvial zones were used by way of comparison (cf. BROWN 1997).

The research and their external implementation into a 3D-model resulted in an electronic file of the terrain model, which was then cut out of three synthetic panels by means of the CNC method. Custom-fit indentations were also cut out of the panels thus enabling an easier location and fastening of the printed buildings within the model (Fig. 8). The roads and the accompanying ditches were cut directly out of the terrain (Fig. 15).

On the three base panels, with a complete weight of 250 kg, 550 buildings were inserted. New results from excavations and research can be retrospectively implemented by exchanging the buildings on the cut out panels (Fig. 8–9).

The setting of the model and its media display

The installation of the model within the museum comprises of a table at the child-friendly height of 65 cm along with a projector attached to the roof of the ground floor (Fig. 10). By operating two touch screens attached to the sides of the model, the visitor can gain additional information on specific parts of the settlement or buildings (Fig. 11–13). In a time travel, the development of the area in late Celtic, late Roman, Mediaeval and modern times can be projected onto the situation dating to the end of the 1st cent AD. The projection of the modern-day map in the scale of 1:25’000 of Windisch and the surrounding area enables a direct localisation of the Roman buildings within the present-day town and is also met by great enthusiasm by the visitors (Fig. 13).

Fig. 8 – Finish in the museum: the printed buildings are introduced in the CNC-cut terrain-model by the model-builder R. Zanini (author, Kantonsarchäologie Aargau).

Fig. 9 – Overview over the finished model from southwest. In the foreground the biggest building of roman Switzerland, the so called “forum” which is excavated in these days (author, Kantonsarchäologie Aargau).

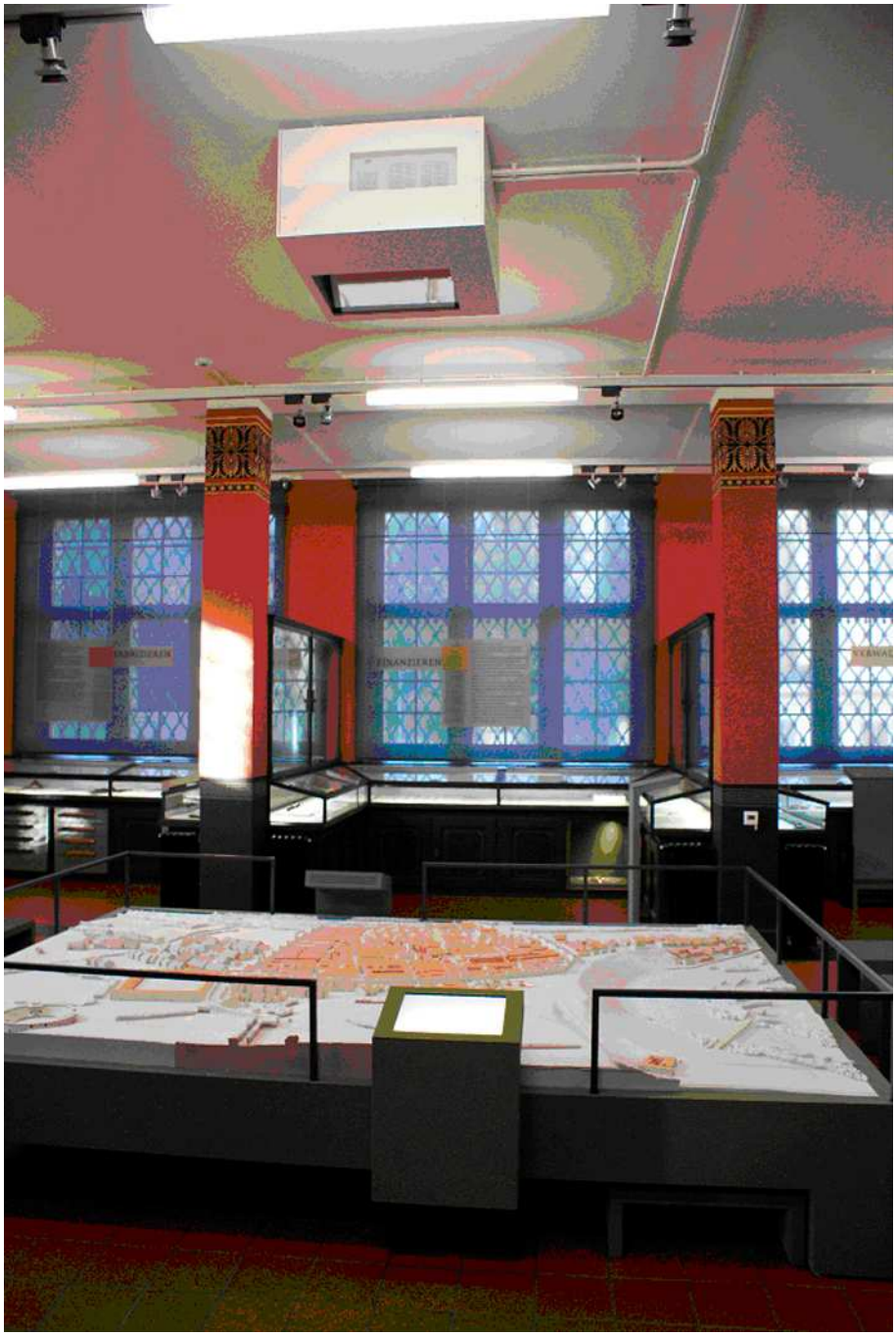

Fig. 10 – The whole installation of the model in the museum with the projector on the roof and the touchscreens on two sides of the model-table (author, Kantonsarchäologie Aargau).

Fig. 11 – Detail of the northern part of the model with the river Aare, the dump to the north of the camp. The area is highlighted by the projector and at the same time additional information about the dump is provided on the touch-screen (author, Kantonsarchäologie Aargau).

Fig. 12 – Overview over the model with all the streets on show, highlighted by the projector (author, Kantonsarchäologie Aargau).

Fig. 13 – Model of roman Vindonissa around 90 AD with a projection of the modern-day map of Windisch (author, Kantonsarchäologie Aargau).

Closing thoughts

The complexity and size of the model of Vindonissa is without peer in Switzerland. Outside of Switzerland, such models have hardly been constructed. It appeals not only to the archaeologically interested public; moreover the combination of the 3D-printing technology with the precision method makes it a reference point for architecture, product design, industry design or engine building (Fig. 14–15).

The realization of the new model of Vindonissa is an example of successful cooperation of state institutions (Cantonal Archaeology Service of Aargau, Aargau Geographic Information System AGIS), Colleges (University of Basel, University of Applied Sciences North-western Switzerland, University of Applied Sciences Basel Cantons) and private companies (Digitale Archäologie Freiburg i. Br., R. Zanini Formenbau Menziken, VDS Visual Data Systems Arlesheim, I-Art Interactive Basel).

At the moment further projects for a 4D-Visualization of the Vindonissa Model are in the pipeline in cooperation with the institute for 4D-technologies of the University of Applied Sciences Northwestern Switzerland. Using 3D glasses and a projection of the model on a screen, the visitor are able walk through the camp following the footsteps of the legionaries[8].

[8] Link to a television broadcast about the realization of the new model http://www.ag.ch/vindonissa/de/pub/FN [24 feb 2011].

Fig. 14 – Detail of the western part of the legionary camp in the background, in the foreground buildings of the western civil settlement (author, Kantonsarchäologie Aargau).

Fig. 15 – Detail of a street-scene in the eastern civil settlement (author, Kantonsarchäologie Aargau).

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Ubiquitous Computing for Augmenting the Learning Experience within an Urban Archaeological Tour in the City of Graz by use of an ArcheoApp for the iPhone

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Abstract: A particular problem for students of urban archaeology is that objects found at archaeological excavations have been removed to a museum or depot and the site is built over, thus no longer visible. Methods of labelling these sites and providing information about history and contents are available and should be made easily accessible using ubiquitous/mobile devices (e.g. iPhone, iPad etc.). We applied Radio Frequency Identification (RFID) first, however, the handling of both the transponder and the receiver along with a mobile device was technologically working, but had some usability disadvantages. Based on this experiences, we developed an application for an iPhone (iPhone App) and used Quick-Response Codes (QR-Codes) instead of RFID. The current ArchaeoApp is developed to use it for learning purposes along a route of 13 points of interest for a lecture on urban archaeology.

Keywords: Urban Archaeology, iPhone App, Ubiquitous Computing, Smart Tags, QR-Codes.

Introduction and Motivation

In archaeology researchers deal with a lot of archaeological artefacts and features, which usually are described by information on separate pieces of paper labels. Although such labels are practical, information on paper has some limitations. Consequently, the support by electronic information is apparent.

Originally, the idea of this project was to use radio frequency identification technology (RFID) for tagging archaeological objects. This was obvious due to the fact that we have past experiences with the application of RFID based technologies (HOLZINGER et al. 2010; HOLZINGER, SCHAUPP and EDER-HALBEDL 2008; WEIPPL, HOLZINGER and TJOA 2006; HOLZINGER, SCHWABERGER and WEITLANER 2005). For the first experiment we used a RFID-reader device (smartSCANNDY, see Fig. 1) along with a separate handheld device.

Although technologically working, it appeared to have lacking usability; i.e. to handle two devices simultaneously is awkward. Based on these experiences, we decided to use 1) a smaller device (iPhone) and 2) Quick-Response (QR-Codes) having the advantages of optical readable, i.e. functioning with any handheld having a camera. Currently nearly all mobile phones have integrated cameras. The goal was to support an urban archaeological tour in the context of a lecture held 2009 at the Institute of Archaeology in Graz (see Fig. 2). After getting to know the basic terminology of the current legal framework and historical development of the methods, the main focus of this lecture is an introduction to the current methods of practical archeology, in order of their application in the field. Taught is the "theory of practice", the basic

methodological approaches to prospecting, surveying, excavation, documentation, typology and chronology as well as age determination methods. Key issues are here for example in the aerial archaeology, scientific survey- and age determination methods as well as the stratigraphic excavation method, layers genesis and interpretation of findings. Practical exercises on selected topics (cartography, surveying, measurement, find documentation, photography) are included. The program is supplemented by field trips and field exercises at archaeological sites and open excavations in and around Graz. Based on the urban archaeological tour in the City of Graz 13 archaeological points of interest (POI) have been used.

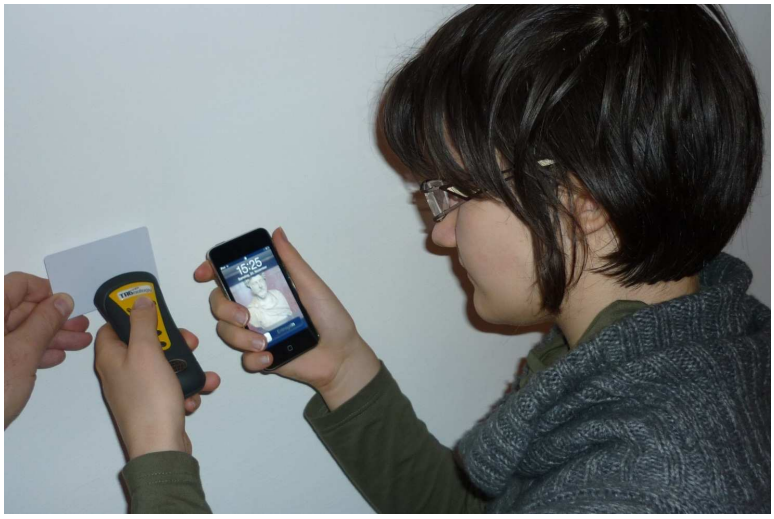

Fig. 1 – The SmartSCANDY device in operation (left), reading information from a RFID tag (we are grateful for the support of TAGnology, http://www.rfid-center.at).

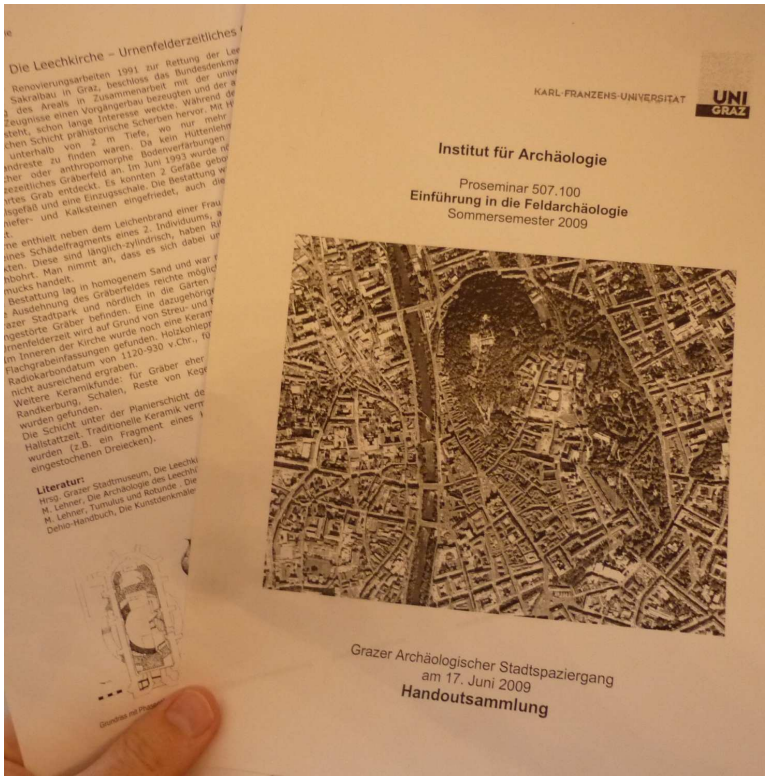

Fig. 2 – Paper based script of the Archeological City Tour, collection of 34 handouts worked out by students within the lecture of M. Lehner, Graz).

Selected points of interest (POI)

1. Leechkirche
2. Karmeliterplatz
3. Schlossberg
4. Reinerhof
5. Stadtmuseum
6. Admonterhof
7. Die Grazer Stadtmauer
8. Hauptplatz
9. Franziskanerkloster
10. Das frühmittelalterliche Gräberfeld / Alte Universität
11. Grazer Burg
12. Römersteine
13. Romanische Kirchen

Fig. 3 – Aerial view showing the 13 points of interest (M. Lehner, Graz).

Short archeological description of the 13 points of interest

1.) Leechkirche

This is the most important early Gothic sacral building in Graz. 1990 to 1994 the church and the church hill were archaeologically investigated by the Bundesdenkmalamt (BDA). Apart from two previous-phase round churches of the Romanesque style, it was shown that within the core of the hill an iron-age grave-mound is hidden, which was erected 600 BC on the area of a late bronze-age urn field (LEHNER 1996).

2.) Karmeliterplatz

In 1998 an early urn field cremation grave was found during restoration work within the yard of the former cloister (13th century BC). After all, this is the earliest documented grave of Styria (today in the Styrian country archive). At the Karmeliterplatz and in the adjacent Pfauengarten, archaeologists were able to secure findings of a gigantic fortified settlement of the Late Bronze Age and Early Iron Age during a 7000 sqm rescue excavation (April 2002 to August 2003). Today, nothing of both excavations is visible (HEYMANS 1999; KRAMER et al. 2004).

3) Schlossberg

This is an excellent example for the continuity of settlement. Findings are known from the late stone age until modern age, covering a range of 6000 years. Nevertheless, there were few regular excavations, because the whole suitable settlement area on the hilltop was covered by a castle in the Middle Ages (besides other, the residence of the Styrian margraves as the Babenberg Leopold V, who died here in 1194), which was destroyed by Napoleons´ troops in 1809. Today most of the area has been built over (ARTNER 1997; KRAMER 2003).

4.) Reinerhof

In the course of renovations in the years 1992–1994, excavations took place, in course of which the “Stadthof” (first mentioned in 1164) of the Cistercian monastery Rein has turned out to be a late Romanesque “Saalgeschossbau”, which in return has been marked on the modern façade. A large amount of finds was discovered including ancient roman, medieval and prehistoric pottery (KRAMER et al. 1995).

5.) Stadtmuseum

An emergency excavation took place as the City Museum of Graz was expanded in 1995 and 1996. It showed, that the area was used since the eleventh century. Basements and walls belonging to medieval buildings came to light. In fact the modern western Wall is set to a foundation which dates back to the thirteenth century. During the new architectural planning two early modern latrine pits have been integrated (KRASCHITZER 2004).

6.) Admonterhof

In the 12th Century mainly metal-working craftsmen settled in the place where, in the late 13th century, the Admonterhof (Stadthof the Benedictine abbey Admont) was built. Due to the fire risk, they had been pushed to the edges of the then existing castle’s lower settlement, which entirely consisted of wooden houses. During the excavations in 2001 and 2002, necessary for the construction of an underground car park, 4 building phases were determined up until the 17th century, creating Admonterhof in its present form. Since the 1930s, it has been owned by the Kastner and Oehler storehouse (LEHNER 2004).

7.) Die Grazer Stadtmauer

When dealing with city archaeology, one can also see the constant change of time by looking at the city wall: First mentioned in 1265, it is not always possible to distinguish between the wall sections of the 13th, 14th and 15th centuries. Today, only a few of the fragments of the city wall still remain, all of them in later buildings, and the exact course of the wall is still unresolved (TOIFL 2003; LEHNER 2003).

8.) Der Grazer Hauptplatz

2001, large quantities of medieval material were found in the profile of a 38 m long trench. The subsequent excavation over several months provided evidence of a continuous settlement activity of today's Hauptplatz from the early 11th to the early 15th century. After small pit houses (semi-subterranean “Grubenhäuser”), there were two phases of timber buildings until, in the end of the 13th century, they were completely replaced by stone houses, which in their turn were removed around 1420 by the redesign of the square. A small part of the rich finds, including, besides the ubiquitous ceramic; glass vessels, coins, keys and tools is now on display in Hauptplatz, tucked away by the side-street to Davidgasse (STEINKLAUBER et al. 2002).

9.) Franziskanerkloster

A part of the Graz city wall was composed of the west wing of the earliest city monastery in Graz, built in the middle 13th century. However, the area had been already settled in the 12th century. In the 16th century there was a transformation, during which the city wall was demolished and a new building was erected. Between 1989 and 2010, five excavations by the BDA and the Institute of Archaeology have been carried out during construction (LEHNER 2009).

10) Frühmittelalterliches Gräberfeld in der Alten Universität

In 2003, 17 graves, dating from the 8th and 9th centuries AD, were found in archaeological investigations during construction on the university, which had been opened in 1585. 6 of the graves contained grave goods including pottery jars, rings, and headdresses and a small iron knife. The finds – unfortunately with limited accessibility for the public – are displayed at the locality in a corridor of the house Hofgasse 14. It is believed that there is an associated early medieval settlement in the area of Hofgasse / Freiheitsplatz, which, however, is not supported by findings (GUTJAHR 2007).

11.) Die Grazer Burg

In 1438, under Emperor Friedrich III, the construction of the citadel was started, which consisted initially of only two buildings: the main building and “Friedrichsburg” In 1500, under Emperor Maximilian I, the famous late Gothic double spiral staircase was built. Up until the 19th Century, there were many additions, alterations and demolitions of the medieval buildings. In the summer of 2010, in a short rescue excavation in the eastern wing adjacent to the Burgtor (eastern medieval city gate, the 13th century city wall was exposed, together with what are probably some high middle age warrior burials.

12.) Die Römer in Graz (Römersteine)

The two Roman stones in the stair tower of the Grazer Burg (castle) are from Flavia Solva and were placed at their current location during the time of Maximilian I. Another stone originating in today's Slovenia is located in the courtyard of the Palais Saurau in the upper Sporgasse. One can state the following about the Roman settlements of the within today´s Graz city limits: The findings, which are mainly concentrated at

Schlossberg and in Strassgang, show evidence of a settlement activity from the 1st to the 4th century AD, especially in the peripheral areas of the “Grazer Feld”. However, up until now, no Roman settlement has been excavated in Graz. An important indicator of settlement are the numerous burial mounds, according to which up to 30 settlement sites are presumed to be in today's municipal area (ARTNER 1997; KRAMER 2003; GRAZ IN FUNDEN 2003).

13.) Romanische Kirchen

The Romanesque style refers to a period from the 11th to the 13th century. Characteristic of this style are round arches, thick walls and small funnelled windows. The archaeologically explored Romanesque churches in Graz are: the Leechkirche, the chapel of St. Thomas on Schlossberg and the parish church of St. Peter; still unexplored sites include the Stiegenkirche, the Grazer Dom (Cathedral), the Rupertikirche, St. Martin, and the parish churches Strassgang, St. Leonard and St. Veit.

Related Work

Although there is some related work on the use and comparison of RFID versus QR-Tags, there is no such work available within archaeological education.

Osawa et al. developed a support system for outdoor learning using exploratory observation and conducted an experiment to use their system in nature observation. Their system used both RFID tags and QR-Tags to locate positions on a horticultural farm and its surrounding forests. They used a handheld computer along with a reader to detect the tags, where the students got a description and an educational hint. Additionally they used a mobile phone with a camera along with QR-Codes. Their evaluation showed that both RFID and QR-Tags were regarded as useful for outdoor learning by the students. The comparison of the two tag systems showed that the QR-Code was preferred, due to the easy handling with lightweight mobile phones (OSAWA et al. 2007).

A further work was presented by Chang et al. and describes a novel wayfinding system aiming to increase life independence of cognitive-impaired people (e.g. mental retardation etc.). They used geo-coded QR-codes which embed the coordinate (x, y, floor) along with a social computing approach to shorten the learning curve of the end user. For this purpose they attached geo-coded QR-codes which can be imagined as a new kind of traffic sign system to selected positions on routes. The navigational photos served on demand to the end user who uses the built-in handheld camera to take the QR-code when it is in eyesight range. A tracking function is integrated to timestamp the visited positions and issue alerts in case of anomalies. They also found QR-codes, in comparison to RFID sensor networks, as a cheap, easy and useful alternative tracking system increased which increased the sense of security and also lowers the entry threshold to accepting the assistive technology (CHANG et al. 2007). A general approach to tagging objects can be found in (GOH et al. 2007). Moreover there are examples of cultural mobile guides that put the end user and their need for mobility in the focus of attention (e.g. AUGELLO et al. 2006; PILATO et al. 2006) and there is some previous work which has been done on augmenting the learning experience in museums (e.g. HALL et al. 2006).

The ArchaeoApp Implementation

Based on the archaeological problem description in section 1, a concept for a mobile application has been created. In the beginning we thought on which platform the application should be developed. Besides of the increasing popularity, primarily due to the robust hardware equipment, the choice fell on the iPhone – or rather on the iOS platform, respectively. The iPhone has an integrated high resolution auto focus camera for an easy and precise capture of the used QR codes. Furthermore, the built-in GPS and the compass are also ideal for geo-location and thus suitable for navigation in the field. In the current version the app was implemented as a tab bar application in Objective-C, based on the iOS SDK 4.1. As our test device, we used an iPhone 4 with the current operating system iOS 4.1. The application also runs well on all models of iPhone 3GS series with the latest iOS versions. For the implementation of the software we made use of existing frameworks. For the recognition/processing of the QR codes, we used the Open Source Encoder ObjQREncoder by Jeff Verkoeyen, http://mac.softpedia.com/get/Developer-Tools/ObjQREncoder.shtml. For the geo-location and map view we used the already integrated framework "CoreLocation" and "MapKit". These two frameworks are not only for retrieval of up-to-date maps, we are also able to determine the position of the device on the map, i.e. the ArchaeoApp can also be used for navigation purpose. The archaeological information, described in section 1, is displayed in a so-called "Web View". In this view you can easily embed web content in the application. In our case this is done by using HTML code, having the big advantage that the content can be edited without much programming knowledge.

Fig. 4 – The ArcheoApp on geo-location “Leechkirche”.

Conclusion and Future Work

Future work includes the implementation of three adaptive levels (learner, tourists, children) and a so called archaeological scavenger hunt (Schnitzeljagd in German). Consequently, the primary use for learners of Archaeology will be expanded to tourists and children on the basis of a game-based approach, in order to

raise awareness for cultural heritage. Such an archaeological scavenger hunt is similar to a geocaching experience (O’HARA 2008).

To date no work on implementation of an archaeological scavenger hunt has been reported, although there are a few museums mentioning the usefulness for education (see e.g. the American Museum of Natural History, who also provides a direction App, http://www.amnh.org/apps/explorer.php).

Massimi et al. point out that mobile computing enables a group to accomplish efficient fieldwork in teams that they once performed in isolation, over several trips, or not at all. Field researchers can deduce new information from findings they make while in the field, and apply it immediately to the situation at hand. This is especially important in fields where the time or resources to conduct several studies isn’t available. This domain can be termed mobile collaborative problem-solving (MASSIMI, GANOE and CARROLL 2007).

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Visualising a phantom: 3D-reconstruction, architectural survey and modern urbanistic valorisation of Schloss Neugebäude, Vienna

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Abstract: Based on conventional architectural analysis and archaeological documentation work, a new 3D-reconstruction of Schloss Neugebäude (Vienna) with its vast gardens and surrounding dwellings has been elaborated from 2009 to 2010 by “Liv|in’ past”. However, by showing the first planning stage of Maximilian II and his architects this model is trying to evoke some kind of a historical phantom actually never to be accomplished. Thus, ample historical research had to close the gaps in the archaeological record, shedding light on fundamental questions of architectural history. By using analogies from 16th century Italy, France and Bohemia, the actually unfinished core of the representative southern façade, an impressing ensemble of columns and vaulted arcades, was tentatively reconstructed and linked to a specific fashion of Late Renaissance architectural design. In the same manner, the original shape and subsequent historical development of the roofing was convincingly explained for the first time. Regarding the large gardens and hunting facilities, compelling new evidence could be gathered in combination with the results of the preceding 3D-modeling, allowing for further complex interpretation of Austrian architecture in the late 16th century.

Keywords: virtual reconstruction, 3D-modeling, heritage, urban development.

Fig. 1 – Engraving by J. A. Delsenbach, 1715 (Österreichische Nationalbibliothek).

Introduction

This paper tries to deal with the question of how an archaeological and architectural survey, finally amounting to a three-dimensional virtual model, may help us to gain benefits not only for a single historical site, but also for its urban context and the people living in such areas[1]. Apart from objects in the very centre of cities, many historical buildings were originally erected in an open and pure natural environment which, over the course of centuries, quite often was turned into housing or industrial areas and thus covered with buildings of different style, size and purpose of use. Therefore, "Urban Archaeology" often has to deal with monumental sites of an originary rural character which nowadays are often surrounded or even partly covered by more recent structures of municipal outfit. The focus of our study, Schloss Neugebäude in Vienna, is considered to be the most important Late Renaissance castle north of the Alps (cf. LIETZMANN 1987: 36–58, 198–203; KNÖBL 1988: 7–10, 81–94; HOLZSCHUH 1989: 366; LIPPMANN 2006–07: 143, 161; GRIEMANN 2008: 3–13). Nevertheless, its fate has been rather lamentable until today. More than 400 years since the end of the initial building activities, the City of Vienna is taking up its responsibility for this worthy heritage in its property by trying to start a comprehensive revitalisation initiative. This commendable action was immediately confronted by two main questions: What could be an optimal usage for this huge complex? How should rules and conventions of modern heritage management be applied to a monument which actually never has been completed, lacking any documentation of the originally intended design by the commissioner and his architect (LIETZMANN 1987: 59–64, 161–170; HÖHLE 1989; WEHDORN 2004)? The first answer was easy to be found: This important cultural site should in any case be accessible to the public and thus become a tourist attraction with other functions to be added. However, the second question proved to be more complex due to the difficult definition of valid construction or reconstruction principles. Following a suggestion of the architect Manfred Wehdorn, a decision was made to create a convincing model of the site's perfection, as it was most probably originally intended by Emperor Maximilian II, the commissioner, and his unknown architect. At this stage, the elaboration of a most plausible 3D-model, based on the serious assessment of all sources available, was assigned to the authors of this paper. As a first task it was necessary to define clear margins within a serious assumption of how the different parts of the castle and the rest of the site were most probably intended to be shaped by their creators. Only then can one start a fruitful discussion about the options and permissions for renovation, reconstruction or modern architectural interventions. Therefore, we would like to show on which conditions and assumptions our work relied, how we gathered all the information needed for a scientifically sound 3D-model, and how we could justify our work as an "idealised" but nevertheless most plausible picture of an important historical site.

Approaching the phantom: Historical and architectural analysis of Schloss Neugebäude

Schloss Neugebäude is located in the southeast of Vienna. The site has not earned a proper amount of appreciation over a long period of time due to its extraordinary and partly tragic history (cf. LIETZMANN 1987: 59–105; KNÖBL 1988: 31–34, 97–123; HÖHLE 1989; WEHDORN 2004). Initially planned as a noble

[1] This work was conducted by the visualisation team "Liv|in' past" (D. Maschek, M. Schneyder, M. Tschannerl). The project was commissioned by the "Stadt Wien", the city authorities of Vienna, to build an idealized model of Schloss Neugebäude as Maximilian II planned it until his death in 1576. This model will be part of an urban development program in the modern area surrounding the castle.

hunting lodge and summer residence by the emperor Maximilian II, the building process after his death was continued only half heartedly by his son Rudolf II. Finally abandoned in the 17th century and partly demolished by Maria Theresia in the 18th century, the castle was used as a powder depot during the 19th century. In the early 1920ies it was connected to the crematory of the Zentralfriedhof. Thus, Schloss Neugebäude in Vienna’s 11th district never got beyond the status of an architectural phantom. Instead, it became a fragment of great hopes and ambitions, a testimonial of disrepair as well as a shadow of great Renaissance architecture north of the Alps (Fig. 2).

Fig. 2 – The Neugebäude in its present state (http://de.wikipedia.org/wiki/Schloss_Neugeb%C3%A4ude).

Over the last decades several different attempts were made to analyze the beginning and purpose of the original concept of the castle. In the 1980ies, excavations undertaken by the Stadtarchäologie Wien directed by Ortolf Harl shed some light on the sequence of building phases and the original design of the gardens (summed up by LIETZMANN 1987: 101–104; SEEBACH and SCHREIBER 1989; WEHDORN 2004). As opposed to the previous scholarly concentration on 19th century plans, historical paintings and the analysis of the present state, those excavations for the first time provided valuable information on building activities, which were intended in Maximilian’s first concept, but had never been carried out. Furthermore, the floor plans of some parts of the building and its surroundings could finally be clarified. Additionally, several art-historical publications have exhaustively dealt with prototypes of the castle and tried to identify its architect. Historical documents point to the participation of the Mantovan Jacopo Strada in planning and design (LIETZMANN 1987: 110–136; LIPPMANN 2006–07: 146–147, 153). Furthermore, various architectonical details indicate the work of the Roman architect Giovanni Sallustio Peruzzi, son of the famous Baldassare Peruzzi (KNÖBL 1988: 21–25; MERZ 2001: 99, 251 n. 46–47; GRIEMANN 2008: 8–11)[2]. Peruzzi was in charge of some important papal building projects like Castel Sant’Angelo and St. Peter’s, before Maximilian II called him to Vienna in 1567.

Summing up the evidence, this first phase of research has generated two main conclusions in terms of Neugebäude’s building history. They are of major importance for the presented visualisation: First of all there is an essential difference between Maximilian’s original plan and the way the actual building was executed. Neither the castle, nor its gardens were finished as planned. Changes in planning and building can already

[2] Against Knöbl’s arguments but without convincing evidence cf. LIETZMANN 1987: 107; LIPPMANN 2006–07: 164 n. 26.

be detected in Maximilian's lifetime, but they become even more evident after his death in 1576, when his son Rudolf II continued the project. The Neugebäude therefore provides a variety of possible visualisations, which do not wear out by clearly separated, historically evident building phases or stages[3].

Secondly, the castle's later history, mainly between the 18th and 20th century, led to the fact that only a minor part of its original appearance as in the time of Rudolf II and even less so under Maximilian II can still be experienced. The magnificent gardens as well as the impressive pillar galleries and interior rooms were rebuilt, bereaved of their building elements or simply left to decay.

So the main purpose of the new 3D-visualisation concept was to recreate an image of the originally intended look of the castle as accurately as possible by the means of regional surveys, archaeological studies, architectonical observations and analogies (Fig. 3). The visualisation is intended to be seen as a scientific test arrangement, which makes it possible to approach an assumed historic truth by checking different hypotheses. Finally, it is all about a most precise illustration of an architectural phantom. As a second step, the scientific cognition can be used as a basis for further discussion, which deals with questions of monument conservation and concepts of revitalisation. Last but not least, this listed building can now be analysed in its urbanistic context in order to work out concepts for evaluating and improving the infrastructure for visitors, thereby increasing the attractiveness of the whole area.

Fig. 3 – Aerial view of the reconstructed area from northeast (Liv|in´ Past 2010).

The main building consists of two side-galleries – orientated east to west – and a central structure which shows articulated risalites to the north and south (Fig. 4). Those risalites are also called middle-risalites due to their central location in the composition of the façade. The northern part of the core, which is enclosed by the galleries, is still mainly original and intact, as wall structures and vaults unambiguously show.

[3] Cf. St. Peter's in Rome: BREDEKAMP 2000: 9–10, 121–123.

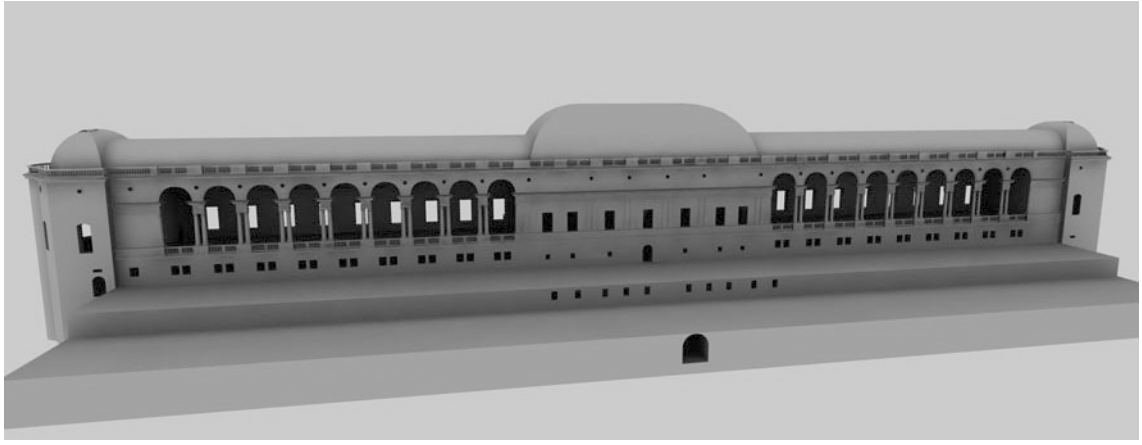

Fig. 4 – Untextured view of the main building with its columned galleries from north (Liv|in´ Past 2010).

The risalite’s part orientated to the south was only built in its fundaments but never finished, as the excavations of the 1980ies could prove. This is probably one of the already mentioned changes and reductions of the original design realized by Rudolf II. In order to reconstruct the originally planned prospect of the southern risalite we can, apart from looking at the foundations, only use analogies from Late Renaissance and Early Baroque architecture. The foundations of the southern risalite show a tripartite layout with a main hall and two minor halls on each side of it. This layout can also be traced in the core building. The architectural structure of the southern risalite obviously adds to a huge *loggia* with a wide opening in its centre, framed by two narrow openings and another two identical openings on its sides. Further projections of the fundament show that these openings in the façade were framed by massive resting bars put in front. This indicates the positioning of columns. The dimension of the projections allows the placing of double columns in the corners of the risalite and the outer edges of the middle *loggia* in the style of the *Loggia di Davide* of Palazzo del Te in Mantua (cf. MARKSCHIES 2003: 72–73; BAZZOTTI 2004: 51–55; LIPPMANN 2006–07: 144–145 Fig. 6, 147, 152, 155; FROMMEL 2009: 156–157). The central opening, which can be reconstructed as a monumental arcade due to the still visible edges of the vaulting, was framed by two single columns (Fig. 5).

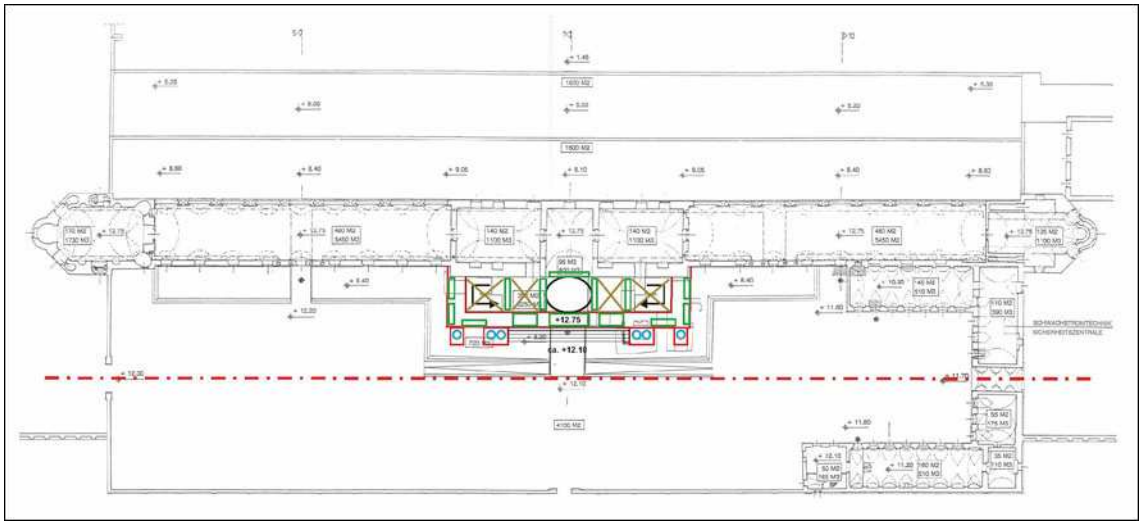

Fig. 5 – Drawing of the southern risalite with vaults, arches and columns added (Büro Manfred Wehdorn, additions by Liv|in´ Past).

This kind of design was quite popular for monumental *loggias* and columned façades in Late Renaissance and Manneristic Italian architecture (cf. LIETZMANN 1987: 183–187; HOLZSCHUH 1989; MARKSCHIES 2003: 60–61, 80–81; BAZZOTTI 2004: 30–32; LIPPMANN 2006–07: 152–161; COFFIN 2008: 122 Fig. 6; FROMMEL 2009: 144 Fig. 165; 152 Fig. 176; 192 Fig. 229; 206 Fig. 247). The layout and especially the covering of the inner parts of the middle-risalite are also based on the foundations and the connection points of the preserved façade of the core building with reasonable solutions for the entrance, using hypothetical patterns of access and departure. You could best compare this to Raffael's and Antonio di Sangallo's *loggia* of the Villa Madama in Rome. This *loggia*, orientated towards the hippodrome, shows a ground plan conceptually similar to the foundations excavated in Schloss Neugebäude. The front elevation of the Villa Madama consists of a central room, opening north through a large vault, which is set apart from its flanking rooms by a shallow dome. The adjoining rooms are covered by groined vaults[4]. In the case of Neugebäude this three-part *loggia* is flanked by two more spatious units on its east and west side, which are also vaulted. The fact that these two rooms are directly corresponding with two doorways in the basement can be seen as an indication for staircases on both sides leading up into the middle *loggia*. As engravings from the 17th and 18th century show the driveway, the main access to the castle led in from the south (cf. LIETZMANN 1987: 39 Fig. 8; 40 Fig. 9; KNÖBL 1988: 36, 50–51). This means that the middle-risalite in its never completed form was planned as a magnificent and representative main entrance, giving access to the halls on the ground floor, the crypto porticoes and the corridors in the basement (Fig. 6).

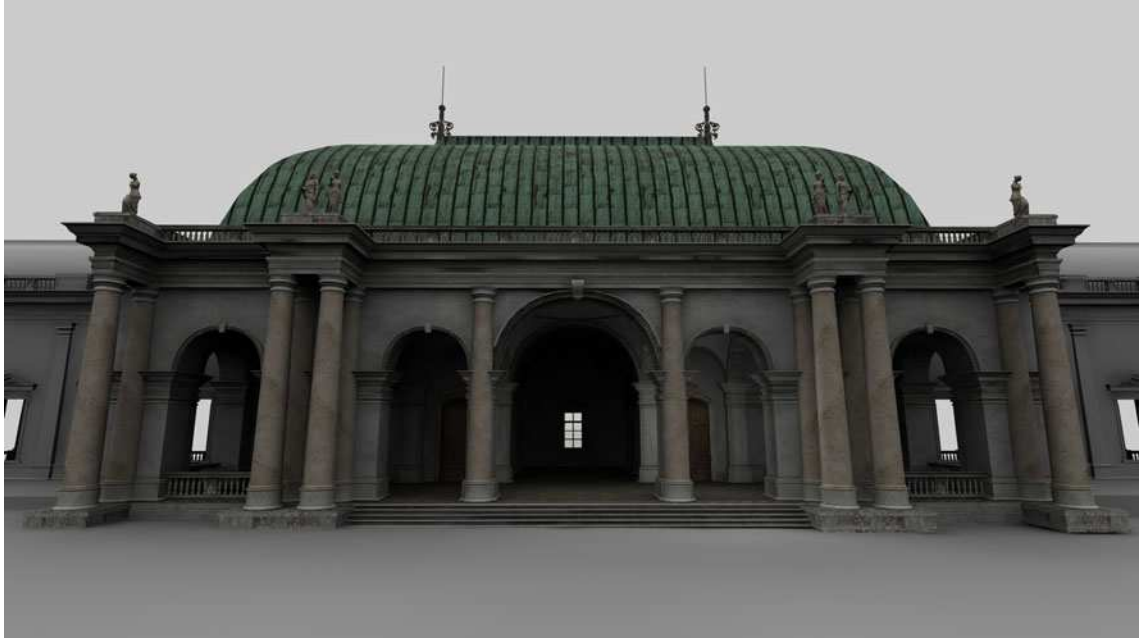

Fig. 6 – Reconstructed southern risalite (Liv|in´ Past 2010).

[4] On the design of the Villa Madama and the *loggia* see FROMMEL 1984: 311–322, 343, 352; COFFIN 1991: 61–63 Fig. 45; MERZ 2001: 91–92 Fig. 86; FROMMEL 2009: 144–148. Cf. HOLZSCHUH 1989: 368; SEEBACH and SCHREIBER 1989: 374–376; COFFIN 2008: 113 Fig. 28.

Reconstructing the northern side of the castle was much easier thanks to the fact that historical images without exception show the northern façade. This might be put down to the fact, as described above, that the southern part of the middle-risalite was never fully realized. In marked contrast to the middle-risalite, the east to west oriented column galleries must have nearly been finished by the time of Maximilian’s death in 1576 for they can be precisely seen in 17th century documents. Herbert Knöbl convincingly showed that major parts of these galleries were demolished to be re-used in the building of Schloss Schönbrunn and the Gloriette in the 18th century (Knöbl 1988: 103–118) (Fig. 7). This is mainly true for the columns, parts of the cornice, and the mouldings. Consequently, the design of the northern façade as seen in our visualisation cannot only be based on distinct historical evidence, but also on exact measurements of original building components (Fig. 8). The side-risalites with the “chapel” and the “grotto” as well as the basement of the chateau together with its crypto portico could be used for the visualisation without any alteration because their architectural substance is still mainly intact[5].

Fig. 7 – The Gloriette in Schönbrunn (http://www.austriatvoygid.com/wp-content/uploads/2011/01/aus_wien_gloriette130b.jpg).

[5] For the design of the “grotto“ cf. LIETZMANN 1987: 47–48; HANSMANN 1988: 57–61; COFFIN 1991: 28–31; BARISI, FAGIOLO and MADONNA 2003: 114–117 Fig. 7–8.

Fig. 8 – The columned galleries in Neugebäude (Liv|in´ Past 2010).

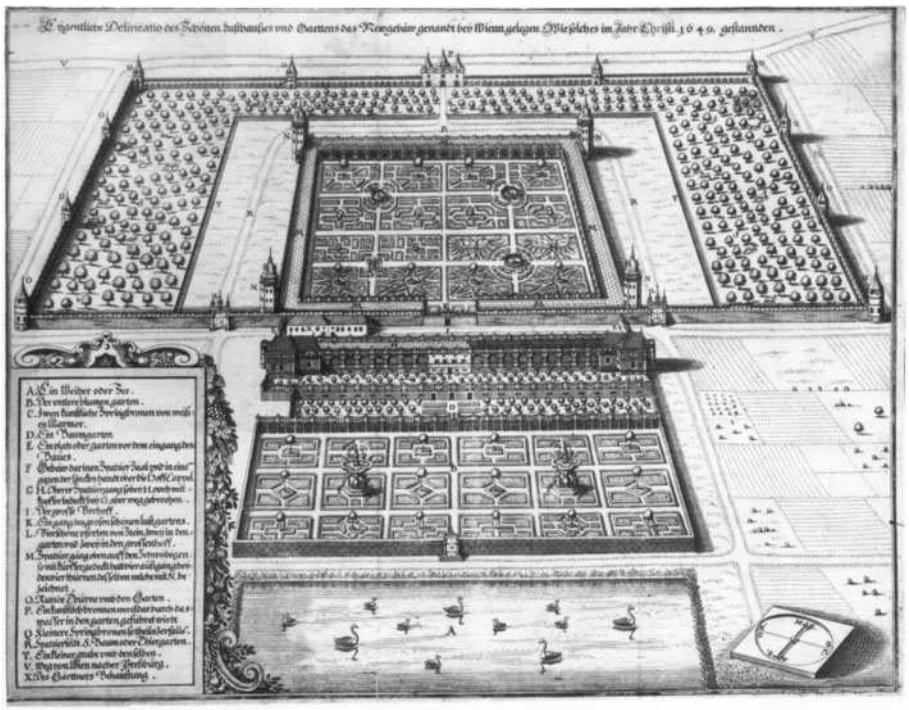

Fig. 9 – Engraving by M. Merian, 1649 (Österreichische Nationalbibliothek).

Dealing with the question of what the initially planned roofing should have looked like was much more complex. Historical pictures are offering different alternatives. The present covering with its pitched roofs in different heights was constructed in the 19th century, while 17th and 18th century views are showing flat roofs surrounded by balustrades (Fig. 9). The chronologically most indicative visual sources consist of two paintings by the court painter Lucan van Valckenborch from 1593 (Fig. 10), which are depicting Emperor

Rudolf II together with his entourage in front of Schloss Neugebäude[6]. Both pictures show the side galleries covered with high pitched roofs, while there is an obvious gap above the middle-risalite. Valckenborch’s paintings are very accurate in terms of topography and architectonical details. In addition, the concordance of both paintings adds to the high historical probability of these depictions. Therefore it is generally believed that these images are historically correct and representative for the building as it appeared in the year 1593.

Fig. 10 – Painting by L. Valckenborch 1590/92 (Wien Museum).

However, based on the 3D-visualisation, some major problems with this widely accepted view could be addressed. Regarding the architectural and historical evidence, it is necessary to propose a new solution for the original roofing of Schloss Neugebäude. In this regard, a look at the documented building process of the galleries provides the first step towards an integrated interpretation of the data available[7]: In October 1576, stone pillars for the galleries were delivered from Wilfersdorf and Sarasdorf. In 1578, others were brought in from the Leitha-mountains. In 1580, stone-masons were working on the north galleries and entrusted with finishing the pillars. This indicates that the galleries could have been finished only after Maximilian’s death. Furthermore, the fundamental changes in the blueprint of the middle-risalite show that the roofing of the risalite as seen in Valckenborch’s paintings has nothing in common with the originally intended concept. If the middle-risalite had been built in the intended way with its richly decorated façade, it would have been necessary to let it stand out in comparison to the galleries. This again would inevitably have resulted in stepped roofing.

The fact that the middle-risalite is shown without a pitched roof in 1593 indicates that the structures below, which had already been completed, were not able to carry a full-length pitched roof in the style of the

[6] A detailled study of these paintings was recently undertaken by GRIEMANN 2008: 14–25.

[7] The chronological sequence is based on LIETZMANN 1987: 73–82 and KNÖBL 1988: 31–34.

galleries. Even more documents support this interpretation. For example, the painters Bartholomäus Spranger and Hans Mont were working in a "torre del fabrica nuova fuori di Vienna" (LIETZMANN 1987: 76, 152–156; KNÖBL 1988: 32). This "tower" has convincingly been identified by Hilde Lietzmann as the risalite on the western side of the castle (LIETZMANN 1987: 153). So this part must have been roofed by 1575. Another painter, Giulio Licinio, is reported to have been working in the middle room of a "torre del pichetho" (LIETZMANN 1987: 76–77, 150–152; KNÖBL 1988: 34). As the middle-risalite of the main building is the only part with three rooms arranged next to each other, this report must refer to painting works in this section (GRIEMANN 2008: 5, 9). All this evidence suggests that in 1581, five years after Maximilian's death, a temporary roofing of the middle-risalite must have existed. At the same time we also know from the archaeological record that this risalite was never finished in its planned form. Thus, the originally intended roofing concept could not be carried out either.

This evidence leads to the conclusion that the pitched roofs as seen on Valckenborch's paintings must have been a temporary compromise to preserve the galleries which most probably were vaulted with a rather fragile plastered wooden structure. This suggestion seems to be even more realistic if we consider Anton de Moys' drawings of defects in the vaulting system from 1600 (LIETZMANN 1987: 51 Fig. 18–19; 87–88; KNÖBL 1988: 49–53) (Fig. 11). The middle-risalite with its brick vault, however, seems to have been covered only by a very flat makeshift roof.

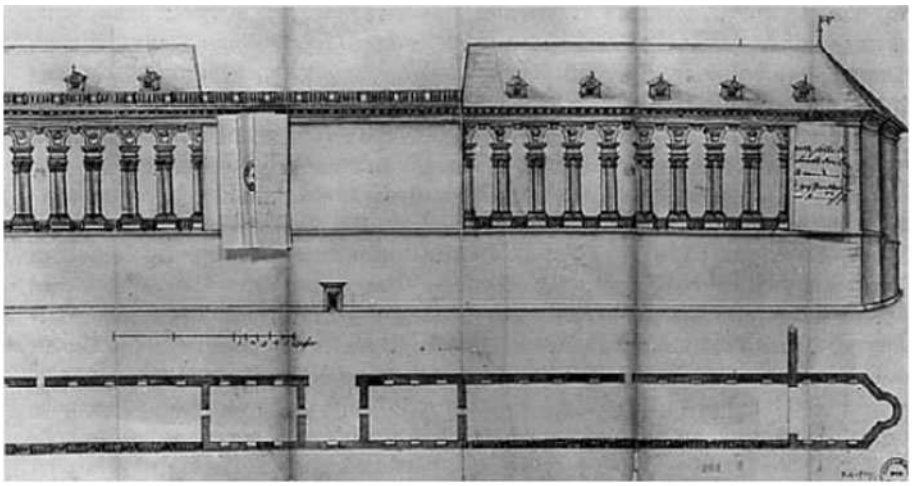

Fig. 11 – Technical drawing by A. de Moys, 1600 (Hofkammer Archiv).

But which kind of roofing could have been intended in Neugebäude's original blueprint? Various documents and accounts of that time frequently mention the transport of copper (LIETZMANN 1987: 69 n. 83–86; 72; KNÖBL 1988: 31–32). Thus, a roof made of this material seems plausible. The flat version proposed by Knöbl is deduced by traces of the makeshift roof, but, as the paintings of Valckenborch show, they seem to have been steep saddle roofs (cf. LIETZMANN 1987: 42 Fig. 11; 88). Vaulting heights and preserved structural connections in the halls of the middle-risalite also point to the fact that in the original blueprint the roof was planned to be raised above the galleries' roofs. Searching for comparative examples of similar Mediterranean pillar-architecture meeting a northern climate, a striking analogy can be found in the copper roof of the Belvedere located on Prague's Hradschin (Fig. 12).

Fig. 12 – The Belvedere in Prague (http://www.gardenvisit.com/garden/prague_castle_royal_garden_and_belvedere).

This monument was designed and built by Paolo della Stella between 1535 and 1563 for Kaiser Ferdinand I, Maximilian’s father (cf. LIETZMANN 1987: 177–179 Fig. 49; KNÖBL 1988: 93–95; MARKSCHIES 2003: 92–93; LIPPMANN 2006–07: 144, 163 n. 13). It was completed only five years ahead of the beginning of construction works at Schloss Neugebäude. This chronological coincidence, the similar architectural structure of the galleries, and the fact that the Habsburgs were commissioners for both buildings, are indicative of similar roofs on Neugebäude and the Hradschin Belvedere (Fig. 13).

Fig. 13 – Neugebäude´s copper roof (Liv|in´ Past 2010).

Another crucial point in the chateau’s planning were the widespread gardens, which are subdivided into a southern garden, a so called *Fasangarten*, and a northern garden (cf. HANSMANN 1988: 79–81 Fig. 53).

The garden south of the castle was surrounded by a wall with galleries placed in front of it and four two-floored towers with a hexagonal ground plan on each corner (Fig. 10). These towers, which must have been finished before Maximilian's death according to several historical documents (LIETZMANN 1987: 72–73; KNÖBL 1988, 32), can be seen in different images from the 17th and 18th century (LIETZMANN 1987: 39 Fig. 8; 40 Fig. 9; 96 Fig. 30; HANSMANN 1988: 80 Fig. 53; KNÖBL 1988: 50–51; LIPPMANN 2006–07: 146 Fig. 7–8; 150 Fig. 12). Unfortunately, these paintings and engravings show the ground plan and the design of roofs and floors in many regards widely differing from each other. So, for the new 3D-visualisation (Fig. 14) once again Lucas van Valckenborch's paintings were used as they are the chronologically closest source. This choice is also supported by Ortolf Harl's excavation results, which proved the hexagonal ground plan as shown in Valckenborch's paintings.

Fig. 14 – One of the two-floored towers in the southern garden (Liv|in´ Past 2010).

The structure and layout of the inner ambulatory can be convincingly reconstructed with the help of Knöbl's research (KNÖBL 1988: 114–115). This proved to be easier as several of the original columns and balustrades were reused as spolia in the castle and the so called *Roman ruin* of Schloss Schönbrunn. The entrance to the south garden was given via a door of which the location is known but not the design. Two alternative hypotheses can be offered here: Either there was a wrought iron gate, or an open arcade with the balustrade-flanked ambulatory of the gallery continued above.

The reconstructed landscaping scheme of the southern garden follows contemporary Italian and French examples (cf. HANSMANN 1988: 27–29, 31–33, 39–41, 51–68; COFFIN 1991: 159–172, 195–214; LAZARO 1999: 40 Fig. 2–4; 44 Fig. 11; BARISI, FAGIOLO and MADONNA 2003: 59, 68–74 Fig. 13, 18; COFFIN 2008: 103 Fig. 15; 109 Fig. 23; 114 Fig. 30; 116 Fig. 32; 165 Fig. 1; 181 Fig. 10.). The south garden was surrounded by the so called *Fasangarten*. This part of the area was bordered by a wall which is now partly integrated into the urn grove of the Zentralfriedhof, into the crematory area respectively (Fig. 15). The shape of the surrounding wall as well as of the towers and their roofs presented in our model were taken from

engravings dating back to the 17th and 18th century (LIETZMANN 1987: 39 Fig. 8; 40 Fig. 9; 96 Fig. 30; KNÖBL 1988: 50–51). Their architectural substance can still be seen today but with various alterations due to the fact that they were used as powder depots in the 19th century. The planting of trees refers to the initially intended use of the area as a hunting and game reserve.

Fig. 15 – Proposal for the landscaping scheme in the southern garden (Liv|in´ Past 2010).

Fig. 16 – View of the northern garden with its artificial pond (Liv|in´ Past 2010).

The garden on the north side of Neugebäude spreads over several terraces and could be reached through the cryptoportico. The inner structure of its surrounding wall was reconstructed in analogy to the partly preserved *Fasangarten*’s wall. The landscape pattern of the plantings follows an engraving by Delsenbach

as the primary source, supported by the analysis of French comparative examples for the relevant period (cf. HANSMANN 1988: 51–57, 66–67; COFFIN 1991: 159–163; BOUDON 1999: 162 Fig. 1–3; 163–164 Fig. 5–6; 165 Fig. 8; 168–169 Fig. 15; 170 Fig. 17; 173 Fig. 24–26; 175 Fig. 30; 177 Fig. 35; 180 Fig. 41–42; 181–182 Fig. 45–46; GUILLAUME 1999: 124 Fig. 2; 125–127 Fig. 4–9; 128 Fig. 11; 129 Fig. 13; 131–133 Fig. 17–19; 136 Fig. 24). The arrangement of the flowerbeds is based on studies by Manfred Wehdorn. This part of the garden has been revitalised and opened to the public due to a project of the Stadt Wien conducted in 2010. Further to the north there was an artificial pond functioning as a connection between the castle and the surrounding countryside, i.e. the natural environment.

Its shape suggested in our model is in line with the main accordance in the few historic images and the archaeological discovery of a central, north-south oriented carriageway supported by wooden beams. There are no other clues to the design of the artificial pond (Fig. 16).

The looks and function of the buildings placed to the northeast of Schloss Neugebäude, the so called *Löwenhof* (Fig. 17), mainly have been visualised according to the shape of the remaining structures, studies on building history and archaeological surveys of earlier years (LIETZMANN 1987: 56–58; KNÖBL 1988: 64–67, 75). Only for the so called *Ballspielhaus* (Fig. 18) the important historical realization arose from close architectural study that this in fact could have been a sporting facility. This suggestion seems to be sound because of the similiarity of its basic measurements with buildings verifiably used for the "jeu de pomme" – for example the Ballspielhaus of Maximilian II in Prague (cf. LIETZMANN 1987: 176 n. 197; KNÖBL 1988: 65).

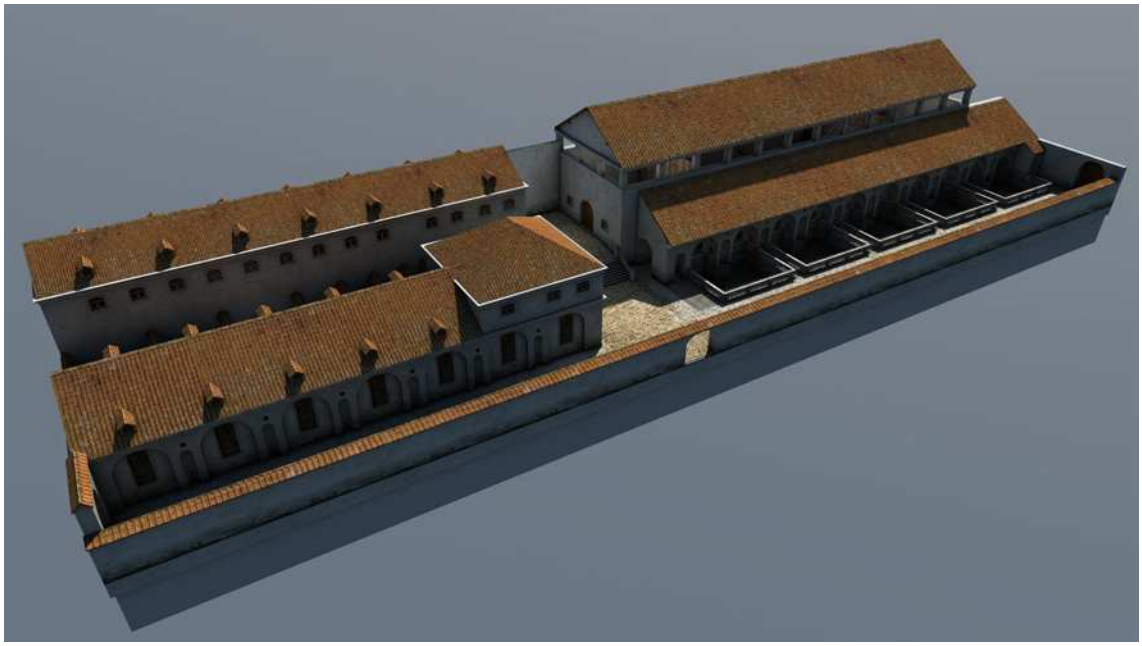

Fig. 17 – The Löwenhof (Liv|in´ Past 2010).

Fig. 18 – The Ballspielhaus (Liv|in´ Past 2010).

Fig. 19 – The ideal reconstruction of Schloss Neugebäude (Liv|in´ Past 2010).

Synopsis

As frequently indicated above, the 3D-visualisation of Schloss Neugebäude, a never finished historical phantom and masterpiece of monumental Late Renaissance architecture north of the Alps, is not an aesthetic end in itself. Rather, it has not only suited to create a better understanding of fundamental problems of planning and design but also helped to give conclusive answers on several crucial questions for the first time by analysing the building in all its four dimensions, including the aspects of diachronic change, unfinished intentions and practical realities. This provides a valuable basis for further deliberations on monument preservation and heritage management concerning the area in its actual state and historical

tradition. Therefore, the 3D-model of Schloss Neugebäude in its never achieved perfect condition is representing the great scientific potential of 3D-reconstructions for the work of archaeologists, preservationists, architects, town planning engineers and, finally, for the historic site in its urban context itself. So, hopefully, this new ideal reconstruction, which is based on a balanced evaluation of archaeology and building history, will contribute not only to a new scientific discussion, but furthermore will bring this ambitious masterpiece of European Renaissance architecture back to the public mind (Fig. 19).

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3D reconstruction and the formulation of a new paradigm of archaeological spaces

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Abstract: The contemporary approach to the paradigm of an archeological space depends on 3D technologies. We are talking about the procedure that is, in an ideal case, infinitesimal approach to the original archeological space. Bearing in mind that reconstruction of an archeological space pertains, first of all, to the area of archeological interpretation, it is necessary to introduce a new methodology into the paradigm of archeological spaces. This opens up the possibility of ensuring observability for spaces created by means of 3D reconstruction, which in the domain of virtual spaces has the meaning of the total reconstruction, but which does not actually mean a full reconstruction of the real space. This paper is related to the investigation of the impact of 3D technology on interpretation of real spaces. The paper proposes the methodology of the theory of deconstruction, which offers possibilities for creation of a new paradigm of archeological spaces.

Keywords: 3D reconstruction, archaeological spaces, paradigm.

Introduction

In the cognitive - theoretical and methodological point of view, heterogeneous areas assign semantic values to the term *space*. Physical, technological, logical, electronic (virtual), topological, mathematical, geometrical, symbolic, absolute, imaginary … are just some of the possible spaces that, depending on the subject matter of investigation, have corresponding places in the hierarchy of meanings in the domain of philosophy of science. In an area such as archeology, there is a series of other spaces, such as: historical, geographical, architectural, allegorical, metaphoric … then spaces of identity, entity, ethnicity, to the way to the integrate to overall intelligible space and human habitus.

Bearing in mind the history of thought and epistemological and methodological dilemmas about real and abstract spaces, from Leucippus, Plato, Aristotheles, to Leibniz, Newton, Kant, and Heidegger and to Bergson, Wittgenstein and Lefevre, in the IT scientific environment, we look at an archeological space as a polyvalent, virtually possible, in line with 3D technological and scientific interpretative forms. Drawing on the history of thought about space, using 3D laser reconstruction, we introduce logically and geometrically founded structures in the perception of a dominantly historical and symbolic space.

We are talking about a collaterally derived result, resulting from the need for a more perfect documenting of archeological artifacts, which is reflected in the opening of new issues in the theory, particularly in the philosophy of space (POLIĆ RADOVANOVIĆ 2010). If we define an integral archeological space, as a vertical (hierarchical) and horizontal (coexistent) structure, where in in virtual reconstruction takes place simultaneous interaction of numerous specified spaces, the question arises as to how 3D reconstruction

gives rise to inevitability of change of the paradigm of archeological space and able overcome the conventional models of thinking.

Physical, Virtual, and Archeological Space

When we talk about archeological artifacts and sites, we think about three-dimensional, physical spaces and historical and symbolic spaces. When we wish to interpret possible contents of the space that existed at the time of construction of archeological sites (artifacts), we use the techniques of 3D laser scanning.

We observe a physical space as the subsistent reality, in terms of three-dimensional expansion in which constituents of reality are contained. When considering the coexistence of different spaces, we proceed from the reality of an archeological site (artifact) and the reality of the set of instruments we use in order to transpose and enable virtual and factography super-structuring. Observation of physical space takes us into the technological space, which allows interpretation of different spatial relations. The principle of operation of a laser scanner is based on focused transmission of a laser signal from the measuring instrument, which reaches the desired object of scanning and is reflected back towards the measuring instrument. The accuracy of the process depends on the appearance of the surfaces of an archeological artifact, optics, and mechanical parts of the system, as well as on the resolution, and thereby on the extent of infinitesimal approximation on the original archeological space (AKCA 2006).

There are two phenomena at the heart of the transposition process, the light and geometrical ones, which belong to different totalities, physical and abstract, and possess the form-relevant quality, which according to its performances has equal impact both on the issues of empirical obtaining of results and on the level of simulation of measuring information (POLIĆ-RADOVANOVIĆ 2005, 2007)

However, virtual space calls for geometry that is invariant to perspective projection. The space of projection of the dimension N is obtained as a perspective image of N+1-dimensional space . The method of transposition of dimensions is immanently technical, but the actual result is nothing technical in itself, it is essentially a geometrical principle (MOHR, BOUFAMA and BRAND 1995). Ideally, the transfer from physical to electronic space, and then in a geometric space, meaning that during this operation does not lose e*ssentia* geometric quality. For example: laser point projected on the surface of marble belonging to the three-dimensional space. Electronic images of laser points on the computer, (in electronic projection space) is seen as a two-dimensional entities. And when combined photogrammetrc triangulation or lidar-based application to simulate the measurements, we have a de facto data as a geometric entity with Gaussian distributions or other functions of probability distribution uncertain (KORPELA,TUOMOLA and VÄLIMÄKI 2007). Then Talking about abstract space. Real archaeological space exist in the hierarchy and in the coexistence of physical, electronic and abstract space. Paradoxically, in an abstract measure space we look measure of reality of archaeological space.

In the geometrical and philosophical-semantic sense, 3D reconstruction of an archeological space enables creation of a virtual set design (AUSTEM 1998; EARL 2007; FORTE 2008) that emerges by reconstruction of a network of objective relationships between diversified positions of space, structure of the space of different genealogical potentials, on the basis of empirical and theoretical results, as well as variations of historical

and symbolic spaces, their complex positions and dispositions as micro-cosmoses of scientific interpretations.

Material finds at archeological sites give us the idea of the physical space as a component of the archeological space based on empirical results and historical and symbolic interpretations. However, the reality of such space only partially expresses the reality of the authentic space that once existed.

Virtual space provides the possibility for super-structuring, technological and ideational reconstruction of an artifact or a site back to the time of its creation, but always as one of possible views of a possible space (BOUROUMAND and STUDNICKA 2004). Thus formulated multidisciplinary approach to archeological space is, in its nature, a techno-archeological interpretation. Depending on the number of exact data, we can speak about the extent of infinitesimality approximation to the original archeological space and the historic reality. Thus 3D reconstruction may be described as way to integrate and intersect all the partial perspectives the resultant of which is a complex opinion about the object and subject of investigation, and the archeological space no longer has only one universal interpretation, but gets a series of undiscriminating interpretations, which represents the quality that takes us into the ambiance of the theory of deconstruction. Space becomes the *term-means* of explication, analogous with Jacques Derida's notion of *difference* (1978). Space as a variable dimension, in the context of the theory of deconstruction, possesses its own infinitesibility that initiates the tendency to create the final meaning, so as to enable the actual notion to be always capable of being supplemented. Hence the possibility as well to formulate a new paradigm of archeological space, in which interpretation equally appertains to virtual ability of the spirit and virtual realization of an electronic medium in which it subsists owing to the specific potential of the computer memory space (FAUGERAS 1993). Potential and reality (*energeia / actus – dynamis / potentia*) thus become mutually analogous, they interrelate as *infinite* and *finite*.

Methodological Investigations

We investigate an integral archeological space as a simultaneous existence of different spaces that are mutually in relationships of hierarchy and coexistence (POLIĆ-RADOVANOVIĆ, RISTIĆ, NIKOLIĆ and KOZIĆ 2010). We model the *hierarchy* of space starting from Euclidean space towards a Non-Euclidean space. When we wish to model *coexistences* of different spaces, our aim is to observe, from the same point of view, the phenomenology of different spaces that emanated in different epochs. And to include them all in an integral space, which we call techno-archeological interpretation. In order to establish the relationships of hierarchy and coexistence of different spaces at an archeological site, we initiate classifications of spatial data into classes and objects, depending on the nature of the entities and their stratified meanings (historical, symbolic, material, light, electronic …). The technique of 3D reconstruction shows to us that a space in our perception takes shape in the form of relations (TSAI 1987), and enables us to redefine, in line with the theory of deconstruction in considering an archeological space, all the notions along the long path that starts from Plato's *primeval image and reflection* (*parádeigma – eikón*), to Foucault's *arrangement patterns* (1991) or Husserl's *actual reality, true reality,* and ac*tual true reality* (1950). Thus we re-investigate all the ways of thinking in the course of the history of thought about space in the light of new potentials of 3D reconstruction.

If we deal with the *parádeigma – eikón* relationship, we formulate relations, depending on the type of data (physical dimensions, parameters of laser beam, a historic datum, interpretation of symbols …), according to the logical structure of their forming, exploring the possibilities of forming new relations. In the case of light and geometrical phenomena, the relations would be formulated as in Table 1.

Table 1

Phenomenon	Transposition	Space as a result
Laser spot in physical space of N+1 dimension	$\longrightarrow$	electronic space of N-dimensionality
Geometrical point of N-1dimensionality (Euclidean space)	$\longrightarrow$	electronic space of N-dimensionality

If the subject matter of investigation is the relationship of *actual reality, true reality,* and *actual true reality* of an archeological space, we have a double paradox.

Table 2

I Paradox	Virtual, 3D reconstruction of an archeological space provides a more realistic image of the archeological space than the real physical space.
II Paradox	The degree of reality of an archeological space obtained by 3D reconstruction can be measured only with respect to the physical space the reality of which is insufficient to us in the extent that a we have small number relevant of material traces for techno-archaeological interpretation

The question arises: How is it possible to measure the reality of a space? One of the criteria would be morphometric similarity (minimal spatial error) that is achieved by 3D reconstruction (BERALDIN 2003, 2004, 2005). The second criterion may be the data quality that, with a minimum number of information, attains the objective of comprehensive presentation of an archeological space. Bearing in mind that, on this level of scientific knowledge, change of the paradigm of archeological space has been enabled exactly with the advent of lasers, holography represents an ideal technique without which the goal of an integral reconstruction of an archeological space can hardly be reached in this century.

One of the possible criteria for the measure of reality of space at any rate must also include the time dimension. In view of the fact that the reality of an archeological space is a set of numerous realities (phases) from its onset up to the present day, in an ideal case, we could obtain a series of *n* images that will successively speak about the life of the archeological space over time. However, at this level of scientific development, such an nD reconstruction is not possible. What is possible is 3D reconstruction that, with the post-structuralistic theory of deconstruction, redefines and reconstructs a space as the *term-means* of explication, continuously subjecting all possible meanings to notional revisions, in line with the pace of technological progress that demonstrates the trend of dispersive acceleration.

Methodologically, this practically means a continuous process of contextualization of meanings, by which *genius loci* is reconstructed in the spirit of its time, from Aristotle to contemporary philosophers. We do this by applying logical expressions formulated at the time that we investigate, and which become descriptions of spatial relations. Space becomes parameters susceptible variabil to Logical testing the results of 3D reconstruction. Results must have function in diferent norms to in order to establishing reality.
For example, by investigating *energeia / actus – dynamis / potential* relationships, we can define the time component of archeological spaces. In this respect we investigate the universality of two statements: *Actus et potentia realiter distinquuntur* (Tab. 3) and *Actus non limitatur nisi per potentiam* (Tab. 4).

Table 3 – *Actus et potentia realiter distinquntur* (Reality and potential is differ)

Actus	Potentia	Explication
Archeological space	3D space	Reality of a space is really different from the currently possible interpretations, and it is limited by the possibility of techno-archeological interpretations of the space, because the technology has not reached the maximum of perfection. Almost every day, we learn about innovations and improved methods of investigations.

Table 4 – *Actus non limitatur nisi per potentiam* (Reality is not limited except by in regard to possibility)

Actus	Potentia	Explication
Archeological space	nD space	Bearing in mind the progress of technologies, the possibility of achieving nD reconstruction limits the degree of reality of an archeological space. Progress of technology in the 21st century in this respect should lead to the maximum of infintesimality approximation to real space.

Conclusion

The technique of 3D reconstruction has paved the way for a new way in thinking in the philosophy of space, creating conditions for formulation of a new paradigm of archeological space. The methodology by which space as a variable parameter is contextualized in the framework of the theory of deconstruction enables infinitesimal closing in on nD reconstruction, which will always have the degree of reality in the reconstruction of an archeological space adequate to the technological progress. A new paradigm of archeological space as techno-archeological interpretation, in this line may be defined as the continuous process of infinitesimal closing in on the primeval image (*parádeigma)* of an archeological space and its reflection in time (*eikón).*

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A harbour gate in Roman Cologne

Hand measurements, laser scanning and digital reconstruction

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Abstract: In connection with the construction of the north-south city railway of Cologne, an archaeological investigation of the Roman "harbour gate" was undertaken during 2007/2008, not far from the choir of the city's cathedral.[1] It was one of three gatehouses that faced the Rhine along the city-wall of Colonia Claudia Ara Agrippinensium (CCAA) (fig. 1). The structural remains at Kurt-Hackenberg-Platz were documented with detailed hand-drawings. On the basis of the hand measurements, georeferenced plans and elevation-drawings were prepared that enabled a three-dimensional reconstruction of the "harbour gate" (fig. 2). During a further operation, the gatehouse was recorded as part of the 3D-visualisation of the Roman town. The digital reconstruction, called "Colonia 3D", does not have the format of a film with a predetermined sequence of images; instead, it comprises a so-called "realtime application" that allows one to access and experience any sequence of pictures and perspectives of the Roman town. The realtime application functions like a Geographic Information System (GIS), in as much as archaeological contexts and finds are linked to the reconstruction, so that the digital model of the town can be evaluated critically. Colonia 3D is the result of a collaborative research project involving the Archäologisches Institut of the University of Cologne, the Cologne International School of Design of the Fachhochschule Köln, the Hasso-Plattner-Institut of the University of Potsdam and the Römisch-Germanisches Museum of the city of Cologne (http://www.colonia3d.de/).

Keywords: Roman Cologne, Harbour Gate, laser scanning, Colonia/3D, realtime application.

The archaeological excavations at Kurt-Hackenberg-Platz, Cologne

For the last ten years, the archaeological research stemming from the construction of the north-south city railway has dominated the work of the archaeology department of the Römisch-Germanisches Museum (TRIER 2010). The four kilometre-long route runs from Cologne Central Station into the southern part of the city. At a depth of 20 to 27 m, the tunnel lies far beneath the archaeologically relevant layers, meaning that the ancient structural remains are exposed only in the areas of stations, access shafts and service shafts. The construction pit of nearly 3,000 square metres at Kurt-Hackenberg-Platz served as an access shaft for the large tunnel-boring machines, and through it the connection with the station "Dom/Hauptbahnhof" was created (fig. 3–4).

[1] The archaeological excavations at Kurt-Hackenberg-Platz were carried out by the consortium KölnArchäologie under the supervision of the Römisch-Germanisches Museum; Fundbericht des Römisch-Germanischen Museums 2004.01: Köln-Altstadt / Nord, Kurt-Hackenberg-Platz. We would like to thank Franz Kempken and Rudolf Nehren for their collaboration.

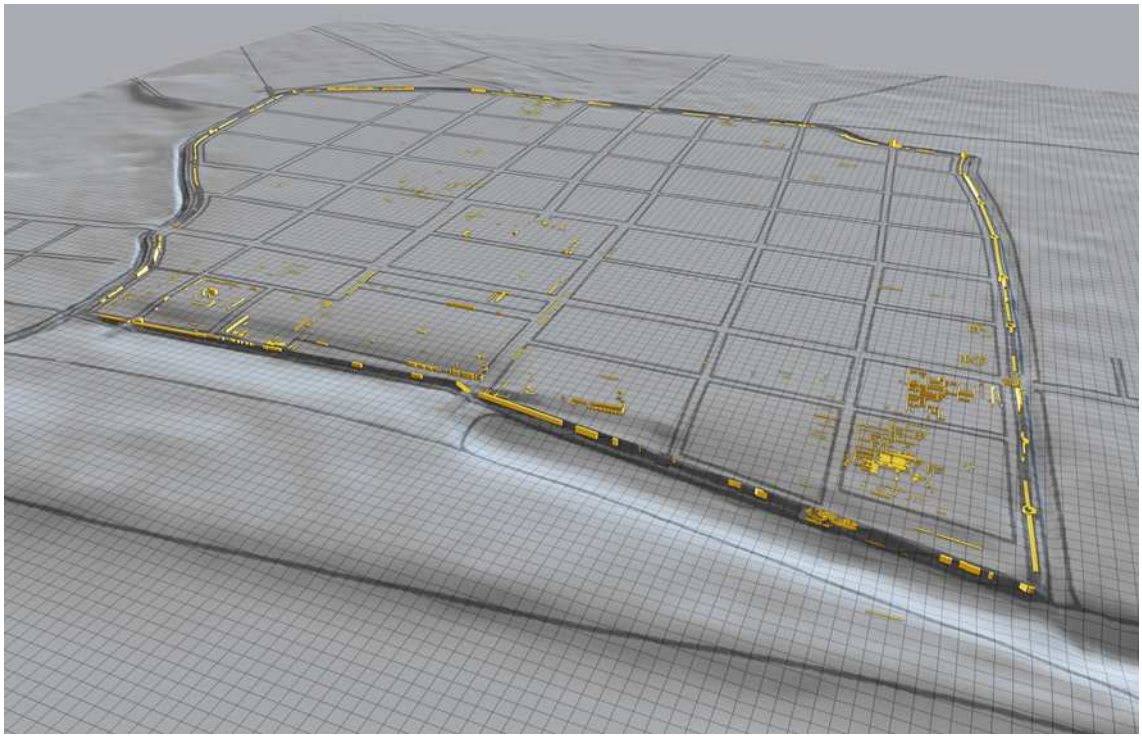

Fig. 1 – Digital terrain model of Roman Cologne, Graphic design by Colonia/3D (Copyright: Römisch-Germanisches Museum der Stadt Köln).

Fig. 2 – Digital reconstruction of the “harbour gate” of Roman Cologne, Graphic design by C. D. Herrmann, Colonia/3D (Copyright: Römisch-Germanisches Museum der Stadt Köln).

Fig. 3 – The construction pit at Kurt-Hackenberg-Platz in Cologne, view from the north side (photo: RGM, A. Schäfer).

Fig. 4 – The construction pit at Kurt-Hackenberg-Platz in Cologne, view from the south side (photo: RGM, A. Schäfer).

The archaeological layers extend to a depth of 13 m at this point because here the former Roman harbour is to be found. A 60 to 70 m side channel of the Rhine offered a natural harbour basin. In the choice of site for the first settlement at Cologne, the topographical situation (comprising a middle fluvial terrace of one square kilometre on the Rhine's left bank, the old Rhine channel and the river island) would have played a decisive role (ECK 2007: 117–119).

Nearly two metres beneath Kurt-Hackenberg-Platz, the consortium KölnArchäologie, under the supervision of the Römisch-Germanisches Museum, came across the monumental remains of the town's fortifications facing the Rhine. A section of the Roman town wall, c.25 m long, traversed the construction pit in a north-south direction (TRIER 2010: 233–235). The view from the south (fig. 5) records the town wall and the outlet of the main sewer located in the foundation of the gatehouse (On the Roman drain under "Hafenstraße": DIETMAR and TRIER 2006: 39–41).

The passageway through the 'harbour gate' is at the height of the slabs covering the sewer. In the late Roman period the entrance was sealed with re-used worked stones; so-called spolia (fig. 6). The projecting sewer outlet comprises ashlar blocks of tufa resting on a foundation of opus caementicium, and its face is contained within limestone blocks. An impression of the high quality of Roman building techniques is conveyed by the red sandstone blocks to be found in the wall bond above the level of the slabs covering the sewer. The blocks border the sewer and are a structural element of the fortified tower's gate jamb.

Fig. 5 – Roman town wall on the Rhine side; “harbour gate” and drain outlet beneath Kurt-Hackenberg-Platz in Cologne (photo: RGM, A. Schäfer).

The reconstruction of the ‘harbour gate’ based on the structural elements

How may we imagine the harbour gate at Kurt-Hackenberg-Platz? There is evidence of a substructure for a 6.5 m deep and 7.4 m wide gatehouse on the inner-face of the town wall (fig. 7) (TRIER 2008: 35). A manhole cover associated with a maintenance shaft corresponds to the level of the pavement within the gatehouse. Between the red sandstone blocks (fig. 2, 6), the inner width of the gate’s opening was 2.7 m. The plan of the gatehouse permits a rough reconstruction of the superstructure: including the elevation of the roof, an overall height of 13.5 m is likely (fig. 8). The substructure of the gatehouse is comparable with that of Cologne’s “Ninth Gate” (DOPPELFELD 1962). Beneath the passageway of both gates ran a drain with an outlet in front of the town wall.

Fig. 6 – Entrance of the “harbour gate” sealed with re-used worked stones (photo: RGM, A. Schäfer).

Fig. 7– Substructure of the “harbour gate” on the inner-face of the town wall, view from the north (photo: RGM, A. Schäfer).

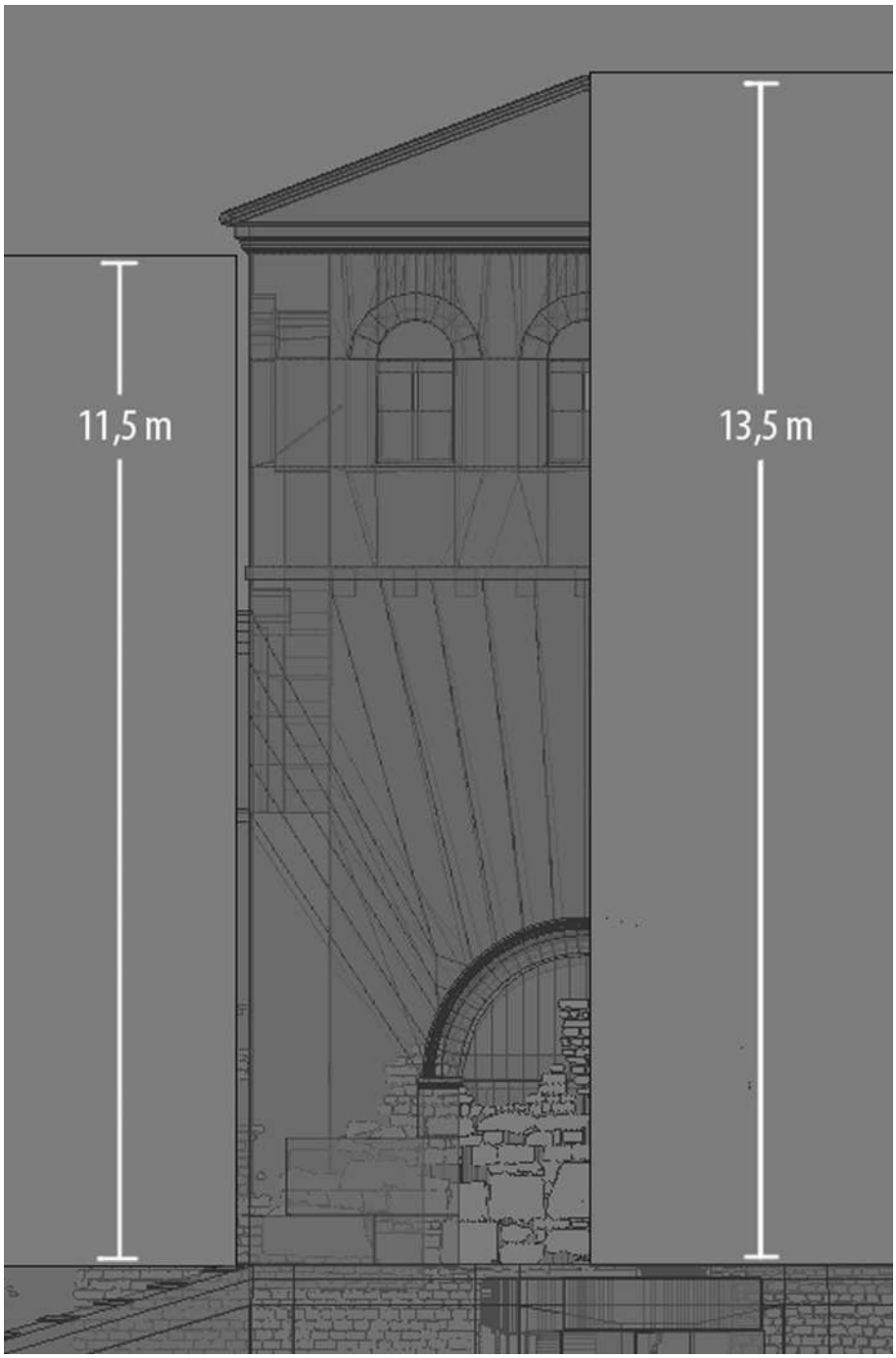

Fig. 8 – Reconstruction of the “harbour gate”, Graphic design by C. D. Herrmann, Colonia/3D (Copyright: Römisch-Germanisches Museum der Stadt Köln).

A sensational state of wood preservation

The foundation of the Roman town wall rested on the firm gravel of the river-terrace. It comprises *opus caementicium* 3 m wide and 3.2 m deep. Due to the wet soil near the level of the groundwater, the foundation’s wooden shuttering remains almost fully preserved (fig. 9). An analysis by Burkhart Schmidt of Cologne University’s Dendrochronology Laboratory established that this shuttering was of fir timber (SCHMIDT 2010). The firs were felled in the Black Forest, transported down the Rhine, and sawn to size at Cologne. The fir planks of the foundation’s shuttering were in excellent condition; they had a length, on

average, of 8 m, a width of c.30 cm, and thickness between 3.5 and 4 cm. The width and thickness hardly varied, reflecting a very high quality of craftsmanship, but despite this, the wood was left in the ground.

Fig. 9 – Wooden shuttering on the inner-face of the Roman town wall's foundation (photo: RGM, A. Schäfer).

A contiguous row of oak stakes in the area of the river bank were found in the construction pit at Kurt-Hackenberg-Platz (fig. 10). This plank wall was situated 4 m before the town wall and ran parallel to it. It functioned as shoring for the Roman town wall's construction trench, as clearly shown by the stratigraphic relationships.

In addition, together with further posts, the plank wall also served as a pile-foundation grill supporting a wooden walkway situated at the same height as the base of the wall. A ramp comprising fragments of greywacke was piled against the walkway that probably assumed the function of a quay (DIETMAR and TRIER 2006: 33–34; TRIER 2010: 234).

Analysis by the Cologne University's Dendrochronology Laboratory (Institut für Ur- und Frühgeschichte) of 150 oak stakes from the plank wall confirms that all the trees from which they crafted were felled in AD 89 (SCHMIDT 2010: 330). Possibly the decision to construct the town wall followed the promotion of CCAA to the provincial capital of Germania inferior during the 80s of the first century AD. Around AD 90/91, Cologne's bank of the Rhine was a building site. Responsibility for the erection of the town wall surely fell to the military, and it very probably occurred under Domitian (AD 81–96). Very soon after the completion of the wall, the harbour basin silted up. By no later than the mid-second century AD, the former river island was firmly attached to the mainland.

Fig. 10 – Row of oak stakes in the area of the river bank of Roman Cologne (photo: RGM, A. Schäfer).

Summary of the archaeological results

One of three gatehouses of the Roman town wall that faced the Rhine is close to the choir of Cologne cathedral. Situated above the high water level, the plateau of the town was linked to the Roman harbour on the Rhine through the so-called harbour gate. At the base of the lowest river terrace a rectangular gatehouse was placed that had a 13.5 m tower rising above it. Through this gatehouse ran the so-called “harbour street”, the northernmost *decumanus* of the central place. An underground drain was situated beneath the street along its axis; it ran under the gateway and ended as an outlet in front of the town wall. The “harbour gate”, the curtain wall and the drain outlet were part of an extensive building project of the late first century AD: the construction of the town’s fortifications. A wooden walkway placed along the base of the wall’s outer face was also a product of this large building site. Against the plank wall of this walkway a ramp was created that functioned as a quay, facilitating the loading and unloading of ships and boats even at low water levels.

The slower current in the partially silted Rhine channel was favourable to river traffic. Soon after the construction of the town wall the harbour basin was already fully silted up.[2] By the middle of the second century AD the river island, formerly close to the bank, was now joined to it (ECK 2007: 119). It is very likely that the main harbour of Roman Cologne was located on the side open to the Rhine, making the area of the river island the most important transhipment point (DIETMAR and TRIER 2006: 43–45).

The digital reconstruction of the "harbour gate" by Claus Daniel Herrmann

For the visualisation of the archaeological contexts of the "harbour gate" and to make possible a 3D-reconstruction for the project Colonia3D, basically two sources were analysed and integrated: firstly, a 3D-scan of the site and, secondly, CAD drawings containing plans and sections of the excavated town wall and the foundations of the gate (fig. 11). The resulting visualisation comprises a polygon model that lends volume to the archaeological remains. The following sections summarise the process by which the various data were combined.

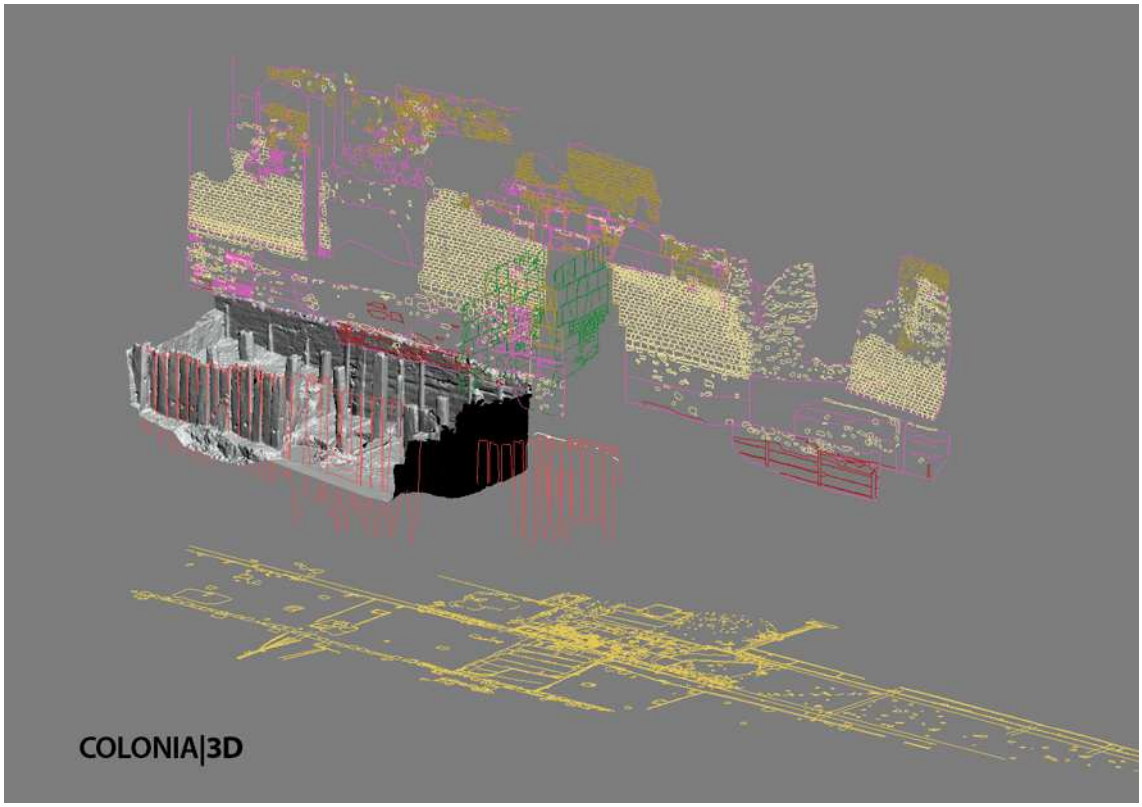

Fig. 11 – 3D scan (grey) and CAD drawings (colour) create the basis for the modelling of the contexts and the reconstruction of the harbour gate (3D scan: J. Broser, Institut für Baugeschichte und Denkmalpflege FH Köln, CAD drawings: KölnArchäologie, Graphic design: C. D. Herrmann, Colonia/3D, Copyright: Römisch-Germanisches Museum der Stadt Köln).

3D laser scanning

Dipl.-Ing. Jost-Michael Broser from the Institut für Baugeschichte und Denkmalpflege of the Fachhochschule Köln kindly supported the project with the provision of data from a 3D laser scan carried out on the site

[2] The Rhine channel was increasingly being silted up with alluvial deposits already by the first century AD; NEU and RIEDEL 2002: 427.

(BROSER 2010). The data from the scan were, as usual, in the form of a point cloud. Each measured point within such a cloud represents a three-dimensional coordinate and a colour value. To be able to incorporate the scan within the digital reconstruction – the real time 3D model – a polygon mesh must be derived from the point cloud (fig. 11).

Polygon meshes depict surfaces comprising contiguous triangles (polygons). The greater the density of polygons, the finer the details of the surface. However, the higher level of detail created by the higher number of polygons creates problems: the quantity of data the computer has to process increases with the number of polygons which, in turn, leads to a slowing of the frame rate in real time; secondly, it is more complicated and time-consuming for the computer operator who works on the mesh. The basic aim is to find a balance between the density of data (thus the level of detail) and manageability.

In the real case of the “harbour gate”, a 3D scan was available that had captured the area of the wooden stakes south of the drain outlet so accurately that the grain of the wood was visible – an unnecessarily high resolution for the 3D visualisation of Colonia3D (fig. 12). Our task was to derive a 3D model from the scan that depicts the volume and position of the individual structural elements, such as planks, posts and stones.

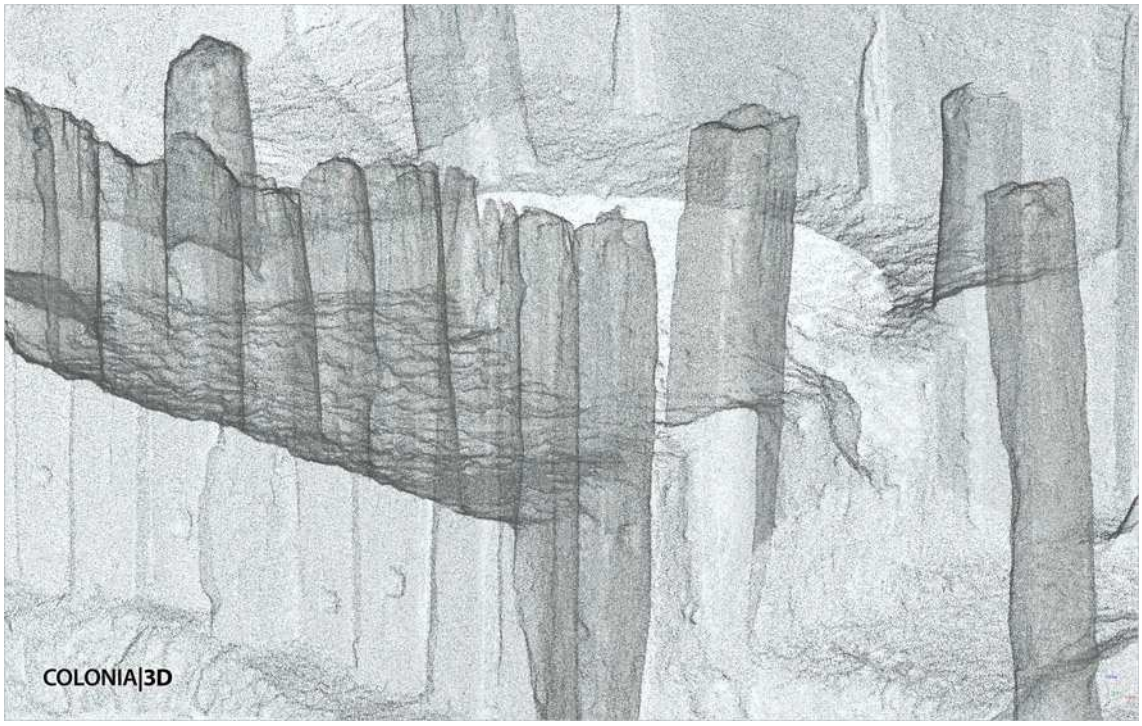

Fig. 12 – The point cloud from the 3D scan being processed in Geomagic (by C. D. Herrmann).

The entire process from 3D scan to solid model can be summarised as:

1. Importing the point cloud.
2. Thinning the point cloud.
3. Cleaning the point cloud.
4. Conversion into a polygon mesh.
5. Regularization (the closure of interiors).
6. Intelligent reduction of surfaces.

7. Exporting to a conventional 3D mesh format (*.OBJ).
8. Retopologization.[3]

This process is not fully automatic because the reduction requires a conscious interpretation of the data, but it is strongly simplified through the use of software.

In this case the software Geomagic was applied from the import of the point cloud to the export as a *.OBJ file, since it was designed specifically for this field of application. Basically any polygon modelling software can be used for the retopologization, but for the 'harbour gate' we employed Blender.[4] Subsequently, the data were exported into 3D Studio Max, where all the 3D models from Colonia3D can be worked on (fig. 13).

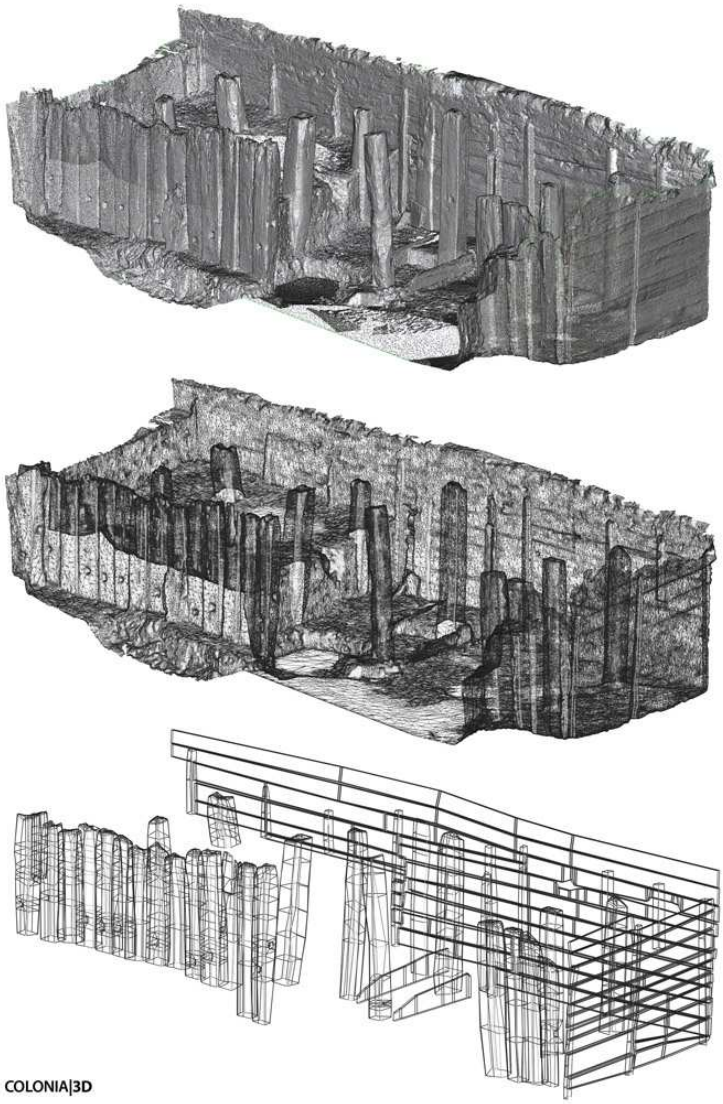

Fig. 13 – Wooden shuttering and wooden shoring for the Roman town wall's construction; Transformation from point cloud to mesh (above: point cloud in Geomagic; middle: exported mesh in 3D Max with a high density of triangles; below: retopologized mesh).

[3] Retopologization means to manually superimpose a completely new mesh on the surface of the exported 3D mesh. The advantage is that the new mesh has a better polygon structure (also called topology).

[4] Blender is an open-source 3D software (www.blender.org).

The processing of the CAD drawing from the excavation in 3D

The 3D scan captured only a relatively small part of the archaeological situation at the “harbour gate” site. More than 50 individual CAD drawings recorded the remaining contexts, including the drain outlet, the sections of wall above the former street level, the wooden shuttering north of the outlet, and the gate foundations.

The CAD drawings also had to be transformed into a polygon model in order to combine them with the retopologized scan, for which two basic steps were required:

1. All the individual drawings were combined and exported from a CAD format into a 3D Max-capable format and thus brought together within a 3D file.
2. The drawings were extruded[5] in 3D Studio Max.

The individual CAD drawings were already spatially organised (georeferenced) in the CAD format, so that a good overall impression of the site was already available with the first step. A hurdle was represented by the georeferenced coordinates that comprised 8 digits: programmes like 3D Studio Max are unable to handle such large numbers. Consequently, before exporting, the coordinates in CAD were offset to a predetermined value towards the zero point. Because the degree of the offset is known, the plans remain, in principle, georeferenced. In step 2, the main task was to determine the depth of the extrusions (fig. 14). Since the majority of the objects were made up of views from multiple angles, this permitted their volumes to be easily deduced.

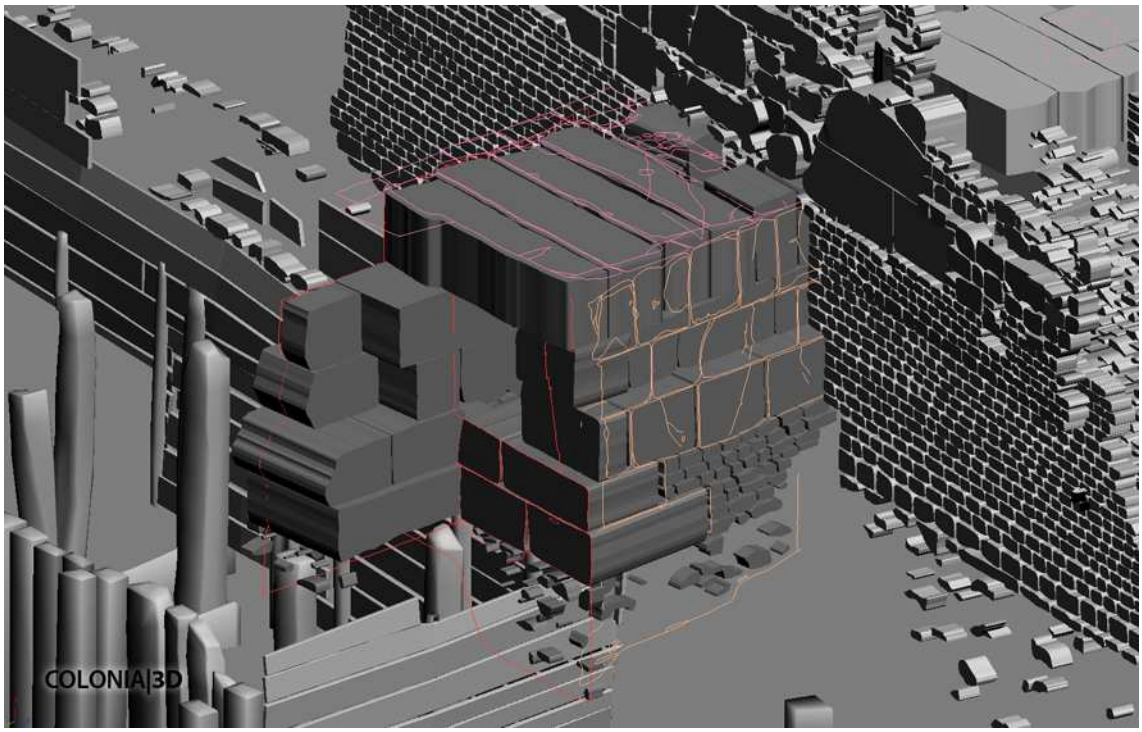

Fig. 14 – Detailed view of the drain outlet. Extruded volumes in grey, CAD drawings in red and orange (by C. D. Herrmann).

[5] To extrude means to give three-dimensional form to a surface; for example, a cylinder is an extruded circle.

The reconstruction of the “harbour gate”

Before the above described modelling of the site took place, a reconstruction of the “harbour gate” in the model Colonia3D already existed. The older version, based on earlier records, could now be amended by the new and exact data. The most important changes were related to the proportions of the structures, the size of the passageway through the gate, and the form of the gate jamb in red sandstone. It was possible to recreate the gate jamb with stone-by-stone accuracy (fig. 2).

Integration in the application Colonia3D

The completed 3D model of the “harbour gate” was promptly integrated within the application, Colonia3D, which may be viewed in Cologne’s Römisch-Germanisches Museum: The 3D scan of the wooden shuttering and the wooden shoring for the Roman town wall’s construction and the CAD drawings of the “harbour gate” (fig. 15) were integrated into the realtime environment of Colonia3D as a three dimensional volume model (fig. 1, 15). This volume model shows the archaeological contexts without any reconstruction. The user of Colonia3D can combine this model with the reconstruction of the Roman town wall of Cologne. The flexible structure of this 3D application allows the easy integration of new data.

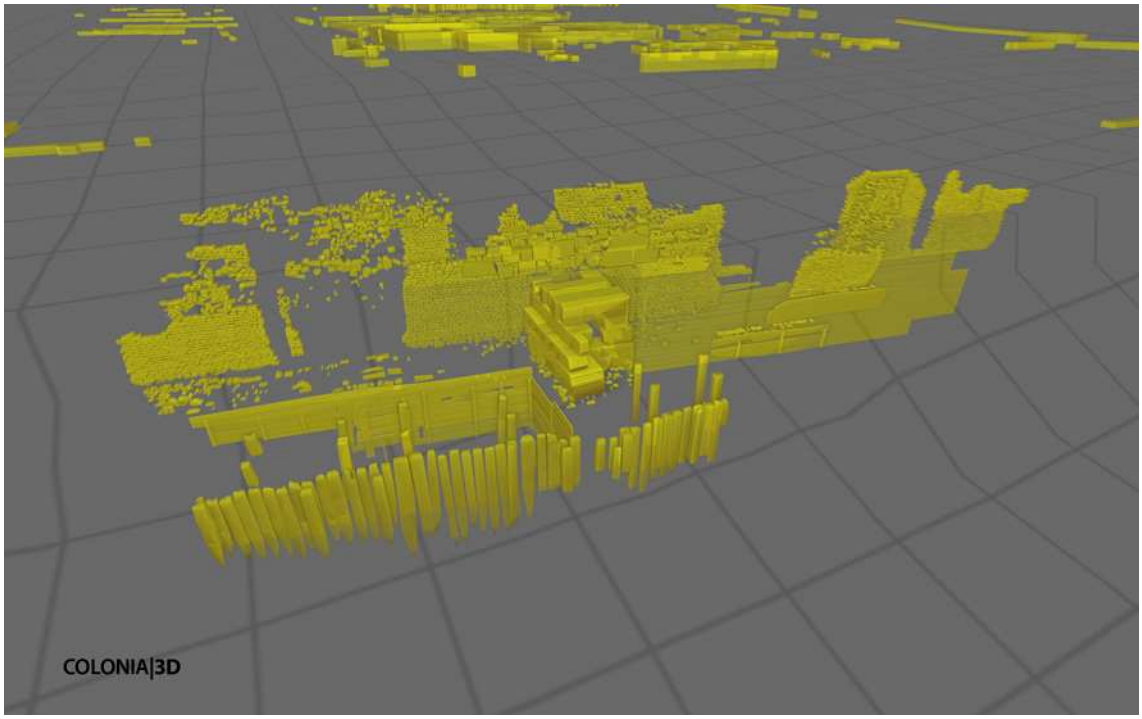

Fig. 15 – Archaeological contexts of the “harbour gate” within the application Colonia3D, Graphic design by C. D. Herrmann (Copyright: Römisch-Germanisches Museum der Stadt Köln).

Translation: Jamie Sewell

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