

SESSIONS

Newbies

Archaeology: A Mediated Practice of Technology and Digital Tools Three-dimensional Laser Scanning as a Case Study Analysis

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Abstract: Archaeological sites are finite nonrenewable resources. The priority of any archaeological research is to retrieve maximum information through recording, sampling, and analysis. Understanding the archeological site is the rationale behind heritage recording and documentation. Archaeology embraces the technical means to record, document, analyze and communicate archaeological information. Today we have more tools and methods available than ever before to capture the physical characteristics of an archaeological site. Now, it is easy to visualize time sequences through computer-based predictive models based on archaeological data, determine the soil type by ground penetrating radars, locate the artifacts by hand-held GPS units, and decide the future excavation area by using satellite imagery and aerial photogrammetry. Each technological solution affects the way the archaeological data is being collected, contextualized and disseminated; and each digital tool transcribes its own method to operate the project. Thus, a critical examination is required to understand how the utilization of technological tools invokes different meanings of archaeological resources. Three-dimensional laser scanner is a surveying tool that captures the digital image of a surface. Archaeologists increasingly use this medium in their projects due to its high accuracy, ability to collect data remotely, rapidity of capture, instant ability to input to the computer and the capability to record massive archaeological structures. However, as with any technological medium, the scanner reveals archaeology with its own principles and procedures. This paper examines how the use of the laser scanner mediates the archaeological pursuit by examining Heidegger's philosophy of technology. The methodology consists of examples that use laser scanner as a recording tool such as the Documentation Project of the Mayan Archaeological Sites in Belize, and the Seddülbahir Fortress; Survey, Documentation, Restitution, Restoration & Reusage Project, Gallipoli, Turkey. The future of archaeology depends on how well it adapts to new technologies. Hence, this paper suggests a balance between the growing trend of technological applications in the field and the archaeological inquiry.

Keywords: Archaeology, Heidegger, Technology, Three-dimensional Laser Scanner.

Heideggerian View of Technology

Technology comes from the Greek word *technē*. In ancient Greece, the word *technē* referred to the skills employed in the pursuance of an art and craft. Greek philosophers Plato and Aristotle were genuinely appreciative of *technē* activities. *Technē* was an art and craft object – it could be a shield, a vessel for drinking or a shoe. Art and technology were not separated; thus an object was not only utilitarian but also judged for its beauty. If an object was produced with purpose and care, along with Greek proportions, then it was excellent as *technē* (IHDE 1993). The Greeks celebrated politics and philosophy as the highest level of the form of human activities. The activities of *technē* occupy the lowest level in the hierarchy of human

activities. *Technē* allowed the citizens of Greece the leisure to pursue the higher forms of human activity. In the seventeenth century, the word *technē* was combined with the suffix *logia*. The word *technologia*, then referred to the systematic study or knowledge of art production (CANIZARO 2000). Over the course of the eighteenth and nineteenth centuries, the word *technologia* continued to describe the study of arts and manufacturers and later to the applied science and practical arts. Starting with the Industrial Revolution, the use of the term *technology* has encompassed totality of the means that were employed to provide objects necessary for human sustenance and comfort.

Martin Heidegger (1889–1976) was one of the most influential philosophers of the twentieth century who advocated the substantive theories of technology (FEENBERG 1999). He brought the ancient Greek's idea of *technē* to a next phase, where he discussed technology as a mode of revealing. He conceptualized *technē* as a process of the exposition of the production of an artifact (SILMAN 2007). He suggested that in ancient Greece, *technē* brought out the concealment of the object, and now in our modern world technology reveals the forces in the nature into a supply of energy that is extracted and stored on command; earth is converted into a coal-mining district, and soil as a mineral deposit (1977).

Accordingly, technology is no longer neutral as it was in ancient Greek. As we human beings interact with the world; the world is revealed and ordered in a definite manner with technology. Technology turns everything it touches into mere raw materials. Nothing escapes the revealing powers of technology; we even become human resources just like the things that we appropriate to become raw materials (HEIDEGGER 1977). Technology is, now, imbued with so many values that it obscures our ability to get the truth and blocks our ability to understand our own selves. Technological development dominates our way of seeing and knowing the world around us. What we experience is not the pure immediate interaction, but what is lived at the limit of technology.

According to Heidegger, technology is enframing (1977). The modern technological enframing draws people and nature around a materialized site of encounter (FEENBERG 1999). In other words, technology restructures everything into a new framework or a configuration. Isn't the enframing characteristic of technology evident in archaeology? Each technological solution affects the way we gather, analyze and communicate the heritage data. Each tool transcribes its own scientific method to operate the project. For instance, to be able to use a three-dimensional laser scanner requires a distinct expertise in which we need to know not only the system parameters, but also we have to excel in software's to translate the scan data into architectural drawings, animations, structural reports or facility management studies.

Revealing does not happen beyond human control. Every technological tool is ordered to be stand-by to be immediately at hand and ready for a future ordering (HEIDEGGER 1977). For example, in the field, we decide to turn on the tool. We expect the device to work efficiently and seamlessly when ordered. Outside the field, the tool awaits at the storage to be used for another field excavation.

Heidegger emphasizes that technology never comes to an end (1977). In the technological age, everything shows up as needing to be reorganized in order to make it more efficient, flexible, and useful in an infinite variety of ways. As we become addicted to the technological instruments, we start to recognize all the experience in terms of ease and flexibility. Isn't it the same when we purchase a digital tool to be used in the field? As we buy the device, the instrument immediately becomes outdated; and a more efficient, accurate and faster one has already been released. Then we strive to purchase the newer release.

This paper does not intend to discuss the influence of Heidegger on archaeology. The way he has challenged archaeological thinking has been the topic of a massive literature and discussed elsewhere (BARRETT and KO 2009, DOMANSKA 2005, DOBRES 2000). He has altered the understanding of material culture of archaeology by emphasizing the element of human agency. He proclaimed the categories of time, space, and temporal dimension of human existence as fundamental issues. With his principles, archaeological artifacts have evolved into agents that have their own lives, became active participants of 'being-in-the-world', and integral elements of interpersonal relationships.

However, as the use of digital tools in archaeology becomes a more recognized phenomenon, Heidegger's doctrine about technology becomes a basis of further discussions. His discussion of 'being-in-the-world' as an unfolding coming into existence through technology is still integral to the understanding of technology (DOBRES 2000). The future ways of thinking about the past depend on how we formulate our approach to the archaeological quest, and how we examine the historic findings. Technological instruments allow us to apply an apparatus to the questioning of archaeological inquiry. As technology reveals archaeology as a resource to be unlocked, transformed, stored, distributed and switched; we start to experience archaeology as an information system. Thus, a critical examination is required of how the utilization of technological applications invokes different meanings during the archaeological pursuit. Three-dimensional laser scanner is just one technological tool in the heritage professional's armory. However the assessment of its use in archaeology demonstrates how archaeological practice is mediated through digital means.

The Utilization of Three-dimensional Laser Scanning in Cultural Heritage Projects

Böhler and Marbs define a three-dimensional laser scanner as "any device that collects three-dimensional co-ordinates of a given region of an object's surface automatically and in a systematic pattern at a high rate (hundreds of thousands of points per second) achieving the results (i.e. three-dimensional coordinates) in (near) real time" (BÖHLER and MARBS 2002). The principle behind the 3D laser technology is that the scanning device sends a rapid series of laser pulses towards the structure. Time-of-flight laser scanners use the two-way travel time of a pulse of laser energy to calculate a range¹. Basically, the scanner emits a pulse of laser light to the object and waits for its return. The time it takes to reach to the object and come back is calculated by the sensor in the scanner and it provides the distance to the object from the scanner. As the scanner moves across the surface of the structure it records thousands of points, converting all this information to measured points each possessing three-dimensional, X, Y, Z Cartesian coordinates, intensity and RGB values. The result is a mass of measured points called a "point-cloud". Therefore rather than selecting somewhat randomly, and one point at a time, the user can collect million points on a structure which will provide an accurate outline or contour of the structure. The laser scanner, particularly the latest generation of scanners, are able to record with a field of vision that is 360 degrees horizontally and 270 degrees vertically, missing only the area immediately below the scanning device itself.

The expectations from scan data differ among different disciplines in terms of work processes, deliverables, value propositions and customers (LOUDEN and HUGHES 2005). The typical distance for a time-of-flight

¹ In this paper, I focus on the time of flight laser scanner as a case study.

laser scanner varies from one-to two meters minimum to hundreds of meters maximum. The system offers accuracy between two to six millimeters. The accuracy depends on the extent on the range between the object and the scanner (BÖHLER et al. 2002). In heritage applications, the device is used to capture a high level of accuracy, often within 5mm. Heritage professionals utilize 3D laser scanning as a means of recording artifacts, structures, cultural landscapes, ruins, and excavation surfaces. The scan data allows countless applications to the heritage professionals for interpretation of the heritage asset. The point cloud serves many purposes, including to derive architectural drawings, to generate structural reports, and to assess deformation analysis. The scan data provides the quantitative understanding of deterioration through drawings, graphic images and volumetric calculations. If the structure is monitored periodically, the data will record the transformations of the historic fabric.

Technology has changed the scale or pace or pattern that it introduces to the human affairs (MCLUHAN 1964). Given this, laser scanning has revolutionized heritage work in many ways. First, with the utilization of laser scanner, all types of surfaces from artifacts, to single structures and archaeological landscapes can be measured, and accurate base information be provided. Second, laser technologies have changed the pace of recording. Scanning technologies have allowed great advances in obtaining measurements and producing highly accurate representations in real time. For a simple comparison, a two-person field crew can barely capture 500 points per day surveying with a total station or other electronic distance-measurement equipment. However, using the scanner, technicians record up to 1 million data points in minutes (LOUDEN and HUGHES 2005). In the author's experience, a large building such as the Jaguar Temple in Lamanai, Belize can be scanned in one to two days. Third, technologies have introduced new patterns to heritage recording. Now we experience increasing numbers of new recording situations resolved with a host of diverse humanistic and technical sciences.

In archaeological sites such as Blue Creek, Belize scanning applications have become an invaluable tool due to their rapidity of data capture, the instant ability to input to the computer, the capability to record massive structures, and the portability of the device in the field. Further, the non-intrusive character of the tool allows the user to collect the data remotely. Since 2008, the Center for Heritage Conservation (CHC) at Texas A&M University has collaborated with the Maya Research Program on heritage documentation efforts in the region. Excavations in Blue Creek confirm that the first of the core public sector buildings were constructed around 100 A.D. on top of the Bravo Escarpment. These structures suggest an administrative area that held economic power and authority, not only in the Blue Creek area but also in the Mayan world. Blue Creek was an administrative center that existed for over 2,000 years.

In archaeological sites, timely documentation is crucial as archeologists are excavating chronologies, layer upon layer. Furthermore, in the case of Blue Creek, rapid documentation of the archaeological setting is of importance as the private lands on which many ancient sites are located are being cleared for farming and cattle ranching. Many of the archeological sites are difficult to access with large, heavy documentation tools. Some sites are located in dense jungle regions and some sites are underground.

Even though located at a different part of the world and possessing different scope and scale; the Seddülbahir Fortress; Survey, Documentation, Restitution, Restoration & Reusage Project², is a demonstrative example to assess the transformation of the archaeological practice by means of scanning. The fortress of Seddülbahir is located on the European shore of the Dardanelles at the southern end of the Gallipoli peninsula. An important example of Ottoman military architecture from the early modern era, Seddülbahir was founded in 1658 by Sultan Mehmet IV's mother Hadice Turhan Sultan, along with its sister fortress, Kumkale, on the opposite shore (THYS-SENOCAK 2006). The Seddülbahir project was the first in Turkey to conduct a comprehensive laser scanning of such a large historical structure, 4200m², and then use the data procured during the survey to generate among many other products, a 3D model of the site, a topographical map, and a two-dimensional set of architectural plans and elevations for the Monument Preservation Board in Çanakkale. It has also now integrated the 3D laser data into the project GIS. Building upon the work done in an earlier survey and documentation project which the team had started in 1997, the team decided to use a laser scanner when the restoration project at the Ottoman fortress of Seddülbahir was initiated in March, 2005 (AKBOY 2007).

Heidegger discusses technology as a revealing phenomenon that unfolds and arranges the world. Hence, the use of laser scanner transforms the entire archaeological work by dictating its own principles and procedures to the project. For example, once the team decides to use a laser scanner in the fieldwork, the transportation of this sensitive device to the project area becomes an operational challenge. If the project is abroad, as in Belize, legal regulations and bureaucratic procedures add a tedious layer in the operational scheme of project planning. In the author's experience, in order to ensure the continuation of work without any unexpected delay, the team has to obtain the legal permissions and resolve any logistical challenges prior to the fieldwork. In order to avoid the shipping expenses and delays, in the Belize project, the CHC team decided to carry the scanner and accompanying equipment with them on the plane. However, traveling with this type of sensitive tool became challenging at the airport customs. The team was exposed to strict security regulations when entering and leaving the country.

Apart from the logistical challenges of transporting the scanning equipment to the project area, the utilization of a laser scanner also brings a new host of issues to the planning of the fieldwork. Preferably, a site visit before the fieldwork helps to alleviate field contingencies and improve project coordination. During the site visit, the heritage professional has to consider alternative work schedules in case of time and access restrictions. For instance, if the site is in a heavy traffic or tourist area, scanning in the night hours may be a good solution. Further, in an archaeological excavation, as the recording required at each part of the dig cannot be repeated, scanning becomes time-critical. In this context, scanning has to coordinate with the excavation schedule. Fig.1 illustrates the scanning campaign in Nojol Nah, Blue Creek, Belize while the archaeologists are excavating the site. Fig. 2 shows the scan data of the excavation surface. In particular work settings such as cramped underground burial chambers, physically inaccessible cliffs or structures located in thick vegetation, the secure position for the scanner footing might be possible from only few locations. In this case, the team has to consider the scan plan in the site visit and decide configurations such

² "The Seddülbahir Fortress Site; Survey, Documentation, Restitution, Restoration & Reusage Project" is referred to as "the Seddülbahir Project" in this paper.

as removing the vegetation before scanning. The scan plan consists of the scan positions and layout of the corresponding targets on the site. Before scanning, the team members strategically position the targets in the site in order to ensure at least four targets from each scan position. Targets constitute the reference points to put each scan together. The targets may also be surveyed with GPS to tie the data with real world coordinates. During the scanning process, the user defines the scan area, point spacing and distance to the object. When moving to the next scan, the user has to overlap 20 percent in each scan to join the scans together. Each individual scan may hold up to one million data points. The number of points depends on the point spacing and the size of the scan data defined by the user.

The weather conditions also impose limitations on the scanning work. Extreme weather conditions such as heavy rain, winds and humidity preclude accurate scan data. For example, scanning in heavy rain can refract the laser beam and yield to erroneous results. Moreover, the tool loses connection with the computer or shuts itself off after long operating hours in the hot and humid air. Fig. 3 shows a CHC team member trying to resolve the disconnection between the scanner and the camera due to the intensive sub-tropical weather during the scanning campaign in the Jaguar Temple, Lamanai, Belize, 2009. Fig. 4 demonstrates the 3-D point-cloud of the Jaguar Temple.



Fig. 1 – In order to record the excavation surfaces in Nojol Nah, Blue Creek, Belize, the CHC team utilized a LMS-Z390i Riegl Scanner which is a long-range terrestrial 3D scanner used to document buildings, sites and medium to large objects. 2009. (Copyright: Center for Heritage Conservation)



Fig. 2 – The 2-D planimetric view of the excavation site in Nojol Nah, Blue Creek, Belize. The delineator cuts horizontal slices from the 3-D point-cloud to produce plans. 2009. (Copyright: Center for Heritage Conservation)



Fig. 3 – The CHC team member trying to solve the connectivity issue of the scanner while operating the scanner on the Jaguar Temple, Lamanai, Belize. 2009. (Copyright: Center for Heritage Conservation)



Fig. 4 – The 3-D point cloud of the Jaguar Temple, in Lamanai, Belize. 2009. (Copyright: Center for Heritage Conservation)

In heritage projects, the utilization of laser scanner has substantially transformed the process of the delineation of the measured drawings. In historic documentation projects, the typical project deliverable of the scan data is a precise measured drawing of the structure. In traditional hand recording, the location of the section that extensively conveys the characteristics of the site is predetermined prior to the fieldwork. Point measurements are taken accordingly on site. In this process, a team member constantly records the progress by producing sketches and two-dimensional drawings in the field. On the other hand, once the laser scanner captures the archaeological site, the scan data has millions of points. Fig. 5 illustrates the scanning campaign in the Seddülbahir fortress site and Fig. 6 shows the point-cloud of the structure. After, registering the scans, the user only has to clip appropriate views from the 3D point-cloud and work on these pieces. Rather than extruding standard forms or joining end shapes, researchers often use AutoCAD (or other drafting software) to trace each element of the structure on the point-cloud. Fig. 7 demonstrates the drafting process of the elevation of the Seddülbahir fortress by tracing each stone from the scan data. The user clips the 3-D point-cloud to represent the desired 2-D view such as the plan, section or elevation and the delineator meticulously generates the measured drawing. The major challenge of any documentation project lies in the translation of the 3-D point-cloud to 2-D measured drawings. In this context, in Belize, while the CHC team assisted the archaeologists by recording each layer of excavation by scanning in-situ, they also prepared hand-measured drawings with the archaeologists (plan, section, elevation and perspective drawings) that show different phases of the excavation. These drawings assisted the archaeologists to assess the excavation progress while the CHC team was processing the scan data to the desired 2D and 3D views.



Fig. 5 – The project team used a LEICA HDS 3000 scanner to record the Seddülbahir fortress site. 2005. (Copyright: Kaletakımı)



Fig. 6 – The point cloud of the North Tower of the Seddülbahir fortress. 2005. (Copyright: Kaletakımı)



Fig. 7 – In the Seddülbahir project, the delineators used AutoCAD to generate the 2-D architectural drawings. The images above demonstrate the drafting process; the 3-D point-cloud (left image), tracing the stones on the scan data using AutoCAD (middle image), the final 2-D elevation drawing (right image). 2005. (Copyright: Kaletakımı)

Furthermore, in the author's experience, the archaeology students have benefited tremendously from preparing hand-measured drawings. While they were rendering the archaeological asset on paper, they were exploring significant aspects of the artifact such as form, construction and material. Through these empirical observations, the students got engaged with the archaeological environment and were able to visually construct each archaeological structure in relation to the other. Back in the camp, the students would discuss the possible scenarios of the excavation surfaces based on their drawings. The drawings became a mediating platform between the historic environment and the students' analytical thinking of the archaeological findings.

Warden and Woodcock discuss that even though new technologies have opened the way for new heritage applications, they seem to disengage us from the historic fabric by virtue of their capabilities for automation, remote sensing, remote production, and redefinition of documentation (WARDEN and WOODCOCK 2005). They suggest that in heritage documentation projects, the use of digital tools have the pedagogical drawback of separating the collector from direct contact from the artifact being collected. The utilization of digital field data in terms of coordinate points obscures the ability to conceptualize the structure in dimension and proportion. The scholars observe that, in particular student surveyors have problems translating the digital data points to measured drawings. They discuss that the lack of dimensional relationship in digital data preclude the students to develop a proper understanding of the relationship between plan, section, and elevation.

Yet, in most heritage projects, the utilization of scanning technologies has already become a necessity. The heritage world is heading to the direction of X, Y, Z Cartesian coordinates, RGB values, reflectivity and intensity parameters. However, this author argues that technological instruments such as laser scanner while providing us with data that was not available before and revealing new features, they also condition the possible ways to see things. Heidegger's critique of autonomous technology is not without merit. As we increasingly engage with technological tools, we start to lose sight of what is sacrificed. While we increasingly define, treat, interpret the uses of the past today with digital tools, we also reduce the quality of our direct engagement with the historic environment. In this context, Woodcock (2006) discusses that heritage documentation is not only about the physical understanding of the building, but attempts to capture the spirit of the artifact. Historic documentation puts project participants and local communities in relation to heritage. For example, during the Seddülbahir project, the team conducted oral interviews with the local

stakeholders. These interviews revealed collective memory of the community but also provided physical information about the site and structures that was not evident before. The study showed that the site had a special place for the local stakeholders because there had been people among the community who had actually served their military service in the fortress, and who had lived and worked on its premises in the past. Further, this oral history project provided a forum where the community voiced their suggestions about the potentials of the site and the further projects (CENKER and THYS-SENOCAK 2008).

Conclusion

In the midst of the immense technological revolution that changed the face of Europe based on science and technology, Heidegger was acutely aware of the fact that these transformations would bring intense philosophical discussions. His ambition was to explain us that technology is a cultural form through which everything in the modern world becomes available for control (FEENBERG 1999). Heidegger argued that technology is relentlessly overtaking us and we are engaged in the transformation of the entire world. He suggested that the answer of how to get ourselves out of the technological system lies in self-manifested things provided by man such as art.

Archaeology is an intellectual pursuit built on scientific research, knowledge, memory and experience (MATERO 2006). Archaeology does not only deal with the physical remains of the past, but also with cultural context. Whatever methodology we use to document our historic environment; our personal, social or cultural engagement with the historic setting should be integral to our efforts. As demonstrated in the Belize project, while utilizing the laser scanner to produce an accurate 3-D model of the archaeological site, producing hand-measured field-notes becomes an engaging tool with the historic fabric. Furthermore, the ethnographic interviews in the Seddülbahir project illustrate that heritage documentation is a significant vehicle to connect project participants and local communities in relation to heritage.

The Belize and Seddülbahir projects demonstrate that the utilization of the laser scanner has indisputably accelerated and facilitated the collection of data in the field. On the other hand the use of laser scanner directly alters the form of information; how it is collected and understood. The different form and arrangement of the scan data from traditional documentation media such as hand-measuring and measured-drawings, is creating a need for a new type of expertise among heritage professionals who now face a host of new kinds of decisions when planning and implementing a cultural heritage project. The logistical challenges of the transportation of the scanning equipment to the field, the utilization of the scanner while controlling the field contingencies, the decisions of how to translate the scan data into project products are just few of the issues that the heritage professionals should address in the archaeology projects.

Technological instrumentation provides us sharp accuracy and precision and allows us to gather information quickly. However, the quality of the deliverables depends on the knowledge and experience of the heritage professional. Without a skilled person, the laser scanner is just another technological tool that collects mathematical data. It should not be forgotten that we, heritage professionals, are the specialists who seek the answers in archaeological inquiries not the technologies themselves.

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Fleeing for their lives: Archaeology of the underground railroad in St. Charles, Illinois

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Abstract: The purpose of this paper is to explore urban archaeology in relation to the Underground Railroad in the town of St. Charles, Illinois. Researching the Underground, which was a metaphorical term used to describe the escape route of slaves from southern states, in urbanized St. Charles provides an excellent venue of combining historical archaeological techniques and providing a voice for often forgotten African slaves.

Three objectives include (1) identifying the town of St. Charles as a stop along the Underground Railroad via historical documents, (2) determining what archaeological evidence supports the existence of the Underground Railroad, and (3) determining if the Young/Marsden House in St. Charles was a stop on the Underground Railroad. Methods used during this research include archival research, such as local histories and land deeds, archaeological excavation in the cellar of the Young/Marsden House, and archaeological analysis of artifacts. Support for this conclusion is historical evidence for the Underground Railroad in St. Charles, similarities to other excavated Underground Railroad sites, and artifacts recovered during excavations at the Young/Marsden House. Future research opportunities, investigating the well and excavating the remainder of the fill in the chamber, are available and will provide a more complete story of the Young/Marsden House.

Keywords: Urban, Historical, African American Archaeology, Underground Railroad, Illinois.

Introduction

The archaeology of the Underground Railroad is challenging due to its clandestine nature and only a handful of sites have been investigated archaeologically. My research explores the question: How do you find archaeological sites and material culture associated with secretive activities in the urban area of St. Charles, Illinois? To answer that question, I am investigating a historic home, known as the Young/Marsden house, to determine if it was a stop along the Underground Railroad.

This paper is divided into three sections. First, I provide the historical background about slavery, anti-slavery movements, the Underground Railroad, and the town of St. Charles, Illinois. Second, I describe the methodology of my research. Last, I discuss the preliminary results of archival research and excavations of a chamber in the cellar of the Young/Marsden house.

Historical Background

Slavery in the United States

Using slaves as a form of free labor was common practice on southern plantations in the United States in the early 1600s as a result of the Dutch, Spanish, and English colonizers (BORDEWICH 2005: 15; HORTON and HORTON 2005: 26; MCGOWAN 2005: 11; REMINI 2008: 22). Throughout the history of the United States, several laws were enacted making slaves property and suppressing the rights of the enslaved and free African Americans. For example, the Fugitive Slave Law of 1850 permitted slaveholders with the aid of federal commissioners to enter any state or territory to retrieve their slave. Anyone caught harboring or aiding a runaway was fined and denied the opportunity to defend themselves (GARA 1963: 523–525; TURNER 2001: xvii–xviii; HORTON and HORTON 2005: 148–149). Citizens of the United States of America were divided on the slavery issue with northern states, including Illinois, prohibiting slavery, while southern states permitting slavery (Fig. 1). It was not until the end of the Civil War in 1865 that slavery was abolished.

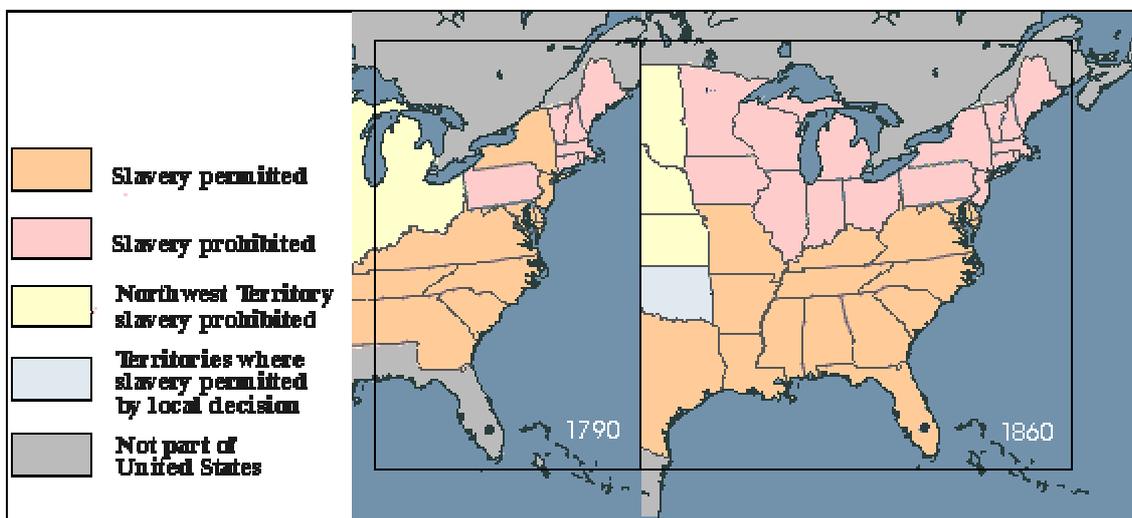


Fig. 1 – Free and Slave States 1790 and 1860. (NPS 2001)

Anti-Slavery Organizations and the Abolitionist Movement

Although aiding slaves to freedom was against the law, several anti-slavery organizations and publications were established. The first anti-slavery society was established in 1775 in the city of Philadelphia (BORDEWICH 2005: 39; HORTON and HORTON 2005: 48, 50; SCHAMA 2006: 189). In 1833, the American Anti-Slavery (TURNER 2001: 16, 130; HORTON and HORTON 2005: 139–140) was established, followed by the Illinois Anti-Slavery Society in 1837 (GARA 1963: 513; BLOCKSON 1987: 201; TURNER 2001: 34, 114–115; HORTON and HORTON 2005: 144; CALARCO 2008: 200–202). In 1843, the Kane County Anti-Slavery Society was organized, which is county in which the Young/Marsden House is located (TURNER 2001: 35). In addition, several anti-slavery newspapers were published, such as the Liberator (BORDEWICH 2005: 140; SMARDZ FROST 2008: xviii). Both the anti-slavery organizations and publications are part of the larger Abolitionist Movement, which had the purpose of informing the public about slavery and promoting the end of slavery in the United States.

The Underground Railroad

The Underground Railroad may be considered a physical manifestation of the Abolitionist Movement as several individuals involved were both white and black abolitionists. The Underground Railroad is defined as a metaphorical term used to describe the network for moving enslaved Africans to freedom whether to free states in the US or Canada and does not refer to a physical railroad. However, the term came from the popularity of the new railroads being built in the 1800s along with runaways seeming to disappear or "go underground" as slave catchers pursued them (SIEBERT 1898: 1; NPS 1998; TURNER 2001: xi, 3; BORDEWICH 2005: 237).

Although the origin of this term may be legend, the Underground Railroad metaphor became a natural and convenient method for abolitionists to communicate with one another without having their plans discovered. For example, a passenger was a runaway slave, conductor referred to a person who took passengers from one station to another, stations or depots refer to stopping places, and coach or train referred to any form of transportation used to transport slaves (TURNER 2001: 2–3, 5; BORDEWICH 2005: 237–238; MCGOWAN 2005: 14). Several routes from the southern states to free states or countries were used by runaway slaves (Fig. 2).

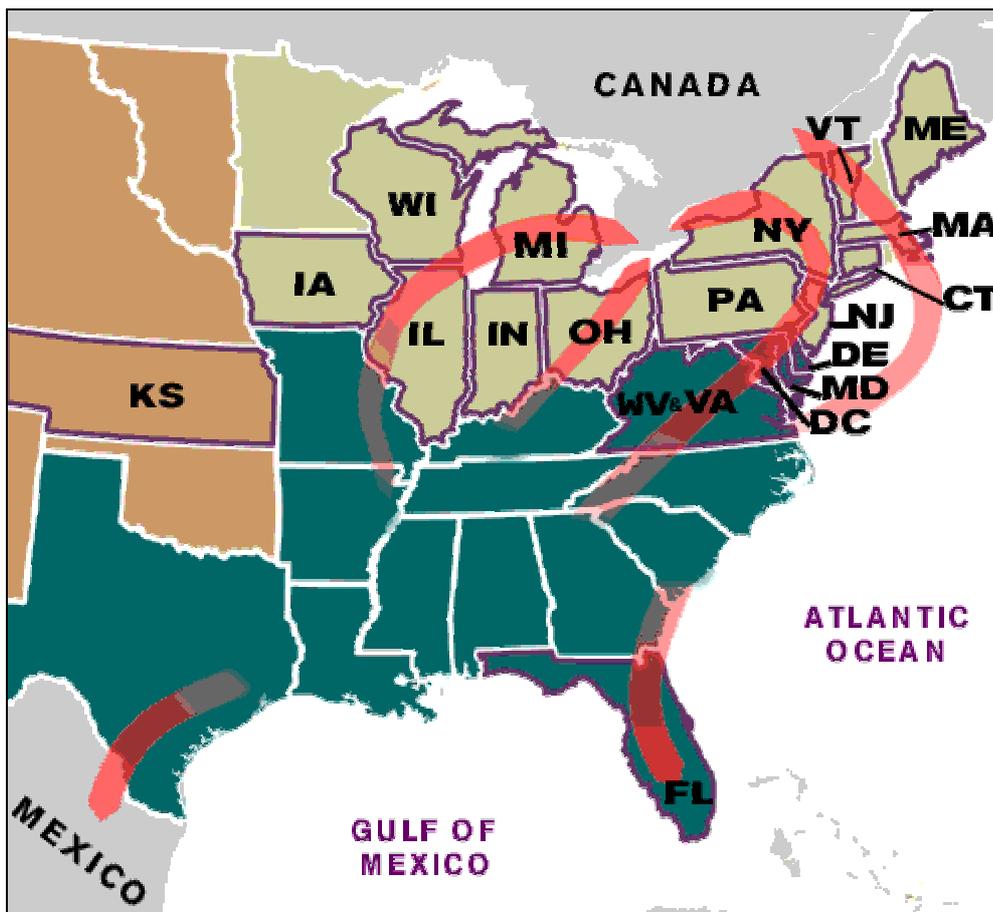


Fig. 2 – General Map of the Eastern United States demonstrating possible routes used by runaway slaves. (NPS n.d.)

The highest period of Underground Railroad activity was from 1835 to 1861. The decline in 1861 may be contributed to the beginning of the Civil War, which was the war that abolished slavery (TOBIN and DOBARD 1999: 54; TURNER 2001: 2).

The Underground Railroad was operated by a variety of people including free blacks, abolitionists, and Church members. Individuals who were involved in the Underground Railroad attempted to keep their activities secret because it was against the law to help or harbor any runaway slave. As a result of the necessary secrecy, most memoirs and family histories were not recorded or revealed until after the Civil War.

St. Charles History

Now that the general climate of the United States during the 1800s has been established and the Underground Railroad defined, a brief history of Illinois and the town of St. Charles will complete the background information crucial for interpreting the Young/Marsden House. Maps identifying the location of Illinois (IL) in the United States, (Fig. 2), Kane County within the state of Illinois (Fig. 3), and St. Charles within Kane County (Fig. 4) clarify the geography of the Young/Marsden project. St. Charles, Illinois is approximately 68.5 kilometers from the city of Chicago.



Fig. 3 – Kane County in the State of Illinois. Kane County is in the northern part of Illinois and outlined in black. (U.S. Census Bureau 2011)

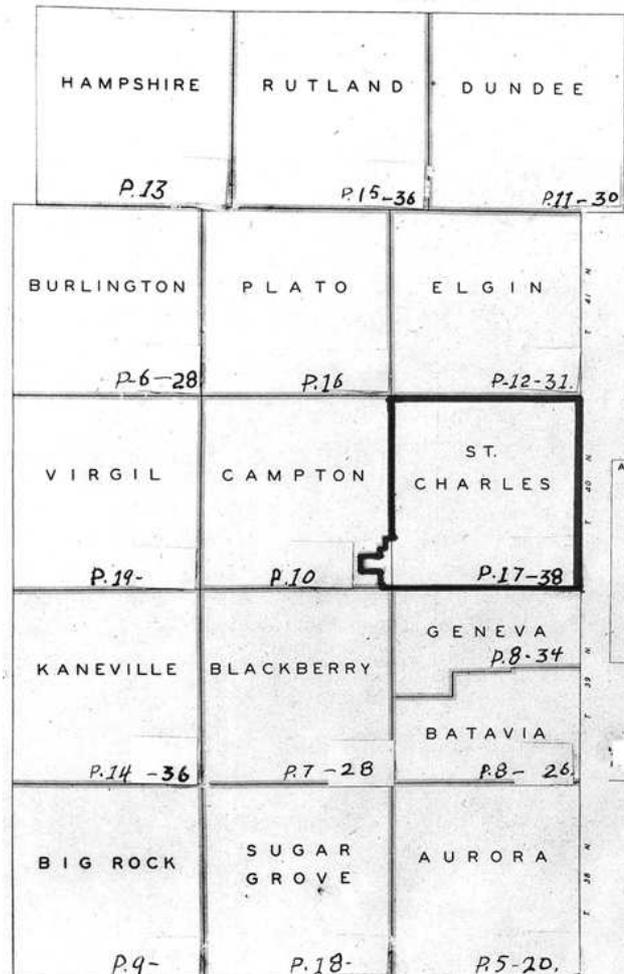


Fig. 4 – St. Charles in Kane County, Illinois. St. Charles is outlined in black. (Kane County Plat Book 1860)

This region of the American frontier was first settled in 1833 mostly by folks from New England and Canada. From its inception, the citizens of St. Charles desired to establish a bustling town, which was possible as a result of its prime river location. By 1837, St. Charles (Charleston as it was initially named) had been surveyed and platted the town, began industries, built roads, and established schools and churches (DURANT 1881: 9, 11, 18; DURANT et al. 1888: 1073–1076, 1080; DAVIS 1940: 4–7; CLAUTER and WILLIAMS 1967: 25, 62; PEARSON 1976: 1–7, 22; SCHS 1990: 33; EDWARDS 1999: 9–10; SCHULTZ ANGEL 2004: 22–23).

In 1843, the Kane County Anti-Slavery Society was organized and met on three occasions in St. Charles (SCHULTZ ANGEL 2004: 38, 45). Additionally, four other Underground Railroad sites (Randall House, the Wheeler Farm, Beith House, and Thomas Collins House) in the town have been confirmed (DURANT et al. 1888; COSTERISAN 2000). Both the meeting of the Kane County Anti-Slavery Society and confirmed sites in the town support the hypothesis of Underground Railroad activity occurring in St. Charles.

Young/Marsden House

The Young/Marsden House is located west of the Fox River and Gideon Young claimed this land in 1835 (DURANT et al. 1888: 1076). Young, a member of the Kane County Anti-Slavery Society (KCASS 1842), sold the property to Dr. Abel Millington in 1838. Darwin Millington, then, inherited the property upon the death of his father, Dr. Abel Millington (DURANT 1881: 21, 67; DURANT et al. 1888: 1081; DAVIS 1949: 7; PEARSON 1976: 14). In 1840, Darwin Millington added an addition onto the back of the house.

Although, Millington does not appear to be a member of the Kane County Anti-Slavery Society, the family may have been involved with the abolitionist movement and possibly the Underground Railroad. Millington donated land for the construction of a Congregationalist Church that was built in 1848. One of the resolutions passed by the Congregational Church, in 1849, demonstrated the anti-slavery sentiment of the church and intention to support of abolition of slavery (CC 1987: 6). In 1852, Roger and Elizabeth Marsden purchased the property (KCIPR 1852: 209–210). Although no direct evidence links the Marsden's to the Underground Railroad, two factors may support the possibility of their involvement. First, Roger Marsden worked in the shoe business with Volentine Randall, who was an ardent abolitionist and likely a conductor on the Underground Railroad (DURANT et al. 1888: 1080), and second, one of their sons fought for the anti-slavery side in the Civil War (DURANT 1902–1904: 208). The property remained in the Marsden family until 1892 (KCIPR 1892: 505).

Historical documents do not provide much detailed information about the Young/Marsden House. What we do know is that the house was built around 183. The second story extension of the house and cellar north occurred around 1840. The plan view of the cellar and chamber indicate the unusual location of the chamber and the size of the cellar (Fig. 5).

Note that the chamber was easily accessible from the current cellar door. The opening was shaped to fit under the original stairs leading from the first floor. Note that the opening of the chamber was not done in a systematic manner; rather it was broken through haphazardly and edges are jagged and uneven.

Additionally, the fill slopes downward from west to east and a wooden board prevents fill from shifting into the cellar addition. The two shelves are not visible from this angle; however, they are located on the opposite side of the eastern wall (Fig. 6).

Within this chamber are two wooden shelves along the southern margins of the chamber. The upper shelf (Fig. 7) and lower shelf (Fig. 8) demonstrate the size and construction of the shelves.



Fig. 7 – Upper Shelf in Chamber. (L. Brown)

The upper shelf is approximately 243 cm by 48 cm and the boards are of different lengths, widths, and thicknesses. Furthermore, the two boards were connected by another piece of wood that is partially visible at the bottom of this photo.

The lower shelf is approximately 127 cm by 58 cm and is one piece. These shelves raise the question of what was the function of the chamber. Three possible functions are addressed. First, was the chamber used as a storage space? Possibly, but the cellar was relatively large so why would someone intentionally break through the limestone foundation to add additional storage. Second, was it used during Prohibition, a period in United States history in which liquor was illegal? Possibly, but what evidence, if any, could support this idea? Third, was the chamber used as a hiding place for runaway slaves? Possibly, but what evidence could support this notion? These questions are even more intriguing because the removal of the limestone foundation has caused structural damage and additional support has been put in place. Ultimately, what was the function of this chamber?



Fig. 8 – Lower Shelf in Chamber. (L. Brown)

Methodology

Historical Documents

A variety of historical documents were examined throughout this research. Several local histories of St. Charles discuss the strong abolitionist attitude in the community. In addition, court records, land deeds, probate records, and genealogical sources helped piece the puzzle together. Historical documents, such as meeting notes of the Kane County Anti-Slavery Society provided information about members, meeting locations, and what was discussed at the meetings. Land deed records reveal the history of land transactions on the property of the Young/Marsden House. Furthermore, three other documented Underground Railroad sites in St. Charles were reviewed. Other sources of information revealed various Underground Railroad routes, which have been established and verified through research by the National Park Service and their “Aboard the UGRR” Program. At least one route passes through St. Charles.

Archaeological Methods

Archaeological methods were also employed, in conjunction with historical research, at the Young/Marsden House in order to help answer the ultimate question: Was the Young/Marsden house a stop on the Underground Railroad? First, we mapped the cellar and the chamber in the cellar, and then excavated some of the fill. Analysis of the artifacts recovered during excavation was the final step.

Typical mapping techniques could not be used in this space and therefore we had to develop our own method of mapping, which ended up being quite a challenge. The profile of the chamber from the entrance (Fig. 9) and 50 cm west of the entrance (Fig. 10) demonstrate the rough, perhaps unplanned, modification of the chamber and construction of the shelves.

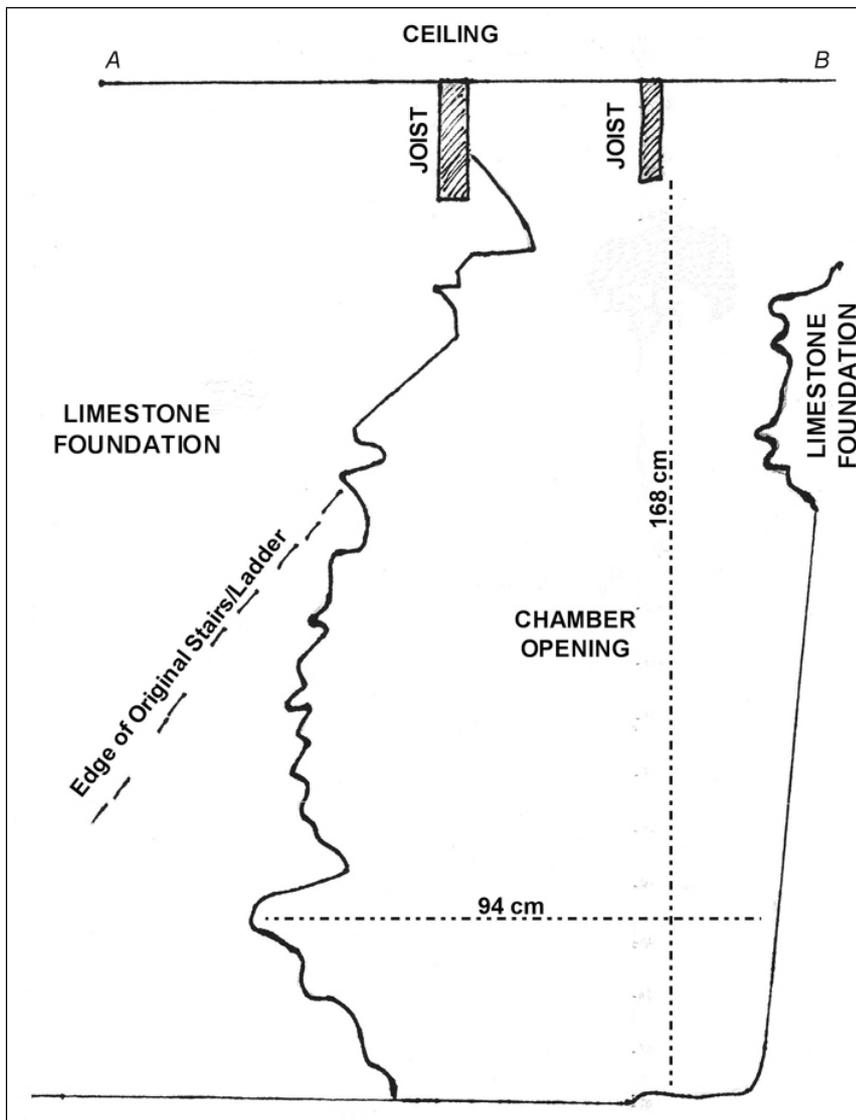


Fig. 9 – Profile of Entrance to the Chamber. Refer Figure 5 for points A and B. (L. Brown)

In order to get a 3-dimensional measurement of the space, we tacked a tape measure to the base of one of the floor joists and used that as our east-west baseline, and then we dropped a plumb line from the joist. After the mapping was completed, we collected any debris from the shelves and loose fill. Large artifacts

were bagged and recorded on-site, while the fill was bagged for screening at a later date. Fill was screened using a ¼ inch screen which is approximately six millimeters.

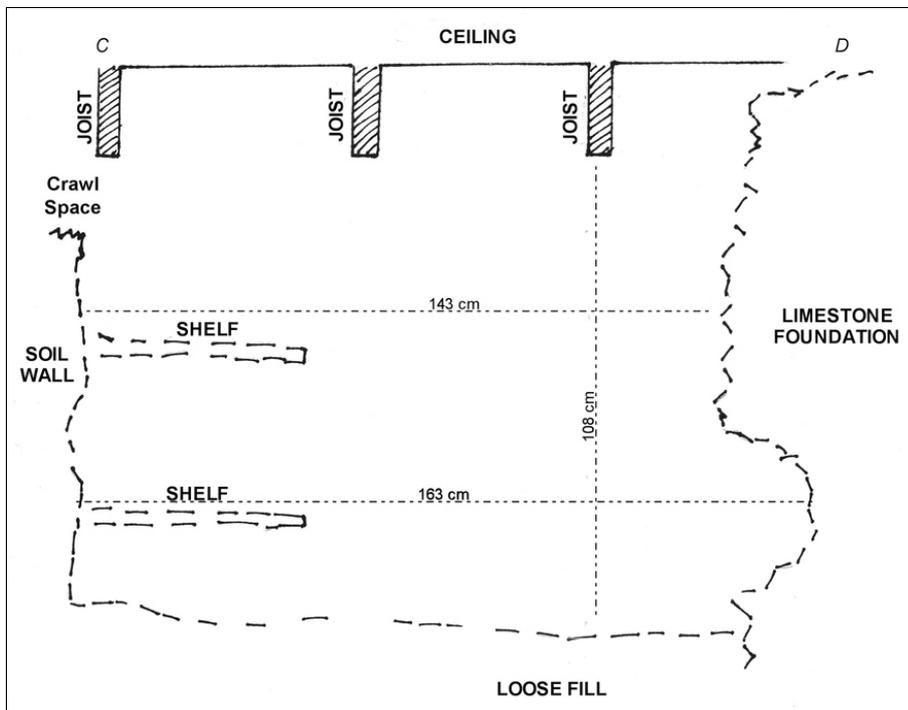


Fig. 10 – Profile of Chamber at 50 cm West of Chamber Opening. Refer to Figure 5 for points C and D. (L. Brown)

Analysis

Artifacts recovered during excavations included two intact glass bottles, a few fragments of ceramic, nails, a pair of broken scissors, a clay marble, a fragment of a clay pipe, and faunal and floral remains. The two glass bottles were recovered from the shelves. Both have dried herbs inside and one bottle is corked. Two ceramic fragments of differing vessels were recovered. One dates to more recent usage, while the other is older, but too fragmented to determine age or function. Several nails were screened from the fill and are machine cut wire nails, rather than hand cut and square head metal nails.

The clay marble, clay pipe, and faunal remains are the most significant finds in the chamber. The clay marble is handmade dating it to at least the 1800s. The pipe fragment is part of the bowl and similar to pipes found in the Midwest during the 1800s. The faunal remains include eggshell fragments, chicken bones, fish bones, and domesticated mammal bones. Not all bones were identifiable; however one cow rib with butcher marks was recovered as well butchered bones from a pig and sheep or goat. Some of these bones do exhibit evidence of rodent gnawing, which most likely occurred after the bone was disposed. Remains of *Rattus rattus* and a mouse were also recovered, which explains the gnawing on some bones. Although gnawing exists, it seems unlikely that rodents dragged in the remains, suggesting that the remains were in the chamber and later gnawed.

Furthermore, it seems likely that the domesticated mammals, chicken, and fish bones were the remains of a meal. Whether or not this meal was consumed by a runaway slave in the chamber is unknown. However, it

seems unlikely that the bones were intentionally disposed of in the chamber; rather the family would have tended to throw it outside of the house, perhaps in a designated garbage area.

Lastly, other artifacts recovered from the chamber can be explained as rodent nests. Paper, insulation, fabric, cloth, and other miscellaneous items were found on the shelves in the chamber. Nuts and nutshells demonstrate that rodents possibly ate and gnawed on most of the flora remains. Based on the type of insulation, a rat poison box, and newspaper fragments in color, it is likely that the rodent problem was a more recent activity. Furthermore, the current owner discussed the problem with rodents, which was resolved when entrance point for rodents was repaired.

Other Underground Railroad Sites

In order to interpret the artifacts from the Young/Marsden House, two archaeologically excavated Underground Railroad sites are briefly examined. The first site is the Thaddeus Stevens and Lydia Hamilton Smith Site in Pennsylvania. Stevens, a committed abolitionist, and Lydia Hamilton Smith, his African-American housekeeper, appear to have modified a cistern near his property that connected to another building also owned by Stevens. Artifacts found in the cistern include ceramics, glass bottles, and faunal remains. Both historical documents and archaeological evidence suggest Underground Railroad activity (DELLE and LEVINE 2004). Another site is the Parvin Homestead also in Pennsylvania. This site has archaeological evidence of a modified cold cellar and artifacts such as a blue bead, faunal remains, and fragments of a chamber pot (DELLE 2008; DELLE and SCHELLENHAMER 2008).

Material Culture of the Enslaved

Based on excavations of plantation settlements and Underground Railroad sites, a signature of enslaved material culture emerges and may be defined by the following artifacts: beads, oftentimes blue, clay marbles, pipes, colonoware pottery, and faunal remains (SINGLETON 1985, 1999; LAROCHE 1994, 2004; YENTSCH 2004; KING 2010). In addition, Underground Railroad sites tend to have archaeological evidence of modifying structures and explaining the rationale for the modification may suggest Underground Railroad activity.

Conclusion

Based on the historical documents and material culture found within the chamber, preliminary results suggest that the Young/Marsden House was possibly a stop on the Underground Railroad network to freedom. Although no diagnostic artifacts were recovered thus far indicating when the chamber was used, the haphazard modification, faunal remains, and material culture suggest human activity. Some of the flora remains may have been carried in by rodents and there is evidence for gnawing on various nuts. However, the faunal remains have evidence of being butchered. The question arises: Why are there so many faunal remains as the chamber is not a convenient or ideal dumping area? A person does not generally enter a cellar and throw out bones especially if meat was still on them. Furthermore, the Underground Railroad was functioning in St. Charles and the strong anti-slavery sentiment of the town offers support for the Young/Marsden house to be a station of the Underground Railroad.

Therefore, based on this analysis much of the evidence strongly supports Underground Railroad activity at the Young/Marsden House. Future research opportunities at the home, including full removal and screening of the remaining fill and an investigation into the well that is currently located under the porch on the north side of the home, will provide a more complete picture of the Young/Marsden House.

Acknowledgements

I would like to thank Dr. Mark Mehrer for advising and mentoring this research project, the Department of Anthropology at Northern Illinois University and Graduate School at Northern Illinois University for helping fund this project. I would also like to thank the St. Charles Heritage Center, St. Charles Public Library, and Kane County Recorder's Office for their assistance in researching the Young/Marsden House and permission to use their research facilities. I would like to thank the Mammal, Bird, and Fish Divisions of the Field Museum of Natural History in Chicago for permitting me to use their collections to identify the faunal remains recovered during excavations. Lastly, this project would not have been possible without the help of the owner of the Young/Marsden House, Faith Tripp Peloso, who kindly opened her home and offered her knowledge of the home throughout the course of this project.

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Analysis of the Mastaba of Ptahshepses using space syntax

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Abstract: In our work, we focused on an ancient Egyptian private tomb, called Mastaba of Ptahshepses, from the fifth dynasty (King Niuserre c. 2445–2421 BCE) located in Abusir. Over time, large parts of the tomb have been destroyed and it has become impossible to reconstruct some of the rooms and walls with contemporary archaeological methods. Searching for a possible solution for the unknown measurements and room layouts, we finally chose an analysis – taken from the field of spatial planning – called *space syntax*. It is a mathematical graph theory procedure, which is used to analyze nodal diagrams of (city) plans to find out the cultural norms behind the morphology of buildings and structures (OSMAN and SULIMAN 1996). Based on the work of HILLIER and HANSON (1984), we worked with simple parameters of Space Syntax to analyze the indoor spaces of the tomb in a geometrical way. By comparing the values to the values from a similar tomb, we completed the fragmentary plan obtaining similar values at related locations within the two different tombs. The results of this method were consistent with the solution, which the current excavation team on-site has found.

Keywords: Space syntax, reconstruction, archaeology, mastaba, graph theory.

Introduction: the tomb of Ptahshepses

The tomb of the high official Ptahshepses is one of the largest and most important non-royal tombs of the Egyptian old kingdom. This tomb, a so-called *mastaba* was built near modern Cairo in the necropolis of Abusir.

Because of its size, in the 1840s a Prussian expedition under the supervision of Karl Richard Lepsius, thought the tomb to be a royal pyramid (LEPSIUS Text, 1897). In 1893 the archaeologist Jacques de Morgan started to excavate parts of the remains, but he had to stop his work very soon because of financial reasons. He published his results at DE MORGAN (1894) and DE MORGAN (1897). Since the 1950s Abusir is an important excavation-site of the Czech Institute of Egyptology, that published a lot of material on Abusir and the mastaba of Ptahshepses; for the most important publication concerning the architecture see KREJČÍ (2009) and the further literature.

Ptahshepses lived in the fifth dynasty at the time of king Nyuserre in the 24th century BCE. His profession as a royal hairdresser and wig maker in an early stage of life allowed him access to the king in person, what ultimately enabled him to succeed in reaching powerful offices with high religious and executive titles. Ptahshepses earned more than 30 titles and became the second man in Egypt to become a Vizier. Along his professional career, he married a princess and became a son-in-law of the king. Being titled the “Chief of All Works of the King”, he had access to the royal building-materials (KREJČÍ 2009).

His tomb exactly indicates the advancement of Ptahshepses: it was initially planned as a typical mastaba with around 30 x 20 meters, but enlarged for two more times on finally 56 x 42 meters – a space of more than 2.300 square meters (KREJČÍ 2009).

The mastaba shows typical characteristics of the fifth dynasty and royal influence. The most important elements are a portico with lotus-columns, an inaccessible room for the statue-cult (a so-called serdab), a central offering courtyard and a boat-room (BÁRTA 2005, for a paper concerning boat-rooms see ALTENMÜLLER 2002).

Due to multiple robberies, large areas of the mastaba got damaged, leaving the tomb in a badly preserved condition. The building material had also been damaged by the wind and sand after the de Morgan's long excavation procedures (KREJČÍ 2009), which made it difficult to reconstruct several artefacts of the remaining walls. An example for that is the area that leads from phase II to the open courtyard of phase III. In this area, remains of several walls indicate that possibly more rooms were situated at this location. The functions of additional, hypothetical rooms are not explored yet. A simple store room, as well as a religiously motivated statue room, or Serdab, might have existed there. CHAUVET suggests a Serdab in her PhD-thesis (CHAUVET 2004). This, she argues, is due to the resemblance of the mastaba to a similar tomb: the mastaba of Ti.

For a deeper exploration of this specific area we chose an analysis called space syntax and compared the ground plan of the Ptahshepses mastaba with a similar tomb – the tomb of Ti in Saqqara (STEINDORFF 1913).

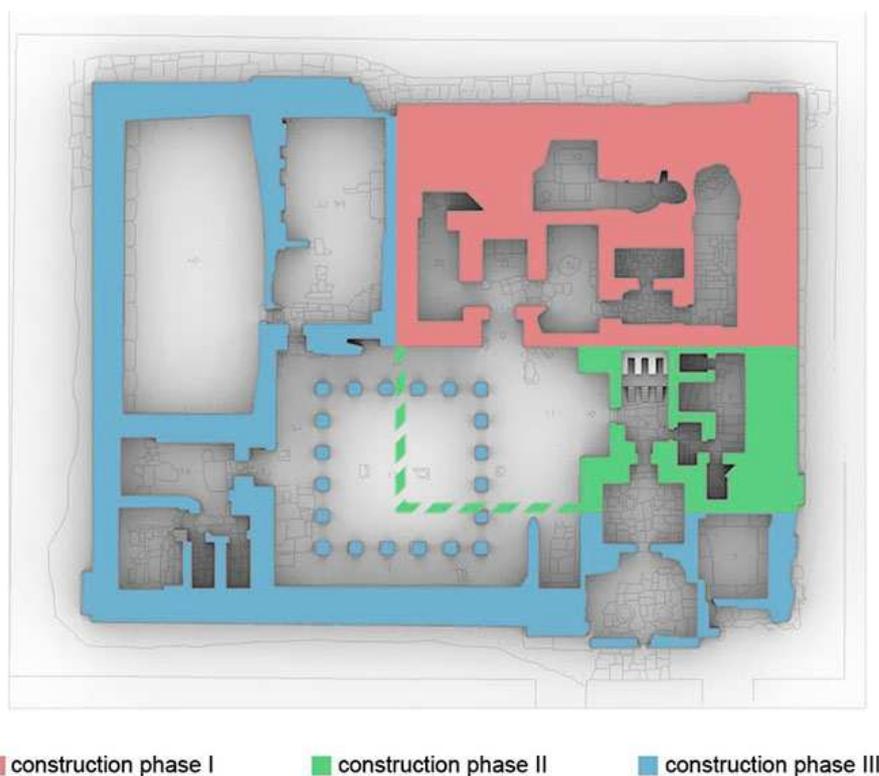


Fig. 1 – Floor plan of mastaba of Ptahshepses based on KREJČÍ 2009: 15 [Fig. 1.12].

Method

If we take a look at the artefacts and objects that surround us, we see that all of them have certain logic to them. One parameter is *functionality*, which gives the object a certain purpose. The other parameter is *style*, which gives the object a cultural meaning. What differentiates a building or construction from an object like a fork is, the building's order and division of the space around, as well as inside (HILLIER and HANSON 1984), thus giving meaning to a special ordering of space and its occupants. If that is the case, how can we access this information? Is it possible to quantify parameters that influence relations between space and people?

Hillier and Hanson argue in *The Social Logic of Space* that with simple, mathematical methods one can analyze the formal organization of spaces. This approach is based on nodal diagrams and is used to look at the ordering of city plans or building structures.

The mastaba itself is a great complex divided into subdivisions. As it was built in three building phases, it offers the visitor an image of a structure that presents its architectural growth. Similar to an urban environment, one finds a sequence of spaces with different dimensions, levels of visibility, access and other parameters.

Our approach was to first analyze the existing structure using space syntax and then comparing hypothetical wall arrangements to the mastaba of Ti, which is not only comparable in structure and time, but is also better preserved.

As parameters for investigation we chose *integration* and *control*, both are notions which were developed early in space syntax theory.

Looking at building layouts, HÖLSCHER, BRÖSAMLE and VRACHLIOTIS show in their paper *Challenges in Multi-level Wayfinding: a case-study with space syntax technique* that measures like integration and step-depths capture important architectural deficits of the building with respect to its navigability and substantiate earlier qualitative findings (HÖLSCHER and DALTON 2006).

In our work we calculated the value of integration, which was found to correlate with pedestrian movement (HÖLSCHER and DALTON 2006, TURNER 2004). Integration gives insight into relations of depth from a certain space, compared to the system as a whole.

$$I = \frac{2(MD - 1)}{(k - 2)}$$

where

$$MD_n = \frac{TD_n}{(k - 1)}$$

I	measure of Integration
MD	mean depth for node n
TD _n	sum of all depth values
k	total number of nodes in the system

The notion of depth refers to the distance between a space and the carrier of a system. The deeper a room or space is, the more steps it is away inside from the building's entrance.

Relations of depth necessarily involve the notion of asymmetry, since spaces can only be deep from other spaces if it is necessary to pass through intervening spaces to arrive at them. [...] the least depth existing when all spaces are directly connected to the original space, and the most when all spaces are arranged in an unilinear sequence away from the original space." (HILLIER and HANSON 1984)

As a second parameter for our analysis, we looked at the measurement of control. While integration is a global measurement – as it takes the entire system into account – control is a local measurement, meaning that it only takes local relations between nodes or spaces into consideration.

Each space has a certain number of adjacent, neighbouring spaces. By summing up the neighbouring spaces one can see from a certain space and then evaluating each seen space, one receives a measure of control for a certain space. A room has a high level of control if it sees (is connected to) many adjacent spaces, which themselves, only see very few other spaces. Therefore it is pointing at visually dominant areas.

In order to evaluate the mastaba in a very detailed way, we used a software that read geometrical vector based data. It allowed us to subdivide each room into a great number of small cells on which the space syntax calculations are conducted.

We used the Syntax2D program, developed by Turner and his team from the University of Michigan. The measurements are calculated according to an introduced grid, respecting the given geometry. This procedure gives not only insight into the formal organization of a given room and its relations to adjacent rooms, as Hillier and Hanson are demanding, but also provides an evaluation for smaller areas within a room.

Application

As a basis for our analysis, we drew digital floor plans using the excavation map of the Czech Institute of Egyptology from the Charles University in Prague (tomb of Ptahshepses: KREJČÍ 2009) and a map of the tomb of Ti after a monograph of JÁNOSI (2006) in AutoCad 2006. The line and polyline entities from the CAD files (*.dwg) could then be imported into Syntax2D.

To prevent the algorithms to extend to infinity we defined comparable boundaries for the two mastabas. Prior to running the analysis, which is based on grid isovists, the grid parameters had to be defined. Its resolution was predetermined by the smallest openings within the plan. The grid resolution has to be precise enough to connect every associated room with at least one point. Although the results are showing sets of squares, visibility is always assessed from the very centre of a grid square (TURNER 2004). At this point it is necessary to point out two major problems concerning this analysis method. Since this method does not respect three-dimensional space, working with multiple floors becomes problematic. To our fortune, this was not a big issue for our work, because the tunnel leading to the burial chamber was far away from our centre of interest. Resulting from these restrictions, a second issue emerges: it is impossible to distinguish visual connection from physical access. Due to this fact it was impossible for us to differentiate between a

magazine and a serdab, which traditionally could not be accessed, but offered visitors a restricted view into the room that was equipped with a statue.

To see how space syntax performs in testing hypothesis, we first modified the floor plan of the mastaba of Ptahshepses by adding an additional space, and then by adding an additional room and corridor, in the courtyard. Each of these variations, as well as the mastaba of Ti, allowed us to use dimensions of control and integration analysis in Syntax2D.

Control analysis

Considering the present state of the mastaba of Ptahshepses, the results of the control analysis show a scattered distribution of slightly increased values within the inner courtyard. Adding a room, where one more room is assumed, the control peak values shift towards the centre of the courtyard. This effect can be enhanced by adding an additional corridor and enclosing the courtyard.

control grid analysis

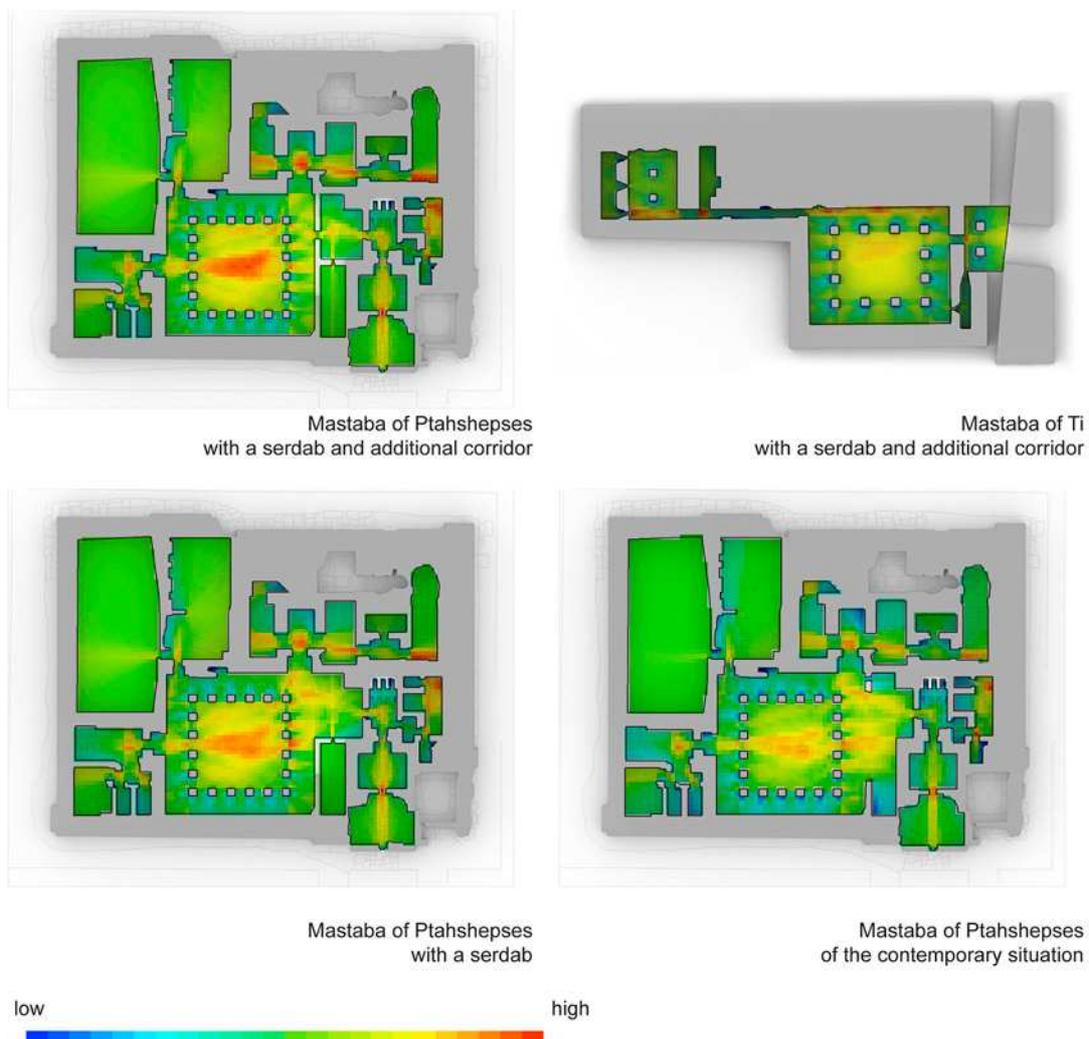


Fig. 2 – Control grid analysis (Hirzbauer, Waltenberger, Vasku plans based on KREJČÍ 2009: 15 [Fig. 1.12] and JÁNOSI 2006: 102 [Fig. 81]).

Looking at the control analysis values inside the inner courtyard of the mastaba of Ti, the peak values are aligned along the axis of the long corridor accessing the burial chamber. This is due to different room sequences and the very nature of control values: it is a local measurement and therefore rates the space, which links the long corridor with the courtyard very highly. The mastaba of Ti's corridor axis is very dominantly crossing the courtyard and persists as singular access to following spaces.

The mastaba of Ptahshepses, on the other hand, has a courtyard that connects a great amount of spaces. Its control analysis compared with the one of Ti suggests, that the concept of a local measurement like control seems improper for the task of evaluating hypothetical room structures.

Integration analysis

Quite different results were achieved when considering the integration analysis. The present state of the mastaba of Ptahshepses reveals a scattered distribution of slightly increased values within the inner courtyard, which again shift towards the centre of the courtyard when either adding a room in a second step or the additional corridor in a third step.

integration grid analysis

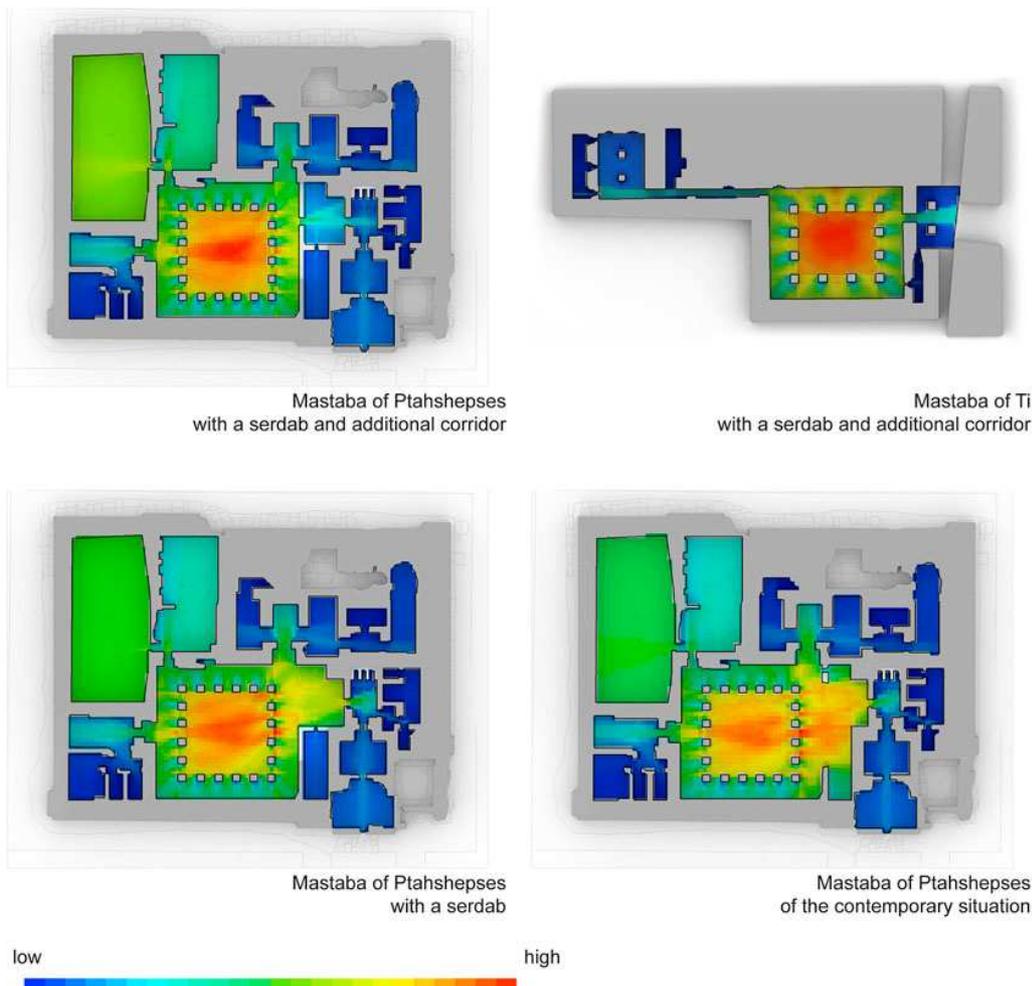


Fig. 3 – Integration grid analysis (Hirzbauer, Waltenberger and Vasku plans based on KREJČÍ 2009: 15 [Fig. 1.12] and JÁNOSI 2006: 102 [Fig. 81]).

In contrast to the control analysis, the integration analysis' peak values at the mastaba of Ti concentrate in the centre of the inner courtyard as well.

The same distribution of high values occurs in the mastaba of Ptahshepses, if we added a room and an additional corridor (see Fig. 2). Since the number of rooms, as well as the sequence of spaces is affected by introducing the wall structures, the global measurement of integration shows vast changes. The result comes astonishingly close to that of the mastaba of Ti, which also holds a serdab between the entrance and the courtyard. Only after reconstructing the previously mentioned rooms and their adjacent wall-structures, does the integration analysis in Figure 2 show results similar to the well-preserved mastaba of Ti.

Conclusion & Outlook

In this paper we showed that space syntax might be applied to archaeological structures. It can be of supporting help to egyptologists and archaeologists to investigate spatial configurations of ancient complexes. It can be used to objectively calculate spatial configurations and test the possibilities of reconstructing fragmentary floor plans. Even though we do not think that space syntax can singularly be an easy-to-solve tool for archaeological problems, it is very well suited to test hypotheses. This is what we did by comparing hypothetical room sequences of a fragmentary mastaba with ones of a well-preserved mastaba. Looking at the mastaba of Ptahshepses, the integration of the courtyard seems more plausible if we construct an additional room in the courtyard.

Our analysis shows that the hypothesis, proposed by Chauvet, of an additional serdab seems reasonable when conducting a space syntax analysis and comparing the results with the mastaba of Ti; although our work could not prove the intended function of said rooms. The results support the archaeological reconstruction of the Czech Institute of Egyptology concerning the remains of existing wall structures of the location in question.

However, we see two problems for working with space syntax in complex, archaeological structures. First, space syntax is limited to two-dimensional floor plans. It neglects the third dimension, which means that one has to work around geometric inhomogeneities, as for example different levels (e.g. burial chamber). Second, due to its simplicity, it is not possible to differentiate between spaces that are physically accessible (store room) and spaces that are only visually accessible (serdab).

Further research is needed in evaluating the use of other space syntax measures for evaluating excavation plans and reconstructing fragmentary parts.

However, as shown in our work, interdisciplinary teams consisting of scientists of the humanities and engineers should bundle their resources and tackle remaining problems. This may lead to creative solutions that can resolve issues, which have kept researchers occupied with traditional methods for far too long.

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St. Mang Square in Kempten

Interdisciplinary Reconstruction and Public Presentation of a churchyard's history

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Abstract: The project covers two important parts of modern urban archaeology: the interdisciplinary scientific research of the recent excavation of a central square in the former *Reichsstadt* Kempten and its public presentation in the modern city. The material reconstruction of the square's history led to new historical insights by forming sepulture-phases of the cemetery and construction-phases of the charnel house.

Keywords: Medieval churchyard, interdisciplinary research, public presentation.

The Project

Cause for the Excavations

Modern urban development of today's cities may occur in the outskirts and affect land that yet has to be prepared for building, or it can take place right in the centre of the city and affect an area that has been in the middle of an urban settlement for centuries. The latter can be described both as a blessing and a curse, since the inner city underwent a lot of concentration processes during the Middle Ages and Modern Age. Here one can find places that have been right in the middle of the city's history and their development might answer a lot of historical questions. On the other hand the soil has a good chance for having been heavily disturbed during the centuries with less chances to reveal a lot of archaeological information, especially about early medieval times. An exception, that often proves the rule, is formed by the typical big spacious squares in the cities' hearts, the market square and the churchyard, which normally hadn't seen any constructions, houses and especially no buildings with cellars and with that provide us with a better chance to get a glimpse on their development in the past.

So it turned out to be in Kempten, situated in the mountainous region Allgäu in Southwestern Germany. In the late 90s, the City Council concluded a development program with the intention to enhance the attractiveness of the city centre. Part of the development program was the redesign of the centrally located St. Mang square, the former churchyard of the *Reichsstadt*. The aim, found under explicit participation of the citizens, was to reconstruct the historical appearance of the square at the turn of the 20th century, which could be found on historical photographs (Fig. 1) and at the same time keep the function of the place as a location for leisure activities (e.g. playground for boules). While the *Jugendstil*-fountain, constructed 1905 by Prof. Wrba was to be preserved, it was necessary to deconstruct a wall and renew the surface of the whole square on which the exact location of the graveyard chapel, destroyed in the 19th century, was to be highlighted. Before the necessary earth moving took place, there was enough time to archaeologically investigate the soil first.



Fig. 1 – St. Mang Square on an historical photograph (Copyright: Stadt Kempten).

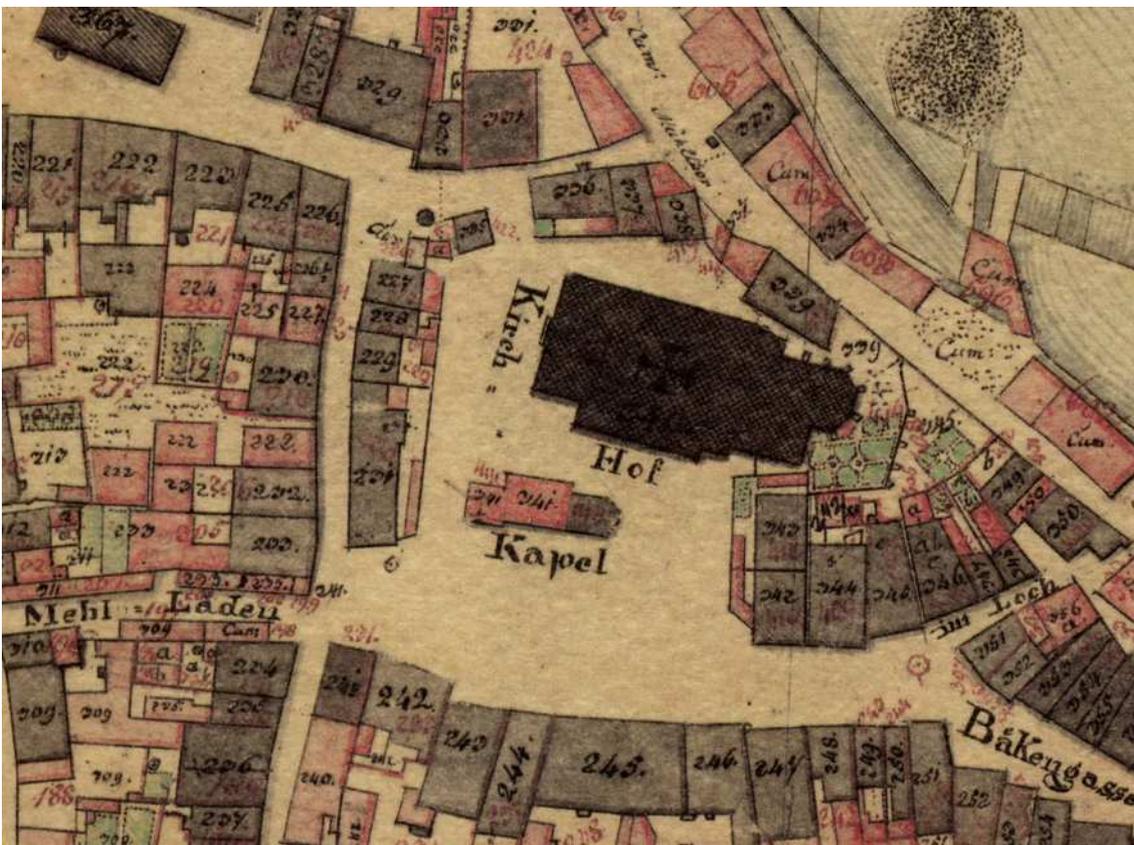


Fig. 2 – St. Mang Square on the kataster of 1823. Former chapel of St. Michael lies to the south of the gothic church (Copyright: Stadt Kempten).

Findings and Features

In 2003 first excavations took place and the expected architectural findings were made, which were interpreted as the wall footings of the Chapel of St. Michael, which had been deconstructed in 1857. In 2008 emergency excavations took place, when it was decided to go deeper with the building measures as it was primary planned. These excavations brought to light the already expected basement beneath, which had still

been in an extraordinary good condition. It belonged to the charnel house of St. Michael and later became the oratory of St. Erasmus – the basement of a big two-storied graveyard chapel. Aside, 476 burials were excavated but no other archaeological feature, neither from Late Antiquity nor from Modern Age, was found due to continuously grave diggings for centuries and a soil composed of brash in which the excavators weren't able to even record the grave-pits.

Public Presentation

After the digging, an active discussion arose among citizens, magistrate, city council, administration and involved archaeologists, whether to conserve the features and present the findings. At last it was agreed to explore chapel and cemetery scientifically and present the results and findings in an installed underground showroom, making use of the architectural remains of St. Erasmus. For this purpose, an architectural solution was found to make the building accessible without destroying the mediaeval structures (Fig. 3).



Fig. 3 – Underground Showroom beneath the St. Mang Square (Copyright: Stadt Kempten).

Methodology

Interdisciplinary Approach

Now it is time to discuss the methodology and the scientific approach, which is an interdisciplinary one. In the field of modern urban medieval archaeology this is necessary, because it is described as an “historical science with physical resources and characterised by a wide spectrum of methods” (e.g. SCHOLKMANN 1998). The exploration of the St. Mang square is based on the cooperation of archaeology, anthropology and architectural history, but it includes geology, natural sciences, used for the radiocarbon dating and historical sciences, needed for the analysis of written relics and historical drawings as well (Fig. 4). The aim lies in the

reconstruction of the squares history. This includes material aspects as a first step, like the building phases of the chapel, the chronology of the ceramic findings, the sepulture phases, the probability of a relocation of the river bed and the analyses of the human remains. In the end it should be possible to partly understand what happened on the square in the last 2000 years. But the central churchyard in the middle of a city has always been more than just a place to bury the dead. It was public space, location for jurisdiction, place to seek sanctuary, meeting place or place for assembly and sometimes even the location of public festivals, dances and other activities that weren't approved by the church itself. This role was completely or partly changing due to the reformation in the 16th century. A change that ought to manifest itself in the archaeological resources as well. In other words, complex changes and developments may be read out of the physical remains if interpreted correctly. In the end it should be possible to reconstruct parts of the city's history including immaterial aspects by examining the development of the St. Mang square. More specifically, the archaeological contribution to the whole project focuses on two main objects: the burials on one hand and the chapel on the other hand.

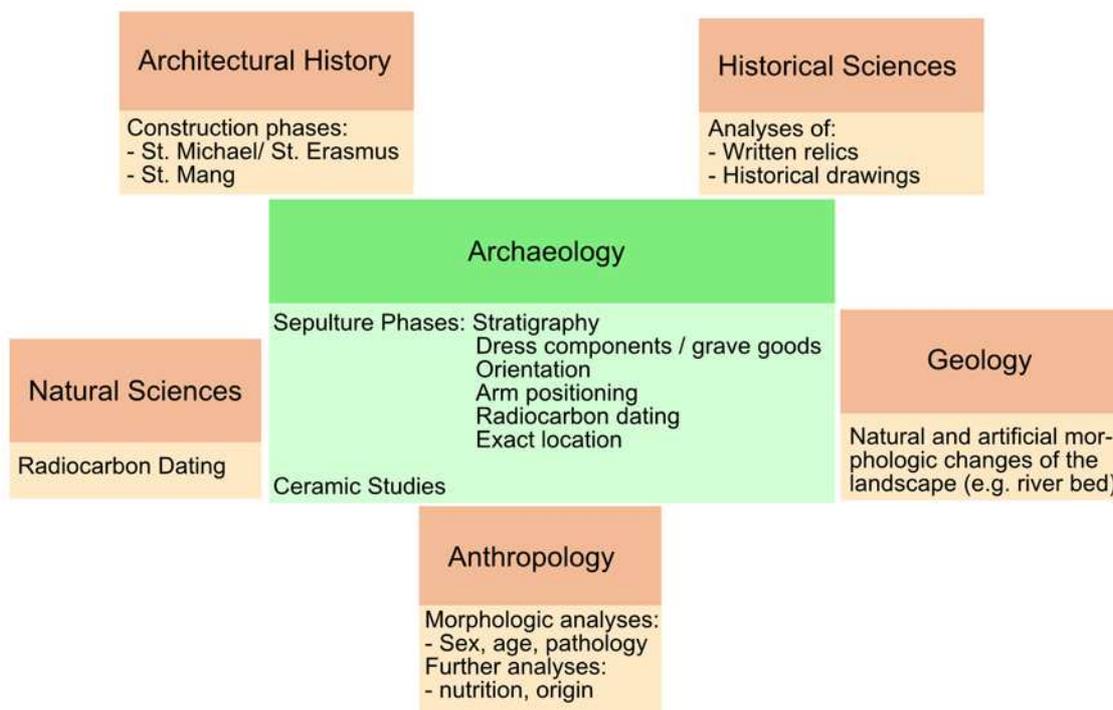


Fig. 4 – Interdisciplinary approach: archaeological research situated between its neighbouring disciplines.

Sepulture Phases

Part of the archaeological input is the definition of sepulture-phases on the cemetery. These phases will be defined by analysing six indications: the stratigraphy, dress components or grave goods, orientation, positioning of arms and hands in the grave, radiocarbon dates and the location on the churchyard (Fig. 5). For 97 graves, the excavators could make stratigraphical observations which are of value and form the base of a Harris Matrix. Datable artefacts were found in 97 (other) burials, including elder material like roman coins and ceramics, which came out of grave infillings, dress components like small bronze clasps and purposely deposited rosary rings. The third point of archaeological interest lies in the exact orientation of the graves,

their deviation from the west-east axis which may have a chronological reason among others. The position of arms and hands in the grave can vary between clasped on the lap, on the belly or the chest, collateral to the body or a mixed form with one hand on the lap and the other enfolding the forearm. The ongoing research points to a significant correlation of arm positioning and orientation, which can be interpreted as a chronological order (Fig. 5). The found correlations are to be verified by radiocarbon dated graves of which seven have already been dated and 18 more will be dated in 2011, and by the analyses of the dress components. The last indication will be the area within a grave is located.

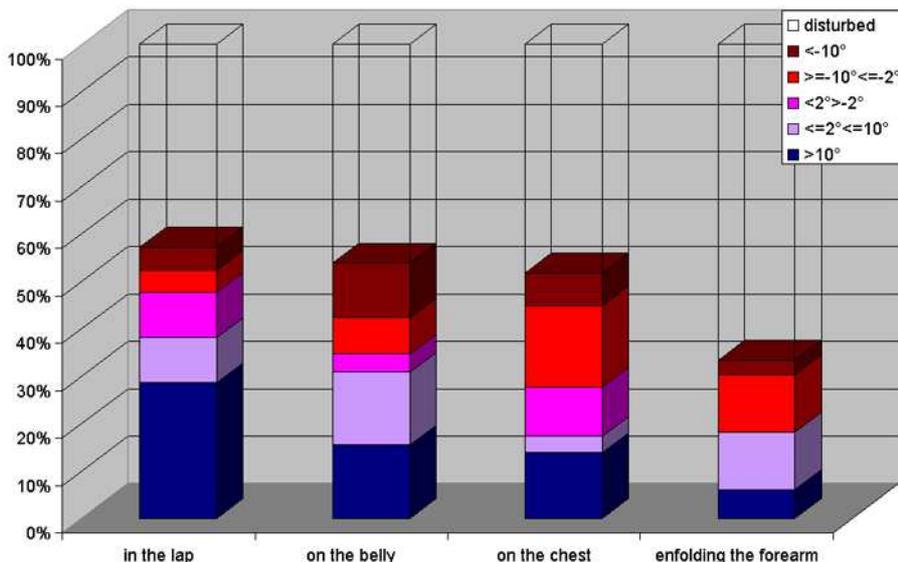


Fig. 5 – Correlation between orientation and arm positioning in the graveyard. The colours refer to the degree value, which displays the deviation from the west-east axis, e.g. “>10°” corresponds with an orientation in southwest-northeast axis.

The so defined sepulture-phases are not an end unto themselves, but are thought to provide the modern anthropologic research with chronological data, in order to find out more about the citizens of Kempten, their origin, their lives, deceases and deaths, in the course of the Middle Ages. As the cemetery was abandoned in 1535, the burials range from the 7th to the 16th century, which covers the whole Middle Ages.

Probably it will be possible to parallelize these sepulture-phases with the reconstruction-phases of the chapel. The remains of St. Erasmus were analysed by the Architectural Historian Azer Araslı, who distinguished six main phases beginning with the first Romanesque building, which was constructed in the 13th /14th century (Fig. 10).

Ceramic Research

As a by-product the ongoing research will give a contribution to the early modern ceramic typology of the region especially to the chronology of vessels of the Late Middle Ages and Renaissance.

Brief Historical Overview and preliminary results

Antiquity and Late Antiquity

Kempten was founded as Cambodunum 15 BC on a hill position on the eastern riverbank of the river Iller. Soon the city prospered and became one of the most important cities in the Roman Province of *Raetia*. The

city flourished especially in the 1st and 2nd century AD (Fig. 6). The area of the St. Mang square wasn't populated to that time, just some broken fragments of ceramic and one fibula from the 1st century were found during the excavations.



Fig. 6 – Cambodunum/Cambidano in antiquity. Left: 1st/2nd century, right: 5th century (copyright R. Mayrock, Kempten).

In Late Antiquity the city's position was abandoned, and a more secure and better to defend place to settle was found below the hill Burghalde, on which a Roman military unit had its base and new city walls had been constructed.

The excavations on the St. Mang square revealed clear evidence of settlement in Late Antiquity. Due to the fact that the place was used as a cemetery for centuries, no clear features from that period could be recorded but a significant amount of 16 coins from that time proof this assumption. It was then, in the 4th century, that this place was part of the city for the very first time and since then continuously populated.

Early Middle Ages

Not much is known about early medieval times in Kempten. The vita of St. Magnus, written 150 years after the Saint's death, tells us that the Saint built a small oratory, an *oraculum paruulum* and a first small *cella* in Kempten in the 8th century. The city is described as ruinous and abandoned but this is of course a typical and topical part of a Saint's vita. Magnus left his companion Theodor behind to build a church *super litus hilare* which was consecrated by the Bishop of Augsburg, Wikterp.

Indeed we do know for sure that Kempten was a lively place to that time. On the raised western shoreline of the river existed a small settlement since the 7th century, with a Christian cemetery and a church (KATA and WEBER 2006). It was probably here, that Audegar founded the abbey of Kempten in 752, according to the chronicle of Hermannus Contractus of the 11th century, and so perhaps renewed what Magnus and Theodor had begun before. The abbey was, from then on, part of the Carolingian Policy and was greatly supported and endowed by Charles the Great himself and his wife Hildegard. It became part of a whole network of abbeys together with Benediktbeuren, Füssen, Thierhaupten, Ottobeuren and others and played a crucial role in running the country and the whole region for the Carolingian domination. Later it became a *Reichsabtei*, was immediate and had its own territory.



Fig. 7 – Reconstruction of the Romanesque church, constructed in the late 11th century (copyright R. Mayrock, Kempten).

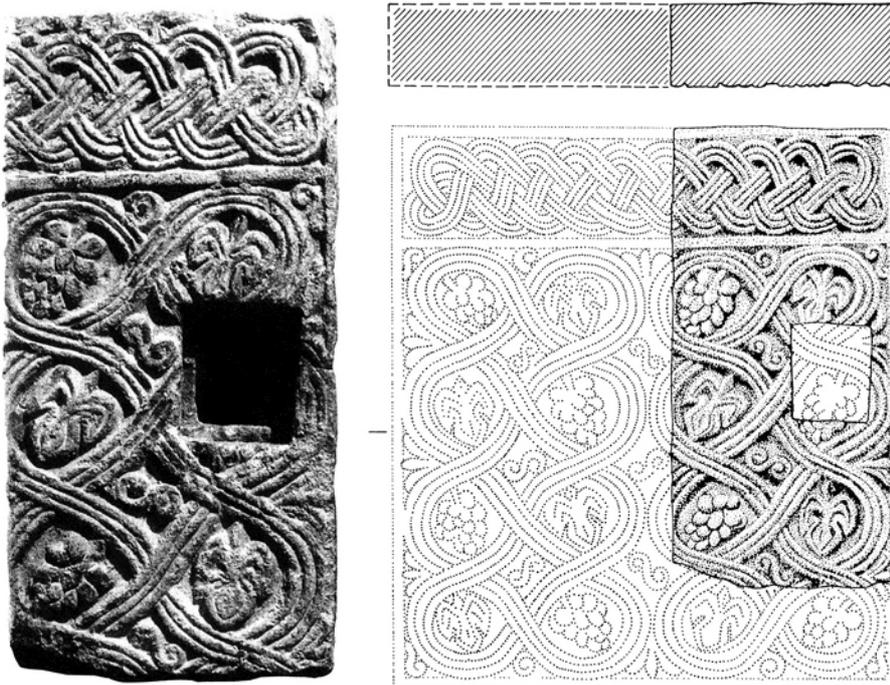


Fig. 8 – Part of the choir screen of the Carolingian abbey founded in the last decades of the 8th century. Later used as reliquary and moved to the church of St. Mang (KATA and WEBER 2006, Fig. 6).

As the oldest radiocarbon dated grave on the St. Mang square dates back to the 7th century, it seems tempting to renew the old theory, that this has been the place for its foundation. As the square was used as a cemetery, one can imagine that there has already been a church, even if we don't have any archaeological evidence until now. Probably there are no remains left, due to the construction of the Romanesque Church in the 11th century (Fig. 7). As a matter of fact, we are now able to reconstruct a complete sacral topography of

early medieval Kempten for the first time. But there is no historical evidence for a relocation, so it stays probable that the first cloister has been constructed on the western shore of the river Iller. This is supported by the fact, that the Iller has always been the border between the two dioceses Augsburg to the east, and Konstanz to the west of the river, with the abbey belonging to the diocese of Konstanz. Here it stood until its secularisation in the 19th century. From the minster of the Carolingian abbey, a small part of the choir screen survived which dates back to the last decades of the 8th century and which is typical for the important monastic centres in the Carolingian empire (JOHANNSSON-MEERY 1993). Later, after it loosed its function, a hollow was cut in for the placement of a capsule and the fragment was used as a reliquary. In the end it became the substruction of the altar in the gothic church of St. Mang in late medieval times, where it was excavated in the 19th century. The St. Mang church on the other hand belonged to the diocese of Augsburg. In our days the church is located on the western shore of the river as well, but it is for sure that the river bed changed and the old one was filled up around 1300, which implies that the St. Mang church has originally been located on the eastern shore of the river in the Early Middle Ages (KIRCHBERGER 2002). We don't know anything about the site of the first small *cella* of St. Magnus.

High Middle Ages

The settlement just outside the cloister had grown and round about 1100 AD a new and bigger church was needed and built on the St. Mang square – the first church of which we have archaeological evidence. The remains have already been found in 1894 and could be confirmed in 2007. It has been a Romanesque three-nave basilica with three apses and steeple, an expression of the rising self-confidence of the settlement (Fig. 7). The first time that the city itself appears in writings, is the year 1289 when it finally gained autonomy from the abbey. Afterwards, there has been a continuous conflict between city and cloister which culminated in mutual destruction during the Thirty Years War.

The Charnel House

As the settlement grew – so did the cemetery. And in the 13th or 14th century a charnel house with a bone house in the basement and an oratory dedicated to St. Michael above was constructed (Fig. 9).

Some times later, approximately still in the 14th century, a fire destroyed the chapel and a big part of it had to be rebuilt. The human remains were removed and it got an oratory in the basement, dedicated to St. Erasmus and a chapel above, still dedicated to St. Michael.

In the next construction phase, which took place in the end of the 14th or the beginning of the 15th century, St. Michael got an polygonal choir of which the foundation was still visible during the excavation. After the building was extended 5 m to the west in the 15th century (Fig. 10), it gained a final shape, which was still to be seen in Renaissance, when the Reformation changed the St. Mang square for ever.

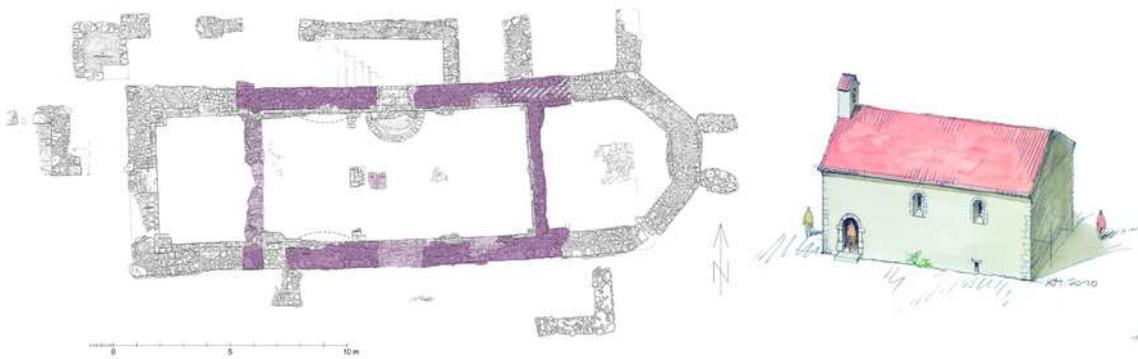


Fig. 9 – St. Michael with charnel house. First construction phase highlighted in purple (A. Araslı). At the right: graphical reconstruction (R. Mayrock).

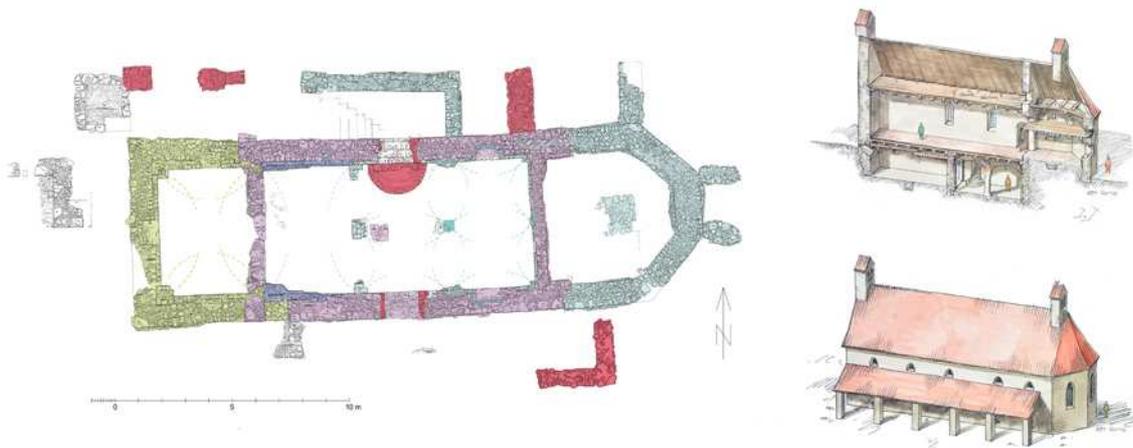


Fig. 10 – Former charnel house. Changes due to the secularisation highlighted in red. Blue: third construction phase, green, fourth construction phase. (A. Araslı). On the right: reconstruction of the 5th construction phase (R. Mayrock).



Fig. 11 – the former chapel of St. Michael and St. Erasmus in the 19th century. Painting by Joseph Buck before the final deconstruction in 1857 (Kulturamt Kempten).

The two storied graveyard chapel got secularised and was profaned in the 16th century when the city became protestant. It was used for public quality inspection of linen cloth and as a wine tavern for members of the magistrate. The graveyard was shut down and the square turned into a market place.

In the 17th century the former chapel of St. Michael got an annex, an outbuilding in which another public quality inspection took place – the inspection of grease.

Finally, the building was deconstructed in the year 1857. The local historian Joseph Buck had the chance to document the meanwhile shabby looking construction by his paintings (Fig. 11). The first floor was destroyed and the basement filled with construction waste and after that nearly forgotten.

Presentation in Public Space

It was soon clear that the remains of the original building, the basement of the two storied chapel, former bone house, then dedicated to St. Erasmus, was to be conserved and presented to an interested public. The room itself is an authentic place, in which a lot of information on architectural history is highlighted and can now be explored by the visitors. Therefore, an adequate space was provided to present some facts about the chapel, the square, and Kempten in the Middle Ages in general. It is a mostly calm room with a very quiet ambiance and a dignified atmosphere where the visitor can get in touch with history.



Fig. 12 – Deposition and presentation of human remains in the former bone house of St. Michael (Foto: Kulturamt Kempten).

The main discussion point was to decide what to do with the human remains. At last it was decided to store them partly inside of the building (Fig. 12), thus giving it three functions:

1. as a burial place. The bones are stored or deposited inside the former chapel and bone house. So today's St. Erasmus connects itself with its own historical roots, again being the last resting-place for the ancestors of today's citizens. This is an important point for the inhabitants, for today's community, and there has actually taken place an ecumenical religious ceremony.

2. as a scientific deposit, belonging to the Bavarian State Collection for Anthropology and Palaeoanatomy in Munich. It is a kind of outpost where it will be possible to gain more information and do more research in future, with the new methodology of coming generations.
3. and as a museum with the task to educate, inform and entertain the visitors to the show room.

To fulfil these tasks, a modern multimedia presentation has been installed with beamers projecting the square's history onto the walls of the former bone house.

In my opinion its an important task of modern archaeology not only to explore, conserve and document for scientific reasons but also to fulfil the legitimate interests of the public. And these are: conservation and documentation but also education of today's citizens, creation of identity or identification with the city and its history, and the generation of attractiveness of an archaeological site in the field of tourism or *histotainment*. In October 2010 nearly 3000 visitors could be attracted to the former bone house amidst of the city. Kempten now has a renewed square but also a new point of interest, where its citizens can learn more about their history and tourists are attracted to.

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SESSIONS

Gone Digital – Digital Applications in Cultural Heritage Research with no Analogue Alternatives

Architecture with concave and convex rhythms and its decoration in Hadrian age: the south pavilion of Piazza d'Oro in Hadrian's Villa

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Abstract: Purpose: Some buildings in Hadrian's Villa, as the Maritime Theatre and Piazza d'Oro, show trabeation with a characteristic curvilinear shape decorated with figured friezes. The dispersal of most of the decoration of Hadrian's Villa in public and private collections involves difficulties in replacing the friezes in each building.

As already known, the architectural decoration of the southern pavilion of Piazza d'Oro, subjected to anastylosis operations in the sixties, had been soon removed, because considered a wrong solution. Also in the Maritime Theatre several figured friezes have been wrong replaced inside the building, as already stated by recent studies.

A new integrated approach applied to the study of the curvilinear shape friezes, belonging to the Maritime Theatre (ADEMBRI, DI TONDO, FANTINI 2009), allowed to make new reliable assumptions about the replacement of the architectural decoration (Adembri, Di Tondo, Fantini, Granada 2010, soon to appear; Adembri, exhibition catalogue of the last exhibition in Hadrian's Villa, 2010); however, the state of conservation of the masonry does not provide enough evidence for the reconstruction of the original aspect of this building.

Piazza d'Oro, which shows an architectural decoration very close to the Maritime Theatre, could be a meaningful comparison to a better understanding of the design solutions adopted in Hadrian's buildings with curvilinear shape.

Figured friezes from Piazza d'Oro, preserved in the Villa and in other Italian and European collections, are the key elements for solving the problem of how the curvilinear marble elements were assembled.

Keywords: Architecture, Architectural Decoration, Reconstruction, Hadrian's Villa.

Introduction

The gratifying result achieved by virtually reallocating *in situ* a fragment of the curved marble architrave frieze from the Maritime Theatre (14 Workshop Vienna 2009, showed also in the exhibition "Villa Adriana. Una storia mai finita", Villa Adriana, Antiquarium of the Canopus, 2010, as explained in the catalogue) led us to carry on the research on this thematic area. We developed the investigation in two different ways: by a side we surveyed by means of laser scanner technology other pieces and fragments characterized by the same metrical and stylistic features identified during the first survey (see Fig. 1). The main aim, in this case, was to extend the digital database of the friezes, not just adding new files, but also improving representation quality, graphic standards and compression. By the other side we decided to broaden the scope of the research by

including Piazza d'Oro, the other building at Hadrian's Villa with bended friezes with the same *sea-thiasos* subject of the Maritime Theatre, as clearly confirmed by historical sources (both the buildings and their decorations were excavated and described first by Pirro Ligorio).

Another reason for including Piazza d'Oro was the better state of conservation of its elevations in comparison to the Maritime Theatre: chances are pretty good that this analysis can provide further useful information to the study of the ancient buildings characterized by convex to concave rhythms of the architectural decoration.



Fig. 1 – Digital survey operation related to the curvilinear frieze (TM_03) coming from Maritime Theatre and reused in the Rometta Fontain.

Previous studies

The most recent research on the Maritime Theatre, developed with the usage of different techniques (both 3D laser scanner and traditional archaeological investigation) was presented at Workshop 14 (ADEMBRI, DI TONDO, FANTINI 2009) by the authors of this paper and was focused on the development of a methodology able to take advantage of new survey technologies. The combined usage of reverse modelling techniques with entertainment software let us improve the level of knowledge of the famous figured bended architrave in Hadrian's dwelling. Friezes belonging to the Maritime Theatre, characterized by curvilinear shape, could be virtually replaced in the correct original location thanks to the combined analysis of different scale surveys. This approach is not new, because Hansen (HANSEN 1960) and Ueblacker (CAPRINO 1985: 62) already tried to carry out an anastylosis based on the architrave's features, but their results were affected by a lack of accuracy of the survey, done with traditional methods; probably there was also a reduced interest on the metric problem concerning each fragment. In more recent times many authors dealt with the topic of the

Piazza d'Oro's friezes (CONTI 1970, BONANNO 1975, MARI 1994, SIRANO 2000), giving once again prove of the relevance of those peculiar architectural decorations inside the design of the whole complex. Besides, is very well known that since the Renaissance scholars and architects found that Piazza d'Oro was of great interest because of its state of conservation and the richness of the decorated friezes, as evidenced by texts and drawings by Pirro Ligorio¹ and other authors.

Between the 1960 and 1970, Hansen and Conti made different hypothesis on the repositioning of bended architraves belonging to Piazza d'Oro, but only in 2000 has been published a systematic census of the friezes' fragments stored inside the Villa (SIRANO 2000).

Research aims

Despite the published erudite studies and the archival records, it can be asserted that all the reconstruction hypothesis of the Piazza d'Oro's architectural decoration are still uncompleted and unsatisfactory. The main problems are the attribution of a fragment to one or another of the two buildings characterized by maritime sea thiasos on bended architraves (Maritime Theatre or Piazza d'Oro) and, down in particular, the correct location inside those architectures: another difficulty in solving of this problem is that the great part of the friezes was altered in ancient times, during the spoliation of the Villa. And many of the stylistic features, which could provide useful information for our research, were erased when the freezes were disassembled and (horizontally and vertically) cut to let them fit in other contexts.

Up to now the lack of certainties about the right position of the architectural decoration, and especially the curved one, is confirmed by the disassembling of the anastylosis made during the sixties on the colonnade and architrave of the south pavilion of Piazza d'Oro.

That being stated, the opportunity to extend the research from the Maritime Theatre to this other complex appeared natural with the aim to provide a deepening of knowledge on both these two mixtilinear architectures.

Certainly, the usage of new survey technologies allowed us to get a new documentation and to make the cataloguing more systematic; so we thought that a digital 3D archive of all the fragments known, at least those preserved in the villa, was necessary to develop the research on Piazza d'Oro both at the level of friezes' details and of building's architecture. The purpose, as in the case of the Maritime Theatre, is to match the metric and formal characteristics of the disassembled fragments with the archaeological remains of the southern complex of Piazza d'Oro.

Another aim, obviously connected with the first, is the developing of a methodology able to determine the right place of the fragments at the time of Hadrian.

The last purpose is to share and disseminate the result of this research by means of virtual reconstructions and real-time applications, that could provide useful information and food for thought for other scholars.

¹ Pirro Ligorio, "Trattato delle Antichità di Tivoli et della Villa Hadriana fatto da Pyrrho Ligorio Patritio Napoletano et dedicato all'Ill.mo Cardinal di Ferrara", Cod. Barb. Lat 4849, ff. 17 v – 18 v.

Methodology

The first step of our research was the gathering of archival researches (HANSEN 1960, RAKOB 1967), so as the direct observation *in situ* of the extant architectural pieces of Piazza d'Oro, placed in the side rooms of the south pavilion.

Many authors provided surveys and reconstruction hypothesis (AURIGEMMA [1962] 1996; JACQUES et al. 2002) that we acquired for a comparison with the laser scanner survey done during the September 2010 campaign.

The survey concerning the architrave fragments has been carried out after having selected the pieces that could provide a greater quantity of morphological and metric information for the anastylosis: that is the elements which formed part of a corner, or a terminal part of the architrave, and also the pieces which show very clearly a change of profile (mixtilinear elements), and of course the bended pieces that can provide the curvature radius.

Moreover, the main object was the development of a methodology of cataloguing that could provide more suited information for anastylosis, because the existent file-cards by Italian Ministry of Culture do not include morphological data, which are of great importance for our research as, for example, the relief depth. Actually the survey of a considerable amount of friezes proved unambiguously that all the ones coming from Piazza d'Oro have a deeper relief than those from the Maritime Theatre, as already stated in literature. And of course this kind of information should be included inside a database as one of the relevant elements for the identification of the place which the friezes come from.

In our proposal of a new file-card cataloguing, it should be added also the three main orthographic views of the optimized mesh from laser scanner survey, the measurement of the main architectural decoration features and, if extant, the angles and the bend radius, with the indication of the place where the cutting plane was set, using an axonometric view of each fragment (see Fig. 2; Fig. 3; Fig. 4).

The procedure we adopted makes an extensive use of reverse engineering applications that split the whole process of converting a 3D mesh in a mathematical model into various steps: after having aligned all the scans and merged them into a single manifold² model (with a correct topology and without holes) it is very important to perform a proper rototranslation of the mesh. This phase can be conceived as a second alignment of each model representing a frieze with the aim to let us use the coordinate planes (top, front, side) to identify the more suitable altitude for drawing a section. Once obtained the section, it is possible to use a planar geometric figure that best fits with the section which, in the case of the bended friezes, will be a circle: different radiuses allow us to guess different location inside the architecture remains. Between the aims we mentioned very important in our opinion is the multiple usage of the friezes models, that is a very simple and immediate management by scholars of various fields. At the same time we consider more proper a methodology able to take advantage of normal and colour map applied by means of Image Based Data Processing techniques based on low-poly parameterized polygonal mesh.

The methodological approach, described above, was also applied to architectural 3D digital models.

The complete point cloud, obtained by registration of all scans, can be used for metric investigations wherever necessary for research purposes. The surveys let us identify the arcs of the walls with concave-

² We refer to three digital models represented by a surface 2-manifold closed or bordered.

convex entablature and quantify the bending radius of each extant frieze fragment. According with the measurement operations performed on these fragments, the bend radius was taken considering the projection of the architrave fillet to the ground.

All metric tests were developed on two-dimensional schemes (plan elevation and section), starting from the point cloud model.

If the point cloud model is an excellent tool for the research, however, it is less suitable for data sharing and scientific results dissemination. Suitable tools and procedures (meshing) convert the three-dimensional point cloud model into a model represented by a tessellation of the boundary surface (mesh), which is managed in the most common 3D computer graphic applications; this allow the data sharing and the development of graphics suitable for dissemination.

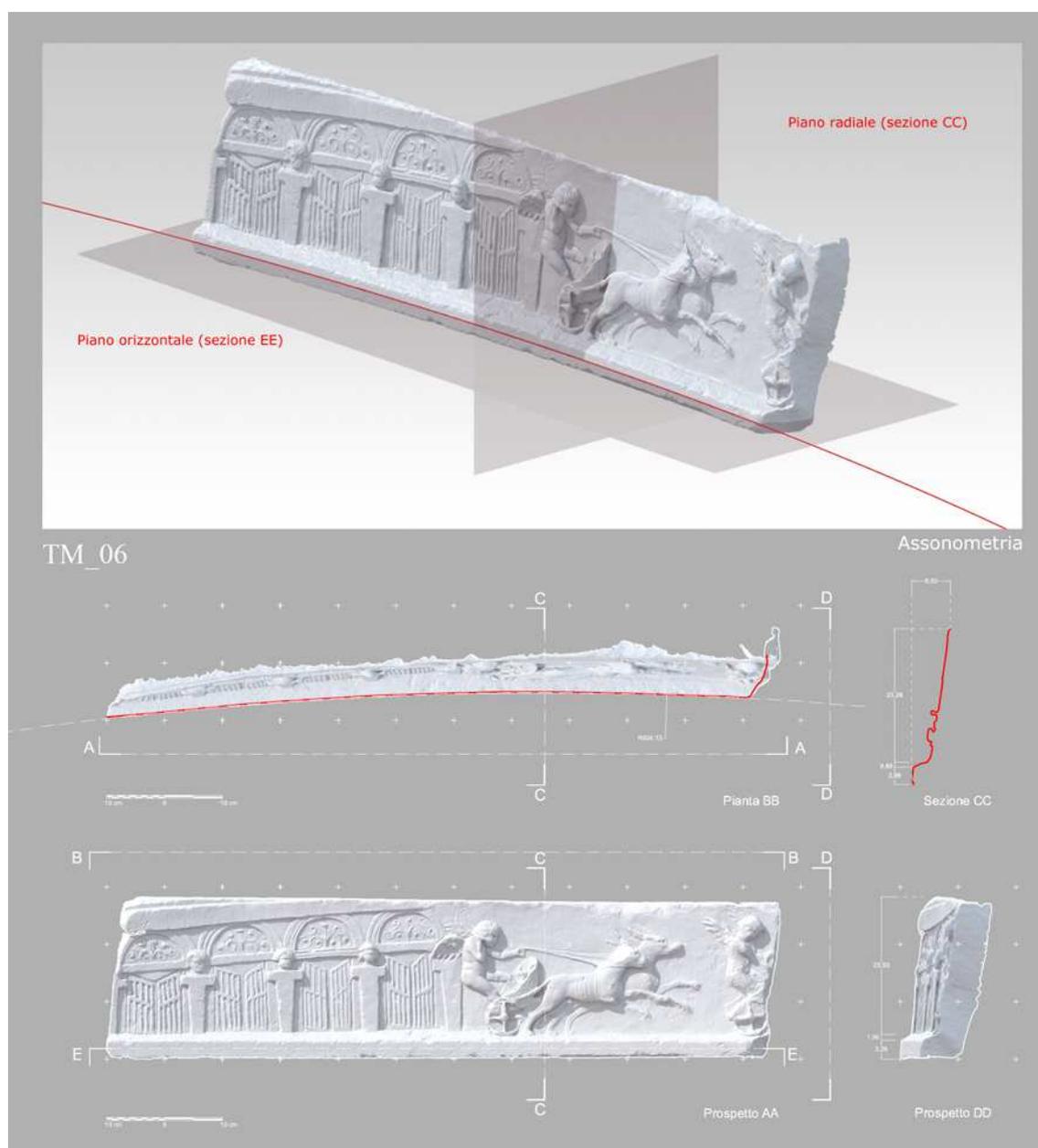


Fig. 2 – Our proposal of new file-card cataloguing, which should be added to the existent file-cards developed by Italian Ministry of Culture.

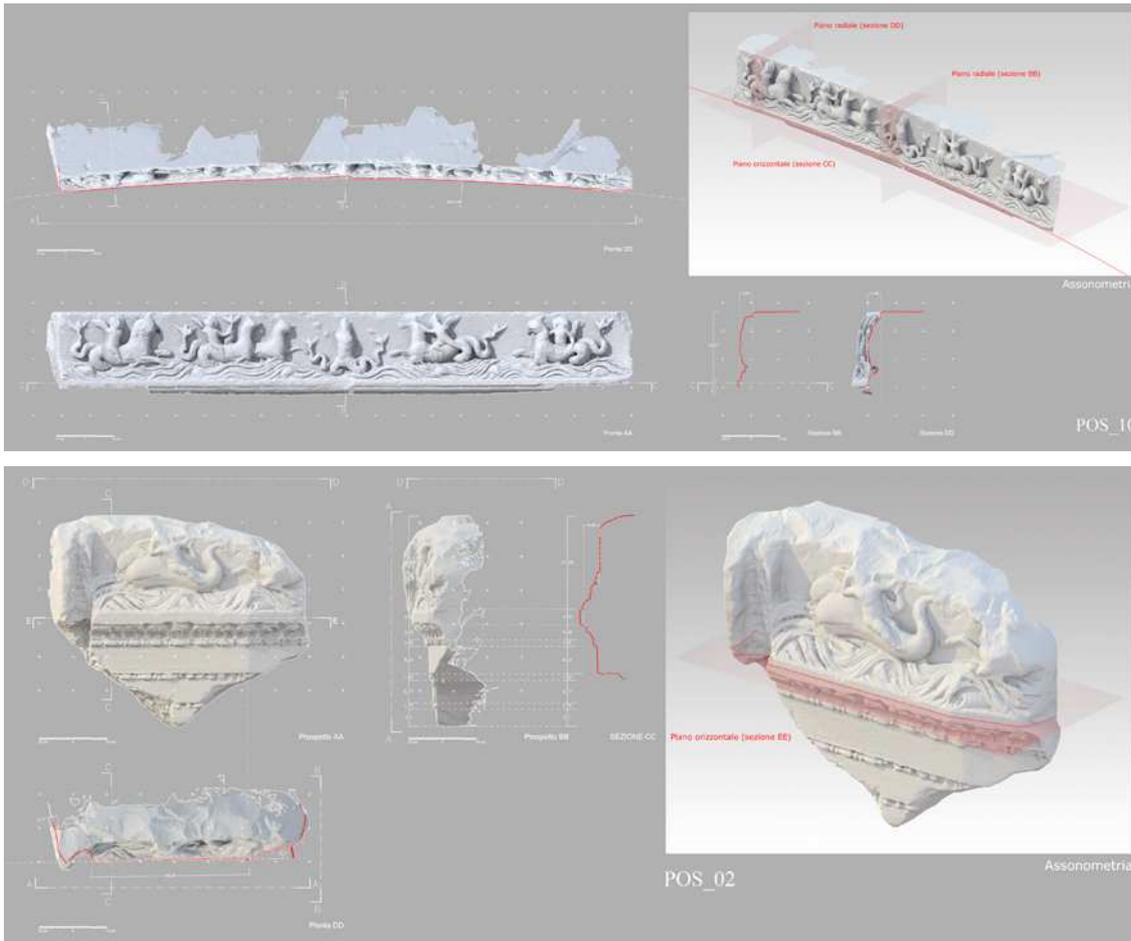


Fig. 3/4 – Our proposal of new file-card cataloguing, which should be added to the existent file-cards developed by Italian Ministry of Culture.

Results

In the last exhibition held at Hadrian's Villa³ a number of pieces, originally located in the famous dwelling of the Emperor, were brought back to the Villa and put inside the Canopus Antiquarium; between them a fragment of concave frieze preserved at the British Museum, from private collection and originally belonging to the Maritime Theatre, with the theme of chariot driven by *erotes*. During the preparatory phases of the exhibition it was possible to scan this piece, by permission of the British Museum, and other two friezes, both removed from the famous Pirro Ligorio's *Fontana della Rometta* at Villa d'Este in Tivoli, one originally belonging to the Maritime Theatre, the other to Piazza d'Oro. The state of conservation of these architraves is quite bad because they were placed in the fountain and consequently they were negatively affected for this non proper location.

A little at a time, ongoing research is trying to solve the problem of the dispersal of the friezes from the Maritime Theatre and Piazza d'Oro and put in order and consider what has already been written by scholars, trying to rectify and integrate the specific literature. Although the differences between the two buildings, the Maritime Theatre and the Piazza d'Oro have points in common that can be understood by an integrated and

³ "Villa Adriana. Una storia mai finita" from April the 1st to November the 1st 2010 (see SAPELLI 2010).

interdisciplinary research. Good results in terms of documentation and cataloguing by means of new survey techniques were achieved: many elements of the architectural decoration belonging to the two complexes were identified in more probable original location. The perfect match between the measures of these elements and the measures of the extant walls or basement proves that our proposal is correct if compared to the previous assumptions, that often led also to incorrect anastylosis (as in the Maritime Theatre or Piazza d'Oro, then removed). We found that these two paradigmatic architectures of the Villa have lots of common features and solutions that scholars ignored and undervalued.

On the other hand, this new approach to the research let us consider new chances of cataloguing and recording the data and of disseminating the results to the scientific community without losing any detail: from the organization of the file-cards (going beyond the Ministry format) to the usage of 3D real-time application for interactive evaluation of morphological and metric aspects of each piece.

In the followings points are briefly explained the results concerning some case studies.

The identification code of each frieze is based on the following criteria:

TM: Maritime Theatre; **PO:** Piazza d'Oro; **S:** South Pavilion of Piazza d'Oro; **E:** East Pavilion of Piazza d'Oro.

The room numbering follows the one adopted in GUIDOBALDI 1994.

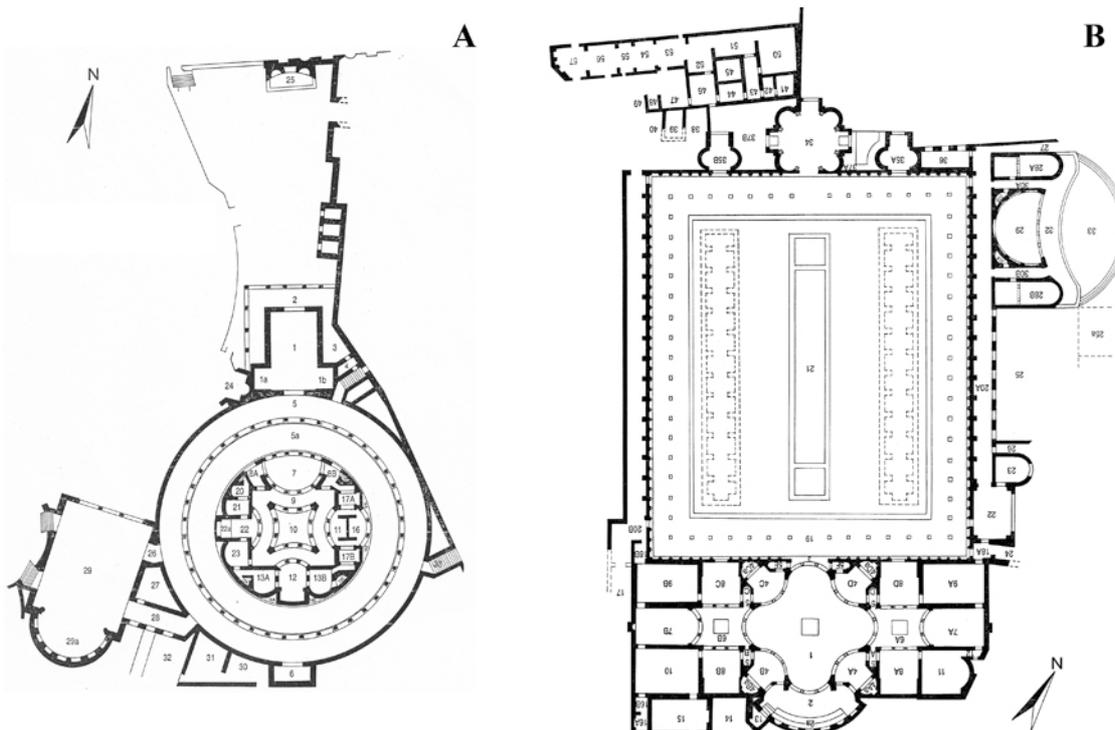


Fig. 5 – A: Plan of Maritime Theatre (GUIDOBALDI 1994); B: Plan of Piazza d'Oro (GUIDOBALDI 1994).

Frieze	Location	Figured cycles	Architrave	Other side	Curvature	Bend Radius (cm)	Replacing Hypothesis
TM_01 (Fig. 8)	Hadrian's Villa Canopus Antiquarium (inv. 114770)	SEA THIASOS (final)	-	Turned into a slab during the modern era.	concave	458	Maritime Theatre Island Vestibule (Room 7 south side)
TM_02 (Fig. 8)	Hadrian's Villa Triboletti Museum (inv. 114768)	SEA THIASOS	-	Turned into a slab during the modern era.	convex	498	Maritime Theatre Island Vestibule or Tablinum Porch (Room 7 south side / Room 12 north side)
TM_03 (Fig. 8)	Hadrian's Villa Canopus Antiquarium	CHARIOT RACE (reused in the Rometta Fountain, Villa d'Este)	-	Turned into a slab during the modern era.	concave	713	Maritime Theatre North-South Ambulatory of the Island (Room 10 north side / Room 10 south side)
TM_04 (Fig. 6)	Hadrian's Villa Maritime Theatre Island Vestibule	SEA THIASOS	Tripartite smooth; smooth <i>Kyma</i>	Chariot race	Convex	the small size of the fragment does not allow to fix the bend radius	-
TM_05 (Fig. 6)	Hadrian's Villa Maritime Theatre Island Vestibule	SEA THIASOS	Tripartite smooth; smooth <i>Kyma</i>	Sea Thiasos	convex	430	Maritime Theatre (Room 11/ Room 22)
TM_06 (Fig. 2)	British Museum	CHARIOT RACE	-	Turned into a slab during the modern era.	concave	631	Maritime Theatre East-West Ambulatory of the Island (Room 10 East side/ Room 10 West side)
POS_01 (Fig. 8)	Hadrian's Villa Triboletti Museum	SEA THIASOS	-	Turned into a slab during the modern era.	convex	450	Piazza d'Oro South Pavilion Hall 6A/6B
POS_02 (Fig. 7)	Hadrian's Villa Canopus Antiquarium (deposit)	SEA THIASOS (final)	Tripartite and marked by perle and astragali; <i>Kyma</i> lesbio	-	straight oblique fold (angle dimension 15,7°)	The length of the bending is too small to fix the possible curvature	Piazza d'Oro South Pavilion Fountain 4D
POS_03 (Fig. 4)	Hadrian's Villa Piazza d'Oro (deposit)	SEA THIASOS	Tripartite and marked by perle and astragali; <i>Kyma</i> lesbio	smooth	concave	361	Piazza d'Oro South Pavilion Fountain 4A/4B/4C/4D
POS_10 (Fig. 3)	Hadrian's Villa Canopus Antiquarium	SEA THIASOS (reused in the Rometta Fountain)	-	Turned into a slab during the modern era.	concave	954 (complete length)	Piazza d'Oro South Pavilion Nymphaeum
POE_01 (Fig. 7)	Hadrian's Villa Canopus Antiquarium (deposit)	THIASOS SEA	Tripartite and marked by smooth torus; smooth <i>Kyma</i>	Straight with bumpy surface.	concave	1115	Piazza d'Oro East Nymphaeum facing Tempe's Valley

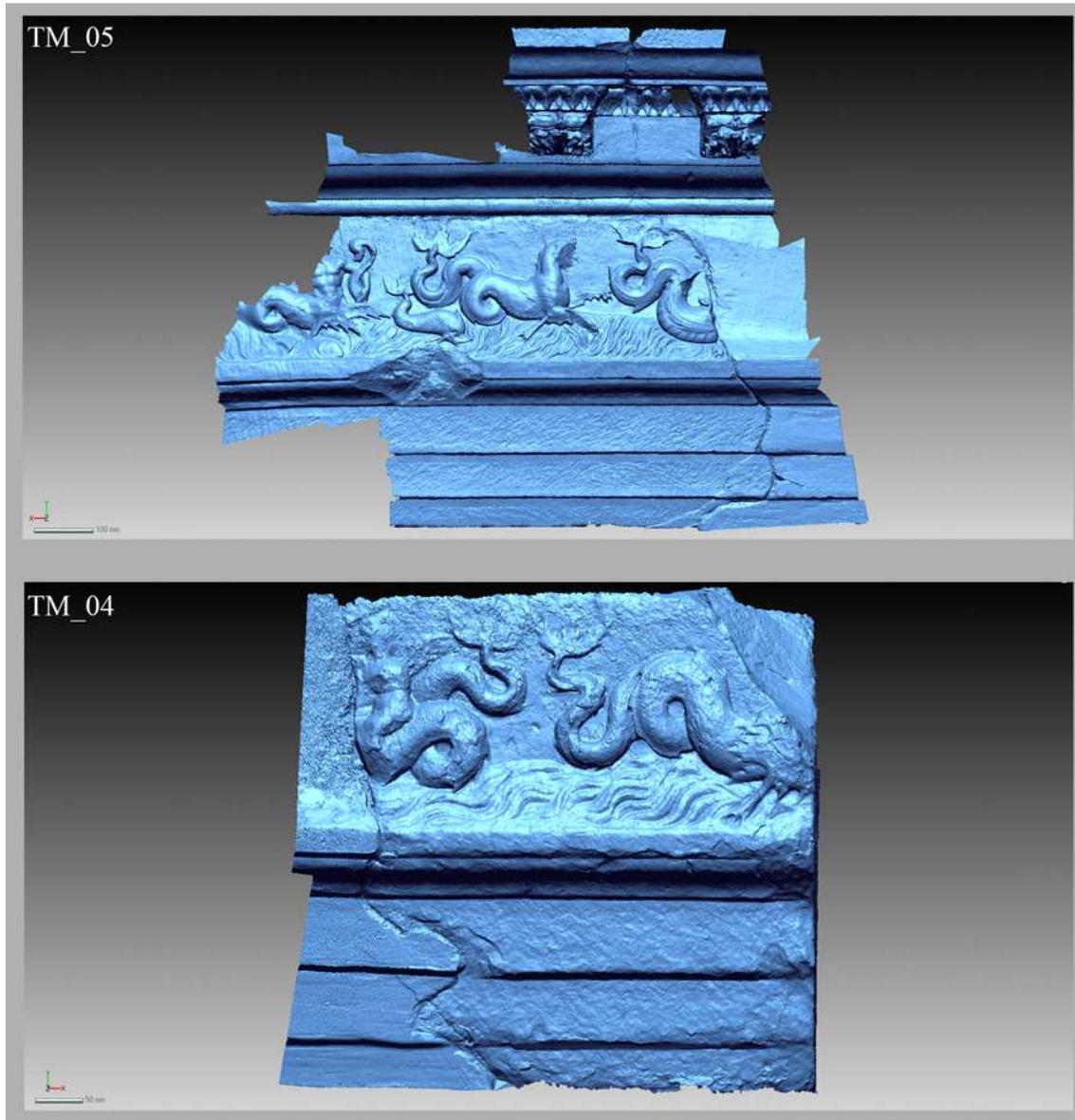


Fig. 6

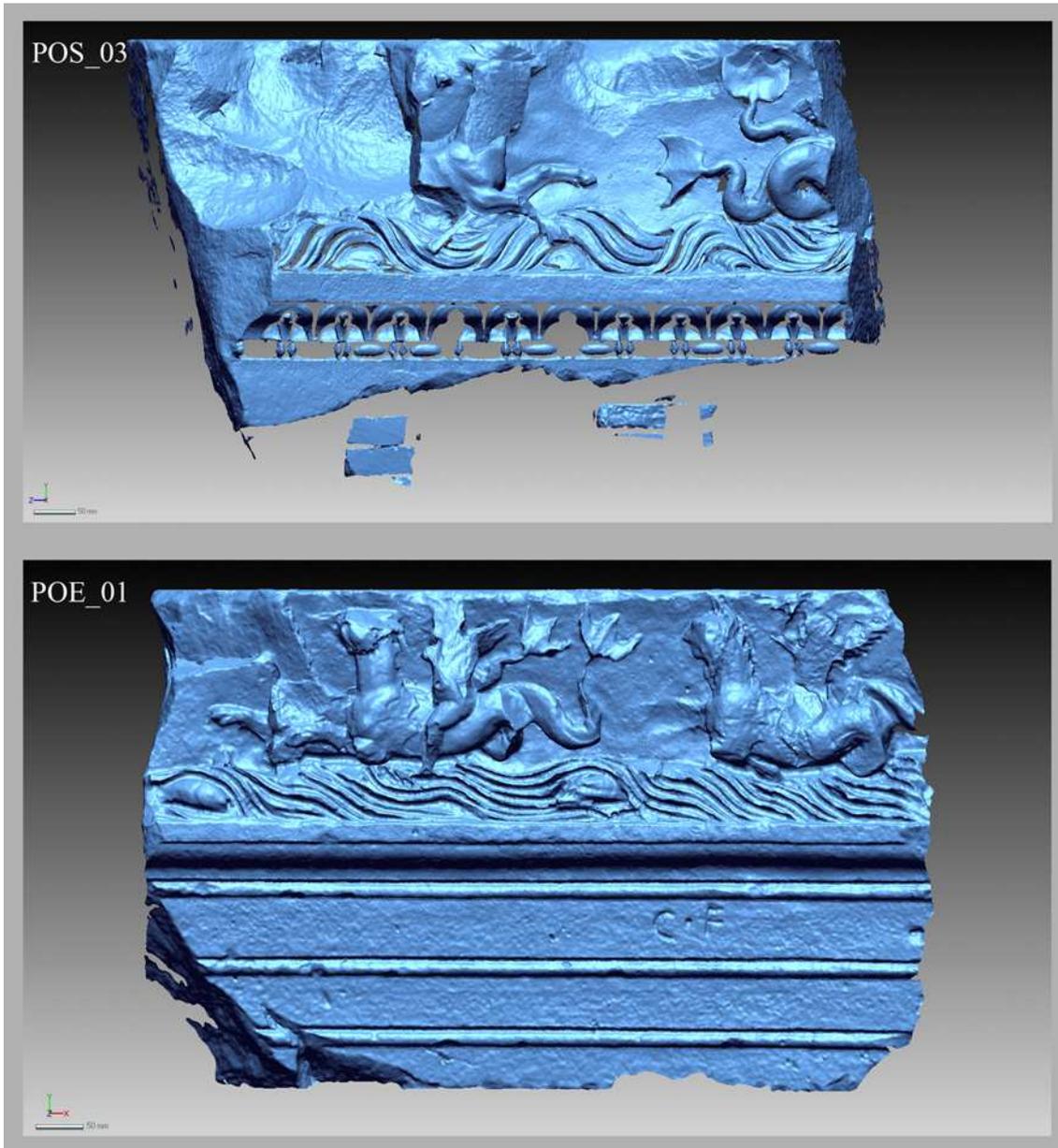


Fig. 7



Fig. 8

Maritime Theatre

Curvature	Bend Radius (cm)	Location
convex	1223	Room 7, north side
concave	1179	Room 7, north side
concave	457	Room 7, south side
convex	500	Room 7, south side
concave	705	Room 10 north side
convex	740	Room 10 north side
convex	752	Room 10 south side
concave	709	Room 10 south side
convex	500	Room 12 north side
concave	456	Room 12 north side
convex	615	Room 16
concave	570	Room 16
concave	386	Room 11
convex	430	Room 11
concave	636	Room 10 east side
convex	680	Room 10 east side
convex	678	Room 10 west side
concave	634	Room 10 west side
convex	429	Room 22
concave	386	Room 22

Piazza d'Oro

Curvature	Bend Radius (cm)	Location
concave	966	Room 2 (Ninphaeum)
convex	404	Room 1 South side
concave	353	Room 1 South side
convex	344	Room 1 SW side
concave	394	Room 1 SW side
concave	353	Room 1 West side
convex	401	Room 1 West side
convex	426	Room 1 NW side
concave	375	Room 1 NW side
concave	362	Room 1 North side
convex	413	Room 1 North side
convex	404	Room 1 NE side
concave	353	Room 1 NE side
concave	356	Room 1 East side
convex	406	Room 1 East side
convex	361	Room 1 SE side
concave	411	Room 1 SE side
concave	401	Room 7A
convex	456	Room 7A
concave	393	Room 7B
convex	450	Room 7B

POS_01

The relocation hypothesis of the friezes on the bended porch of Piazza d'Oro, based on the length of the bend radius measured by means of laser scanner, would be verified by analyzing the bend radiuses of the fragments decorated with hunting cycle, which were located on these porches during anastylosis operation in the '60 (based on the information provided by Hansen: CONTI 1970, 12 note 7), then removed.

POS_10 (see Fig. 3)

The measure of bend radius taken on the back wall of the south nymphaeum of Piazza d'Oro (965 cm) allowed us to replace there the frieze (Radius = 954 cm) coming from the Fountain of Rometta, and today stored inside the Antiquarium of the Canopus. So we can formulate some hypotheses about the original shape of the great fountain.

The small difference between the measurements shows that the frieze was attached directly to the wall of the nymphaeum; this is demonstrated by the recess in the wall (cm 35) and by the presence of a gap (cm 16) (accommodation for metal clamps?) at the same level of the frieze pattern, as we can see above the central niche of the nymphaeum (cfr. HANSEN 1960) (see Fig. 9; Fig.10).

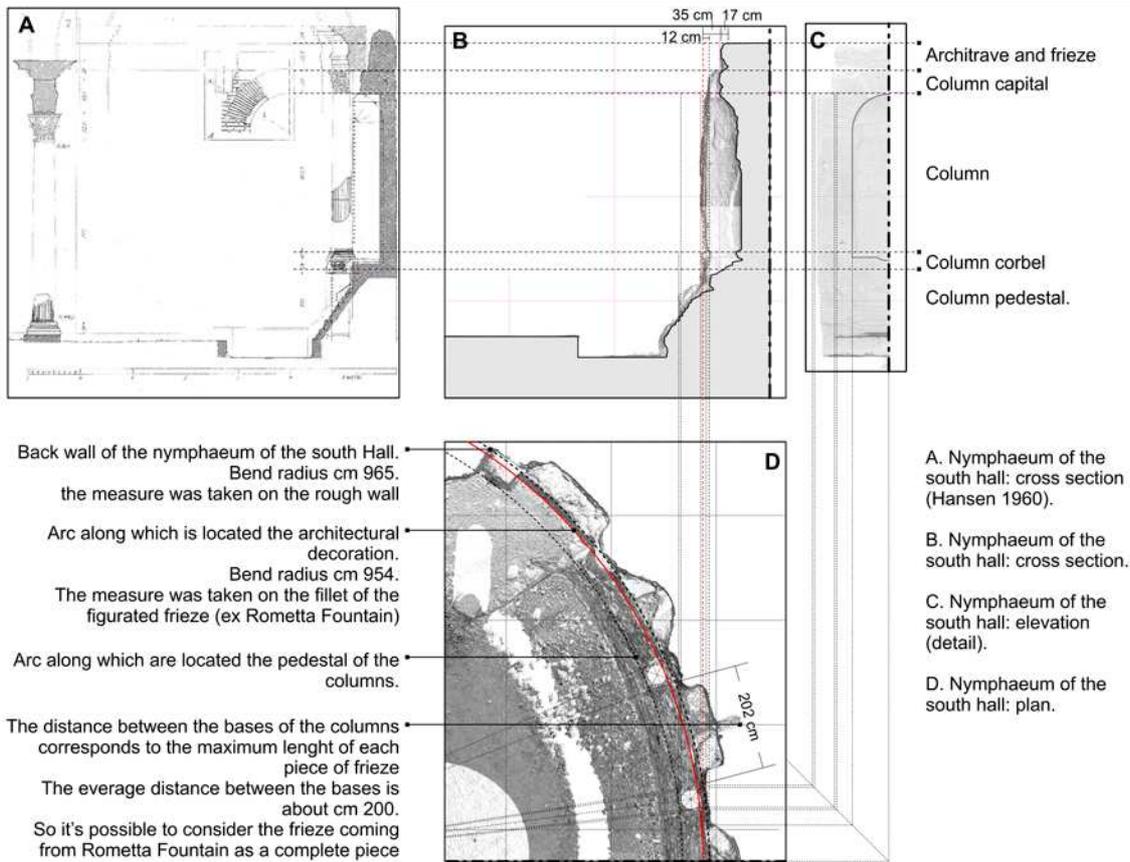


Fig. 9 – Some investigations about the nymphaeum of Piazza d'Oro South Pavilion using 3D digital point cloud model.

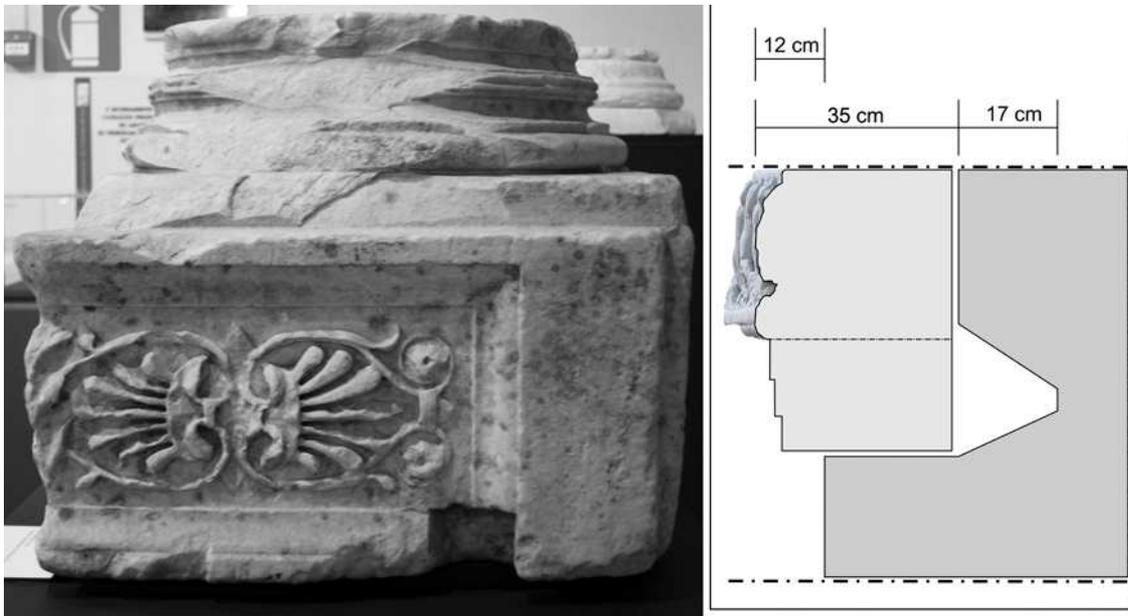


Fig. 10 – On the left, column corbel belong to the nymphaeum of Piazza d'Oro South Pavilion. On the right: a solution about the position of the marble frieze and architrave along the wall of the nymphaeum of South Pavilion.

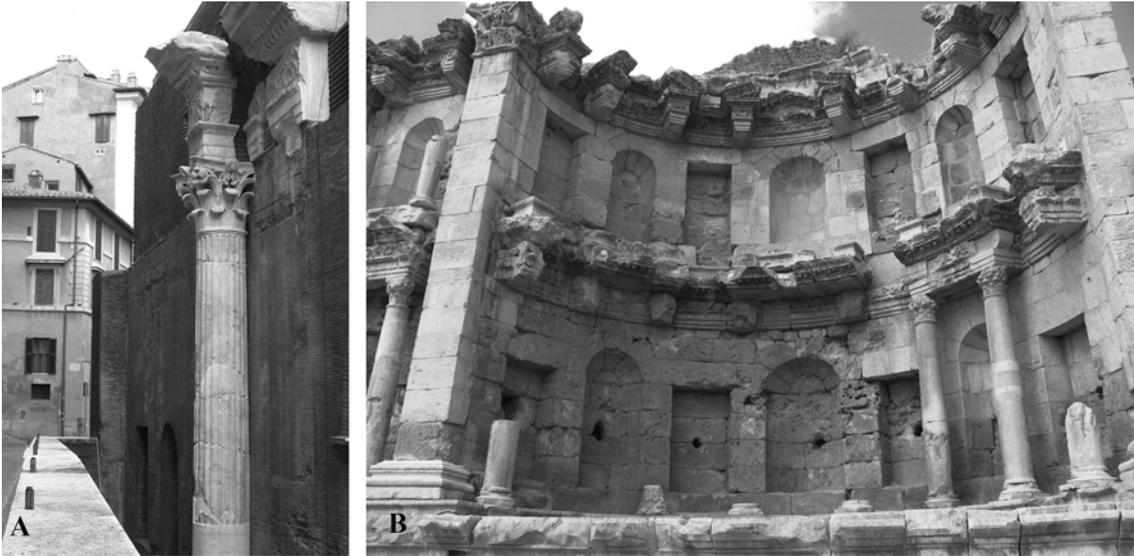


Fig. 11 – A: Neptune Basilica behind the Rotunda Pantheon in Rome. B: Nymphaeum of Jeras in Jourdain.

This hypothesis, compared with the floor plan of the nymphaeum, shows that the frieze pattern had a mixtilinear rhythm with maritime subject over the niches and the columns were in advanced position like in other examples in Hadrianic architecture, as the Neptune Basilica behind the Rotunda Pantheon in Rome or in the Nymphaeum of Jeras in Jourdain (see Fig. 11), both decorated with maritime subject; the columns were put on corbels, partially embedded in the back wall as well as the capitals: the lack of the masonry after spoliation demonstrates that this was the place of marble capitals (see Fig 10). Above each capital a die worked as a link of the sequence of niches and columns: it was equally decorated with maritime subject, a fluvial deity head, as we can see on a drawing attributed to Pirro Ligorio and preserved in the Royal Library at Windsor Castle⁴ (see Fig. 12); on the same drawing we can see that the tripartite architrave follows the scheme smooth torus and smooth Kyma. The entablature ended with a mixtilinear cornice.

The average linear distance between the corbels of the columns is about cm 200, that corresponds to the average length of each original element of the figured frieze applied to the wall; the frieze fragment coming from the Rometta Fountain is characterized by a cm 200 linear length, so we can state that the piece is not a fragment but a complete element in its longitudinal development.

The Nymphaeum in Jerash is very close to the south one of Piazza d'Oro, not only for mixtilinear architecture but also for other features and proportions, as the number of niches; so we can suppose that above the niches, as stated by Hansen (HANSEN 1960) and according to the reconstruction drawing of Pirro Ligorio, even if the hypothesis needs a careful verification of the extant stored architectural fragments, there were gables (see Fig. 12).

⁴ Pirro Ligorio, Windsor Castle, Royal Collection, A12, Vol 186 dal f. 10354 al f. 10504; f. 10377.

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Data integration technology in cultural research

Erik BOASSON / Wouter BOASSON

Abstract: A technique enabling the merging of separately edited databases with automatic conflict detection is proposed. This is based on the same principles as the 'Harris Matrix', used to depict stratigraphical structures. An important benefit of the proposed technology is that this will enable the use of multiple databases in large research projects, e.g., with multiple teams in the field and working with subcontractors. Additionally, it provides a foundation for integrating, and searching through, datasets sharing a core set of properties, organised in similar, but not identical ways. This will help in performing analyses on data from various data sources, such as data resulting from different excavation projects.

Keywords: multiple datasets, modelling, integration, analysis, collaboration.

Introduction

In archaeological research, a lot of data is being collected using various techniques, at multiple locations in the field as well as in the office or in a research lab. These data from various sources are often stored in the computer, in many different ways. However, they all describe part of the history of our world, and as such should often be combined to get a better understanding of our past.

Integrating data from multiple sources is an important but time consuming process, and part of almost every study, ranging from small-scale excavations, to large regional studies. A few examples:

1. using multiple standalone pc's for data entry and analysis;
2. combining Total Station measurements with descriptions;
3. merging lab core-sample C14 dating information in the excavation database;
4. adding data from previous studies carried out by others;
5. museum collections which comprise results from many different institutes.

All modern studies rely on digitally represented data in a variety of ways, enjoying the benefits of, e.g., accessing large collections of data already available in digital form and modern computerized measurement techniques. The management of all this digital data unfortunately introduces its own problems.

The most common *technical* problems encountered in the digital data management are, with references to the examples given above:

1. parallel updates to the same dataset (1, 2, 3);
2. comparing data with different semantics, in the same knowledge domain (3, 4, 5);
3. integrating information stored in technically incompatible information systems (2, 3, 4, 5).

Note that there is often an overlap in these common problems of data management, which can be an extra challenge.

This paper introduces a technique to gracefully cope with the first of these problems, *parallel updates*.

Parallel updates

Problem context

During an archaeological research study there is very often a need to do parallel updates to the same dataset. This is easily illustrated by considering a common organization for an excavation project:

- two teams in the field, each having their own tablet pc for data-entry;
- one team performing all the measurements with a total station;
- at some point in the project, sufficient data has been collected for experts to start correcting and analyzing the already available data, while still more data is being collected in the field;
- the lab produces C14 radiocarbon date values.

In this example there are already 5 sources of information, all belonging to the same dataset, and all collected in parallel. All the information should be combined to answer the research questions.

We assume a well-designed information system, as well as full cooperation from all people involved, so that all the data is collected in a fully compatible way, using the same type of information system. This rules out technical problems of the second and third category mentioned in the introduction, leaving only *parallel updates*.

Traditional solutions

A traditional approach when working in parallel in separate environments (e.g., multiple PCs) is to set very strict rules on numbering and access rights, to prevent two people from both adding data – for instance, describing artifacts – but labeling them with the same number, and to avoid their updating one datum at the same time.

In practice, this could mean that, for example, an expert should not update data still being worked on in the field. Adding data from a lab however could be safe, as long as they are new records. Clearly, this method is error prone, and so many checks have to be performed during every merge. The following example illustrates the issue:

Step 1. Initial entry of the record (not shown).

Step 2. A copy of the database is made, now there are two instances of the same records (Fig. 1).

Id	Shape	Colour
1	Rectangle	Grey
2	Ellipse	Red

Fig. 1 – Copying the database.

Step 3. The field team discovers a mistake in the numbering (2 → 3), and corrects it (Fig. 2).

Id	Shape	Colour
1	Rectangle	Grey
2	Ellipse	Red

Id	Shape	Colour
1	Rectangle	Grey
3	Ellipse	Red

Fig. 2 – Correcting an Id.

Step 4. The supervisor changed part of the description (Ellipse → Circle) after looking at the field drawings (Fig. 3).

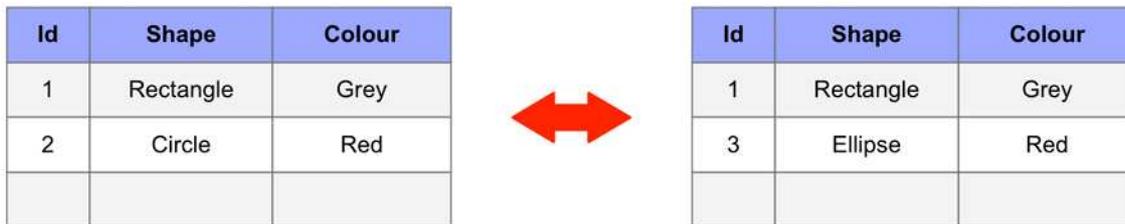


Fig. 3 – Changing the Shape.

There are now several possibilities for combining these two versions, with no way of determining which version is the correct one without having access to specialist knowledge. The following table (Fig. 4) illustrates this problem by listing a few options. Note that it is not even exhaustive.

Id	Shape	Colour
1	Rectangle	Grey
2	Circle	Red
3	Ellipse	Red

Id	Shape	Colour
1	Rectangle	Grey
3	Circle	Red

Id	Shape	Colour
1	Rectangle	Grey
2	Ellipse	Red

Fig. 4 – Three examples of possible conflict resolutions.

Clearly then, reliable *automatic* merging of these two data sets updated in parallel is impossible – there is a conflict. Researchers can of course solve the conundrum, by going back to the sources, but this takes a lot of effort.

What is nonetheless technically possible is to reliably detect the existence of conflicts and provide the sequence of events that caused it. This substantially reduces the workload when merging data sets. Common technical solutions are automated checks for changes in the data during merge or using time stamps for changes, but where the latter is obviously highly unreliable, the first doesn't give a clue about which record is the preferable one in case of conflicts. In the next paragraph a solution is presented that solves as much as possible of these problems.

Handling parallel updates

There are four cases to be considered:

- add data (by hand or from another database);
- update changed records;
- delete records;
- adjust relations.

The goal is to be able to distinguish real conflicts from uncertainties, and therefore in the first place information is needed on the sequence of changes.

Geologists and archaeologists are familiar with the concept of *stratigraphy*, which is applicable to databases too, as it describes sequences. The *Harris matrix* (HARRIS 1979) is the tool for archaeologists to depict the *temporal succession* of archaeological contexts. This temporal succession can be given in a fully *relational* way, no *absolute* datings are necessary. When projecting the Harris matrix onto the database realm, archaeological contexts can be replaced by database objects, where each database object represents one archaeological object.

Succession of changes

The first step is to observe that providing the sequence of events leading up to a conflict requires recording *each change* involved. That is, while the system can still present a coherent view of the data set to the archaeologist, internally it must track all the *versions* of each record, and how these relate to each other. To illustrate, where the data set in the preceding example is simply changed by editing, the proposed system would instead record a change from “2, Ellipse, Red” to “3, Ellipse, Red”, and if it were to be changed back, that change, too, would be recorded. These all result in dependent versions of the records in database, each with its own globally unique identity. Such a set of dependent versions of records, each with its own unique identity, is of course a dependency graph, the computational equivalent of the Harris matrix.

Merging multiple instances of the same dataset involves the following steps:

- build the graph of changes;
- determine conflicts;
- automatically propagate non-conflicting records;
- propose options to solve conflicts.

Fig. 5 shows a diagram of abstract edit and merge operations on a record-version V , which is changed in two parallel sessions, resulting in versions X and Y . Because the dependencies are carefully tracked, no matter what changes were made, we know that they both derive from V and that a conflict exists.

There are now essentially two approaches to resolving this conflict: one is to combine (merge) the changes made in the two sessions to obtain one new version Z . In some cases, the system will be able to do this automatically, in all other cases it will have to present the user with the two versions, X and Y , and their ancestor, V , and let the user decide.

An alternative way of resolving a conflict is to discard one of the two, here depicted by a black node. It is not merely for illustrative purposes that this black version is included: when recording *all* changes, deleting something is also a change that needs to be recorded.

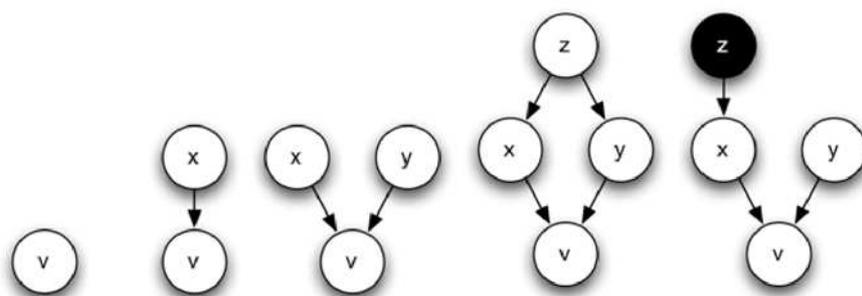


Fig. 5 – V is edited, leading to X. V is also edited leading to Y, causing a conflict. To solve this conflict, the changes made will have to be inspected. One can either merge the two into a new version Z (white), or delete one of the two, here X, by adding a note Z that version X has been deleted.

Notion of a conflict

The notion of a *conflict* can be defined formally in terms of the properties of such a graph of versions. In this paper, we will instead illustrate two important ones informally here. For that, we must first define the concept of a *current* version: a version is current when it has not been superseded by another version, or by multiple versions. In the example above, X and Y supersede V, so that V is not current except in the leftmost picture. In the fourth diagram, Z supersedes both X and Y, &c.

The two primary kinds of conflict that parallel editing can cause are then:

- If a version is superseded by multiple current versions at the same time, changes were made to it in parallel, and there is a conflict.
- Another kind of conflict results when records with the same primary key value are added to a table in independent data sets. When merging, this results in multiple current versions with the same key value, but without a common ancestor. The lack of this common ancestor allows distinguishing this case from the parallel change above.

Other kinds of conflicts can occur when a record can refer to records by its key value. Attention will be given to these in due course.

Example of the approach taken

Because *adding* data is always safe, our goal can be achieved by recording every change in the database as new data, with a guaranteed unique key:

- keeping track of changes of values
- keeping track of changes of references
- recording deletions

The changes from each database instance can thus always be combined, as every change has a guaranteed unique key; several reliable techniques exist to obtain such unique keys. The next example shows what the impact is of using this technique.

Step 1. The starting point is the same as in the first example, and is shown in Fig. 6. "Hid" is the unique History Identifier, used to uniquely identify versions of records, and "PrevHid" lists the unique history identifiers of the ancestor versions. These history identifiers are meaningless numbers; all that matters is that each change is recorded with a unique identifier. The two records are both initial versions, hence the absence of ancestral versions.

HId	PrevHId	Id	Shape	Colour
153427		1	Rectangle	Grey
846288		2	Ellipse	Red

Fig. 6 – Example starting point editing using historical information.

Step 2. Following the pattern of the first example, this database is duplicated and the two instances are then modified in incompatible ways. In the left instance, there is again a change in primary key, from 2 to 3; in the right instance, the shape is again changed from “Ellipse” to “Circle”. This is shown in Fig. 7. Note that the *every* version has a unique identifier.

Although the user conceptually modifies these records, the various instances of the database internally retain the original version with its original identifier, adding a new version with a reference to the old one. In both instances, the original version is no longer current because there is now a version that derives from it. In Fig. 7, this is indicated by showing the current versions in black and the non-current ones in grey. The user only sees the current versions and need not be aware of the underlying versioning.

HId	PrevHId	Id	Shape	Colour	HId	PrevHId	Id	Shape	Colour
153427		1	Rectangle	Grey	153427		1	Rectangle	Grey
846288		2	Ellipse	Red	846288		2	Ellipse	Red
384639	846288	3	Ellipse	Red	298476	846288	2	Circle	Red

Fig. 7 – Two copies, one with a changed Id, the other with a changed Shape.

Step 3. Merging the two instances is trivial as every record has a unique identifier, and hence no overwriting will occur when merging the database instances (Fig. 8). By combining the two instances in one database, analysis of the history becomes possible, and the existence of a conflict immediately becomes clear: there are two current versions that are both derived from the record with version “846288”.

HId	PrevHId	Id	Shape	Colour
153427		1	Rectangle	Grey
846288		2	Ellipse	Red
384639	846288	3	Ellipse	Red
298476	846288	2	Circle	Red

Fig. 8 – Merging the history of both database instances, with separately modified versions.

Step 4. Analysis of the conflict shows that object 2 became 3, and that in the same record the Shape was changed from "Ellipse" to "Circle". This leads to the conclusion that these two modifications can be combined into one object, with Id 3 and shape "Circle". The formal resolution is achieved by creating a new version that combines these two changes and has both conflicting versions as its ancestors, shown in Fig. 9. This way, there is once again only one current version derived from the original record 846288.

HId	PrevHId	Id	Shape	Colour
153427		1	Rectangle	Grey
846288		2	Ellipse	Red
384639	846288	3	Ellipse	Red
298476	846288	2	Circle	Red
981602	384639 298476	3	Circle	Red

Fig. 9 – Deriving the correct state of the object from the history, after merging.

Referencing context objects

The preceding sections form a blueprint for implementing this in an information system. However, to make it work, a few more problems have to be addressed, and this is probably why there are no information systems in use in archaeology that adhere to this principle. Most notably a solution has to be provided to overcome the following problems:

1. references between the various context objects;
2. one context object might comprise multiple database objects.

Technically, an extra administrative layer has to be introduced, which is usually hidden for the user of the information system. This layer tracks the references, and is schematically shown with the light grey arrows in Fig. 10. In this diagram, a red version marks a change of a primary key, whereas white versions may change anything but the primary key.

The light grey arrows are to the record-versions what a normal foreign key relation is to normal records. That is, if one record (of current version P) refers to a record (of current version V) in a different table using a foreign key, that relationship is explicitly stored as a relation from P to V and shown as a light grey arrow in Fig. 10.

Changing V creates a new record version X , and if that change affects only attributes but not the primary key, the situation is as depicted in 2nd diagram. There is no reason why a simple attribute change to V would affect P , and instead of requiring P to be updated to refer to X instead of to V , it is simply assumed to refer to whatever current record version supersedes V .

An entirely different situation occurs when the primary key of V is changed, as was done in our running example. In this case, the foreign key relation breaks because it is based on an attribute of P referring to V

by its primary key, which no longer exists in the database. Therefore it needs to be updated, either to explicitly refer to the new version, or to explicitly *not* refer to it. On the second row, the first diagram shows the situation if one decides that the relation must be maintained, so that a new version *Q* is introduced. The other two diagrams shows possible resolutions of a more complex conflict, in which a primary key change happened in parallel to an attribute change, as was done in the example.

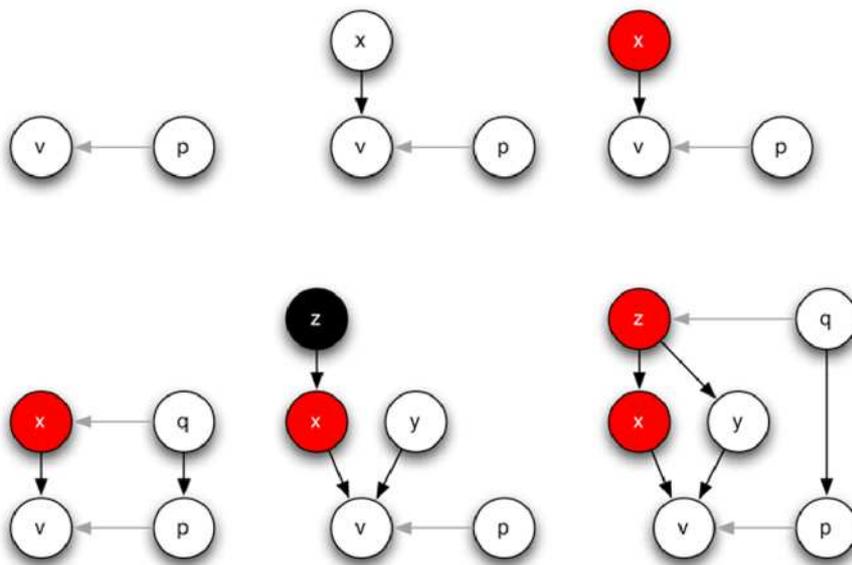


Fig. 10 – A sample graph of changes, incorporating a reference layer.

The middle diagram resolves the conflict by discarding the change of primary key, so that record-version *V* is superseded by only one current record-version, *Y*, and because there is now no longer a change in primary key, *P* need not be updated. In the rightmost diagram, the two modifications are merged to produce a new one, and *P* is updated to *Q* to resolve the reference conflict. Note that *Z* is red as well, because it is a change of primary key of *Y*.

Similar reasoning applies to cases where a record-version is referenced that is subsequently deleted. An informal definition of a reference conflict now follows easily from these illustrations:

- if a record-version *P* references a record-version *V*, and *V* has been deleted or has been superseded by a red version that is current or has a current descendant, there is a reference conflict.

The implementing of these three rules in a database is straightforward and extending an existing data model to include this versioning system requires only minimal changes.

Schema changes

An additional complicating factor is that many projects use slightly different attributes and code domains. But, as it is necessary to store content and reference changes, working with different attributes and structures implies completely rebuilding the software to support the change tracking mechanism. To avoid this, an extra layer of complexity has to be added, to keep a catalogue of the domains and the database schema, which is independent of the actual state of the database schema. Changes in the actual database schema must be

reflected in the catalogue, which must be versioned itself, as for each (historical) record the appropriate version of the catalogue must be linked.

Limitations, benefits, alternatives

The presented solution to handle parallel updates correctly, based on recording the history of changes, has several important benefits:

- reliable automatic conflict detection while integrating datasets which have been edited in parallel
- rules can be put in place to solve specific types of conflicts automatically
- dramatic reduction of the amount of time spent on integrating datasets

However, such an information system also has its limitations, the most important one being that some types of conflicts can never be resolved automatically, although they can be detected. Consequently, the end user should have a good notion of the capabilities of the system in order to fully benefit from it, and in particular integrating the various dataset copies regularly and resolve open conflicts, usually called 'synchronizing', should still be part of the workflow.

Additional benefits

Besides the advantages of handling parallel updates, recording the history of changes has a few other important benefits. Firstly, it gives insight in the development of the knowledge during the research project, which can be of great value when dealing with uncertainties (MOTRO unknown, CHENG et al. 2005). Secondly, a full implementation where not only data changes are recorded, but also the changes to the dataset schema, enables integrating data from various sources using comparable but slightly different storage schemas and code domains.

Implementation

Implementing the recording of changes to attribute values in a database is common practice, and relatively easy to accomplish. Recording changes to relations is more difficult, but is still relatively easy. However, allowing end users to make changes to the code domains and dataset schema whilst still allowing for automatic integrating with conflict detection is challenging, and so far unknown of in information systems.

Other approaches

A different approach to handling parallel updates would be to always connect to a central database server using modern fast wireless networking technology. The benefit of this approach is that there is no need to resolve conflicts: it is possible to avoid them, and it is technically less complex.

The drawback of this approach is that such a system completely fails in case of networking problems, but this is usually circumvented by implementing a caching mechanism in case of network failures. In addition, they are pre-defined information systems for the end users, where dataset schema changes are impossible. Finally, most of these systems focus on data entry only, which removes the need to handle parallel updates. The traditional way of dealing with parallel updates, entirely based on workflow rules, is error prone, and highly time consuming.

Relation to other work

The general approach of keeping track of history as described here is not unique. An excellent example of a similar approach taken in a different field is that of distributed version control systems, typically used to keep track of the changes made to a software system by many developers at the same time. A recent and highly regarded system is *Git* (TORVALDS 2010). *Git*, too, uses unique identifiers and tracks ancestors to allow determining the way a particular version came to be; and it, too, has a notion of multiple ancestors corresponding to a merge. However, differences exist:

- our approach is centered around the detection and resolution of conflicts, instead of on maintaining multiple independent data sets that can be partially or wholly merged upon request;
- version control systems track changes to internally consistent collections of files, whereas our approach tracks changes to records and deliberately treats changes to unrelated records as independent;
- our approach also includes a method for maintaining relationships between objects, even providing for changes of the primary key.

Besides version control systems, there are specialized database systems that have the capability to merge copies, the most well-known of them being the electronic mail software. Also a commercial geodatabase system exists that has the ability to check out a copy and edit it separately, while providing tools to merge the separately edited copies afterwards. But also here differences exist:

- our approach includes a method for maintaining relationships between objects, even providing for changes of the primary key;
- our approach adds an extra layer of version information to store the changes in the database schema and data domains, to even allow for changes of the schema and data domains while retaining support for merging and conflict detection, and possibly automatic resolution.

Conclusion

It has been shown that archaeological research has unusual requirements on digital information systems (BOASSON and VERHAGEN 2006). The first one is that the information system must offer easy adaptation to a specific research project, the second one is handling parallel editing and integrating various data sources, which are technically similar in a full implementation. When comparing the three approaches described to deal with parallel edits on the same dataset:

- manually setting strict rules on the edit options
- keeping history
- using a central networked database

the proposed method to rely on keeping the history of changes stands out for the following reasons:

- independent of network availability
- allows support for schema changes
- superior conflict detection
- possible to implement (partly) automatic conflict resolution
- enables integration of data sources with similar but not identical signature

Currently no information system available offers the full implementation, probably because of the complexity of the software, in particular the option to adapt the data schema to the needs of a specific project. There are systems available that track changes, but to no further extent than providing the end user insight in the history of the data (INTRASIS 2000, ODILE 2004).

The time reduction in data management combined with the fault tolerance of the proposed system justifies development of such a system. The Odile database system (ODILE 2004) is scheduled to implement the proposed change tracking and conflict detection mechanism in the next generation. This will be done in a way that also enables integrating various data sources.

More research has to be done to study the option to deal with uncertainties of the data, based on its historical changes.

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Antra Cyclopiis and the others

The dimension of the entertainment in the ancient town

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Abstract: The roman emperor villas hide special, spectacular – and now almost lost – spaces dedicated to the presentation of epical and legendary events.

The whole research is based on accurate digital survey of the architectures and of the statuary groups, it proposes an approach path that starts from an analysis of the natural forms of the Tiberius's *antrum* in Sperlonga, this solution will become completely artificial in its forms in the *Serapeo-Canopo* of Hadrian's Villa. The *Antra Cyclopiis* change their appearance over time, but they always retain the same function and especially the theme of the sculptural decoration.

The statues that once adorned the *Antra Cyclopiis* today have a different location than the original. Their location in museums has misrepresented the original appearance of *Antra Cyclopiis*. The digital survey, and the successive production of three-dimensional digital models, allows, for first, to replace virtually the sculptures in their old setting recreating the original scenography of the *coenatio* of Sperlonga and this has proved the effective presence of the statues in the place assumed by archaeologists. Secondly, the dimensional analysis leads to rule out the assumption that many scholars argue, about the presence of a Cyclops, equal in size to the one from Sperlonga, in the *Serapeo* of the Hadrian's Villa in Tivoli.

With laser scanner even those areas that are placed in hardly reachable positions can be easily analyzed without the use of any scaffolding. In the case of Sperlonga a full analysis of the intrados of the cave was made, and through the production of contour lines we identified a collapsed zone, this is an important find, while the archaeologists had not yet located it, for this reason it has attracted a particular interest, opening the road to a possible debate on the historical vicissitudes of the events occurred there.

Keywords: *Antra Cyclopiis* Archaeology Digital Laserscan.

Spectacular spaces: the “Antra Cyclopiis”

In Roman times the imperial villa becomes a model of a city miniature, this was because of its extension, even walking between its ruins it is possible to notice how the rooms built on such dimension as to be regarded as real urban spaces and not simply as housing units. As within a city the mechanics of the visit includes sites devoted to entertainment, with the aim to surprise and to amaze visitors. One of the typologies of these spectacular environments is the *Antrum Cyclopiis*, a site for leisure and relax, suitable for hosting banquets, ceremonies and theatrical performances.

The words *Antra Cyclopiis* defined the nymphaeum that has a mural, mosaic or sculptural decoration depicting a subject from the Homeric Odyssey, in particular related to the figure of the Cyclops.

Within the Roman environment this theme allows to exalt the emperor figure. Through the assimilation of Greek culture the Romans tried to amplify and to refine their cultural sense, trying to collect new noble roots to magnify their descendants. In this context the Homeric scenes generally represented were three: the "wine offering" (Fig. 1), the "blinding of Polyphemus" (Fig. 2) and the "escape from the antrum" (Fig. 3). It was usually preferred the first because it extolled the genius of the hero better than the others, Ulysses, is obviously the figure used to identify the emperor himself.

Example of *Antra Cyclopis*, but in a public contest, is the Nymphaeum of Pollio (93 AD) at Ephesus (Fig. 4). Here Domitian emperor, for decoration of the fountain used some sculpture, dating at 34 BC, that Marco Antonio had commissioned for the pediment of a temple dedicated to Dionysus.



Fig. 1 – Mosaic floor of the late-ancient villa of Piazza Armerina (306–12 AD) depicting the "wine offering".



Fig. 2 – Mural painting depicting the "blinding of Polyphemus", Tarquinia, Tomba dell'Orco III (2nd half of IV sec. B.C.).



Fig. 3 – Marble sculpture, “Ulysses under the fleece of aries” (III sec. AD), Roma, Galleria Doria Pamphilj.



Fig. 4 – Photographic reconstruction of the arrangement of the sculptures inside the nymphaeum of Pollio at Ephesus (93 AD). This sculptures (34 B.C.), representing “the wine offering”, have been committed by Marco Antonio, Tiberius’ uncle, for decoration of pediment of the Temple of Dionysus at Ephesus, never built.

Tiberius' cave, Sperlonga, Latina, Italy

Emperor Tiberius (14–37 AD) was the first to arrange, inside his villa at Sperlonga, an *Antrum Cyclopiis* exploiting the natural shapes of the area (Fig. 5).

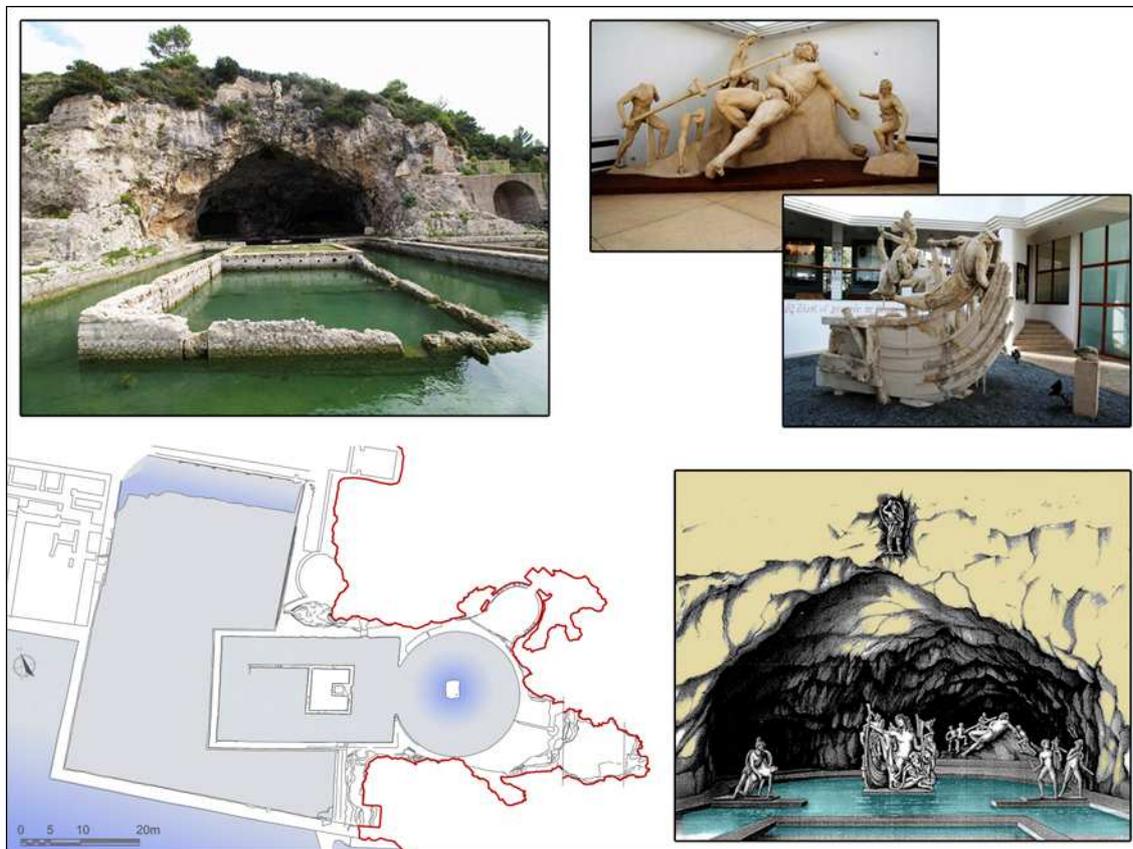


Fig. 5 – Tiberius' Cave, Sperlonga (LT), Italy. Up on the left: the Tiberius' cave now; down on the left: horizontal section of the *nymphaeum* of the Tiberius' villa; up on the right: the sculptures which are now in the museum: up Polyphemus, down Scylla (Copyright: N. Cassieri); down on the right: reconstruction of the arrangement of the sculptural groups inside the cave.

In this particular case the nymphaeum was arranged inside a natural carsic cave, who houses a circular basin filled with sea water, and two smaller caves in the background. Some works were carried out to regularize the shapes and to refine the spaces. Then were collocated the sculptural groups, known like "marble Odyssey", that depict the Ulysses adventures. The scenes represented are five: Ganymede kidnapped by the eagle of Jupiter; Ulysses who collects the body of Achilles and his weapons; Odysseus and Diomedes who steal the statue of Pallas Athena, protector of the city of Troy; the monster Scylla who attacks the ship of Ulysses; and finally the group of the blinding of Polyphemus. The most important, both because they represent the main difficulties, both because of their size, are Polyphemus and Scylla. Probably these subjects take inspiration not only from Homeric literature, but also from *Metamorphosis* by Ovidio, in fact the first three scenes are told only in this last work.

These sculptures are probably Roman copies of Hellenistic bronze prototypes. Proof of this is a large presence of props, who demonstrates that the groups were thought to be made with a ductile material like bronze and not fragile like marble.

Probably Tiberius took cue from so-called *parks Rhodes* in the Rhodes town, where little caves became natural theatres, through the collocation of statues inside them.

Certainly the first intention of Tiberius, in the choice of these subjects, was to celebrate the figure of Ulysses as an example of *new man*¹. In the second he wanted to celebrate the union, in his person, of the two most glorious families, *Julia* and *Claudia*, descendant respectively by Aeneas and Ulysses².

The grandeur, the sophisticated solution and the opulence achieved in the scenographic space of the Tiberius' cave, will be emulated by the rich aristocrats and especially by the emperors in the future years. The Homeric theme of Cyclops, often together with Scylla, will become recurring subject of sculptures which decorated nymphaeums and fountains, and the *Antra Cyclopiis* will be a typological model that its presence, inside of the imperial *caenatio*, will be a requirement. So it is stated, in the imperial villas, this class of environments, generally related by a serial of element: a spatial arrangement that comes by the combination of various spaces, interior and exterior; the presence almost obsessive of the water; the recall to natural cave; and finally, a rich decoration mosaic and sculpture inspired at the Cyclops theme.

The nymphaeums of Claudius at Baia, Napoli, Italy

Certainly the nymphaeum of the Claudius' villa (41–54 AD), at Baia (Fig. 6), belongs to the category of the *Antra Cyclopiis*. Unfortunately this locality is subject to the phenomenon of bradyseism, so the villa, and consequently the nymphaeum, now it is almost 7 meters below the sea level. The discovery was accidental, following a sea storm the wall of nymphaeum, and two statues, emerged from the sand. The statues were still in their original position. This sculptures depict the theme of the wine offering, and unfortunately they have the top eroded by the mollusks. One of these, completely headless, depicts Ulysses who offers the cup of wine to the Cyclops; the other sculpture represents the companion of Ulysses with goatskin, his name is Baios, legendary founder of Baia. Inside the sculptures were collocated lead pipes from which water flowed. In the 1981, thanks to the funding of a private foundation, the nymphaeum was freed from the sand. Contrary to Sperlonga site, here we find a typology of nymphaeum with regular shapes. Now it is possible to admire a reconstruction of the nymphaeum, at the *Museo Archeologico dei Campi Flegrei* at Baia.

The nymphaeums of Ulysses and Polyphemus in the *Domus Aurea*, Rome, Italy

Later in the nymphaeum of the Nero's *Domus Aurea* (54–68 AD) in Rome (Fig. 7), it is possible to find again the same theme (wine offering) but this time the scene is represented in a mosaic belonging to the main vault. This demonstrates that the *Antrum Cyclopiis* had become an essential element inside an imperial residence.

This mosaic gives an important information about the discussed originality of the sculptural groups of Sperlonga.

¹ The figure of Ulysses take conflicting ethical values, because of his cunning. For the first time Homer gives Odysseus the appearance of a new man: he considered Ulysses as the first human being to decide for their own actions, and not depend by the fate or by the will of the gods.

² Tiberius venerated as his ancestors, by his mother, Ulysses and Telegono, progenitors of the *gens Claudia* and founders of the city of *Tusculum*; instead, by his adoptive father Augustus, Aeneas and Iulus, founders of the city of Rome and progenitors of the *gens Julia*.

It's interesting to notice that the figures don't have the polychromy typical of the mythic scene reproduced in mosaic, but the figures have a color bronze with metallic sheen. It is clear that in this mosaic it's not representing a legendary scene but an ancient bronze group.

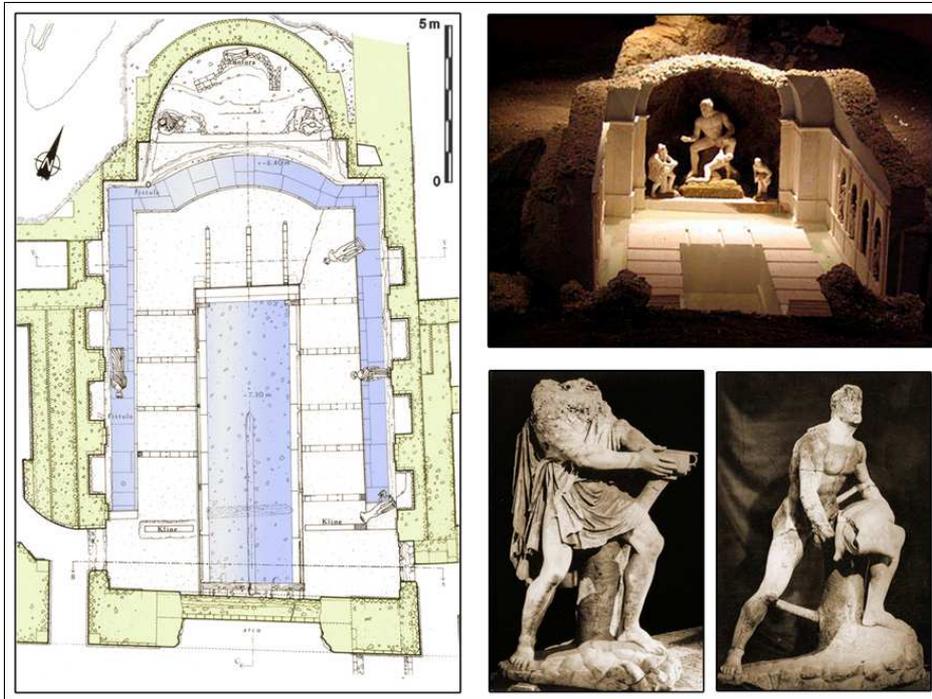


Fig. 6 – Claudius' Nymphaeum, Baia (NA), Italy. On the left: horizontal section of the nymphaeum; up on the right: reconstruction of the submerged nymphaeum (Copyright: L'Archeologo Subacqueo, III, 2, 1997); down on the right: the sculptures of Odysseus offering wine to the Cyclops and Baïos with goatskin of wine (Copyright: B. Andreae).

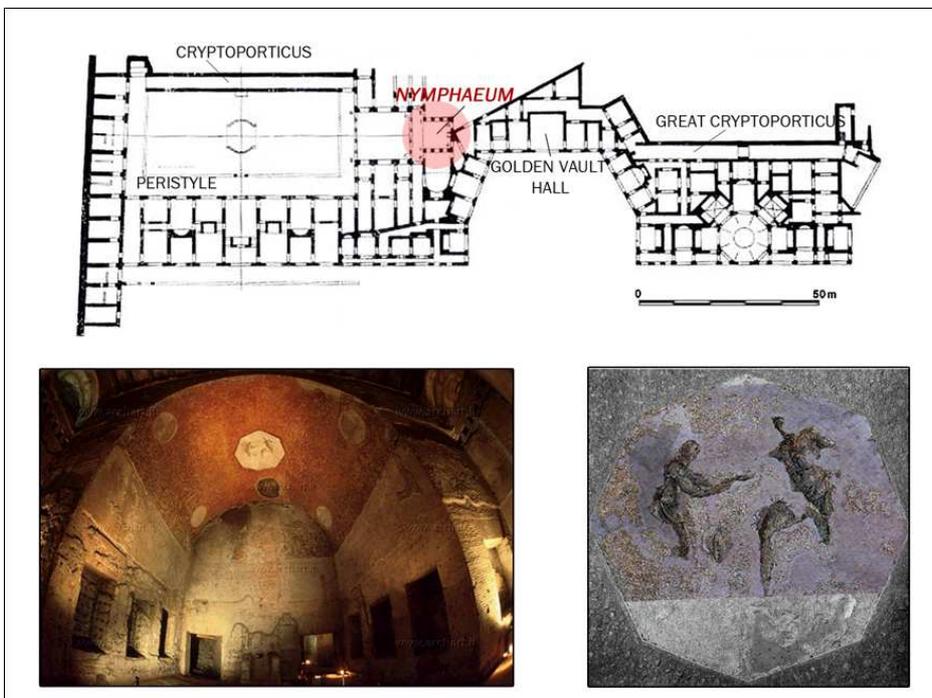


Fig. 7 – The Nymphaeum of the *Domus Aurea*, Roma, Italy. On the top: horizontal section of the *Domus Aurea*; down on the left: the nymphaeum of Ulysses and Polyphemus (Copyright: www.archart.it); down on the right: the octagonal mosaic depicting the offering of wine (Copyright: B. Andreae).

The *nymphaeums Bergantino*, Castel Gandolfo, Italy

Even Domitian emperor (81–96 AD) built, inside his villa on the Albano lake, an *Antra Cyclopis* in the so-called *nymphaeum Bergantino* (Fig. 8), where, in the lines of the plant it is recalled the natural shapes of the Sperlonga cave. Even here the sculptural subjects are Polyphemus and Scylla. Even the collocation also of the sculptures is Sperlonga like: a platform in the center of the circular basin for the Scylla, and a podium in the little cave on the background for the group of Polyphemus.

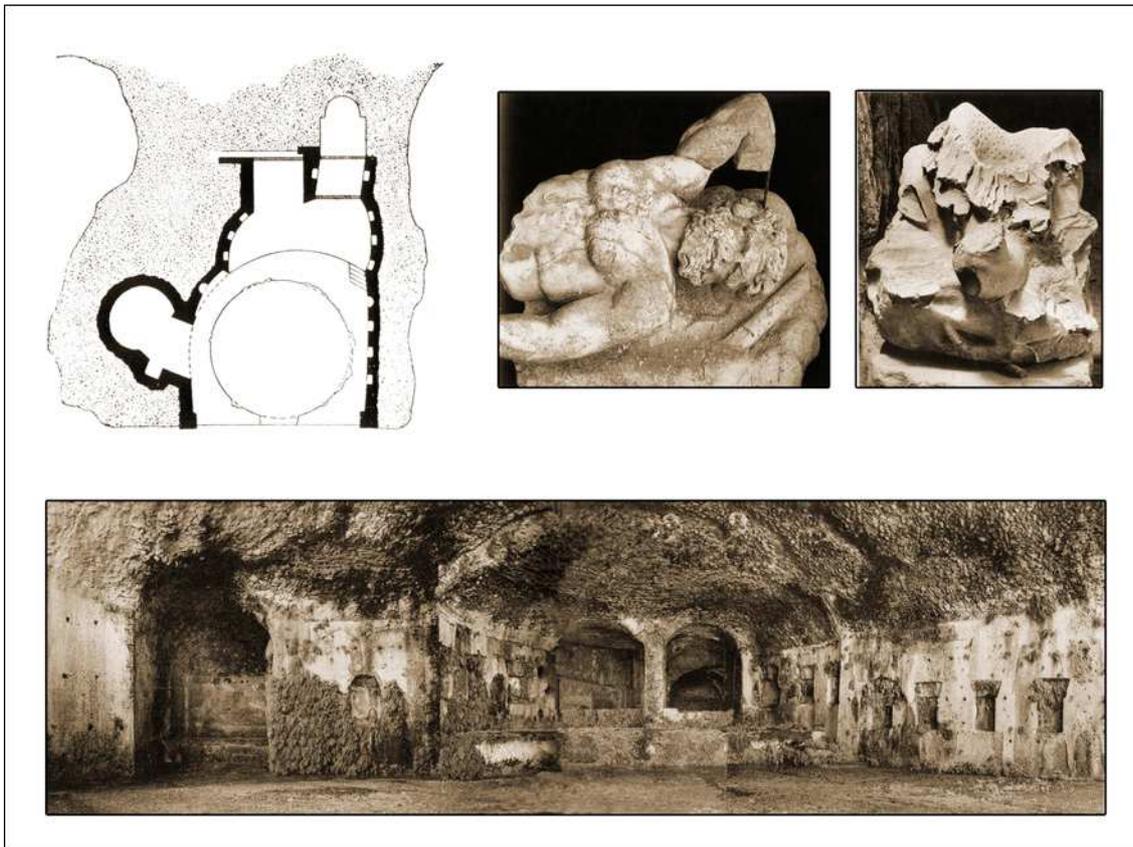


Fig. 8 – The Nymphaeum so-called *Bergantino*, Castel Gandolfo (ROMA), Italy. Top by left: horizontal section of the nymphaeum, fragment of sleeping Polyphemus and fragment of Scylla. Down: unwrapped interior view of the nymphaeum (Copyright: B. Andreae).

The *Serapeo* of Hadrian's villa, Tivoli, Italy

Later the idea was used again by Hadrian emperor (117–138 AD) who revolutionized the concept of Antrum with the artificial shapes of the *Serapeo-Canopo* ensemble in the Hadrian's Villa (Fig. 9). Here it is clear the recall to the cave through the apsidal construction of the *Serapeo*, while the idea of the sea echoes in the *Canopo* long pool. Here, the discovery of three heads, belong to companions of Ulysses³, is reason to believe that there is a group of Polyphemus not yet discovered. Several archaeologists argue this hypothesis, but the spatial arrangement and the dimension of group of Polyphemus, make improbably its presence.

³ These three heads are totally identical to those of the companions of Ulysses of the group of Sperlonga.

Instead is certain the presence of twin sculptures representing the monster Scylla. These sculptures were positioned in the large *Canopo* pool, to the extremity.

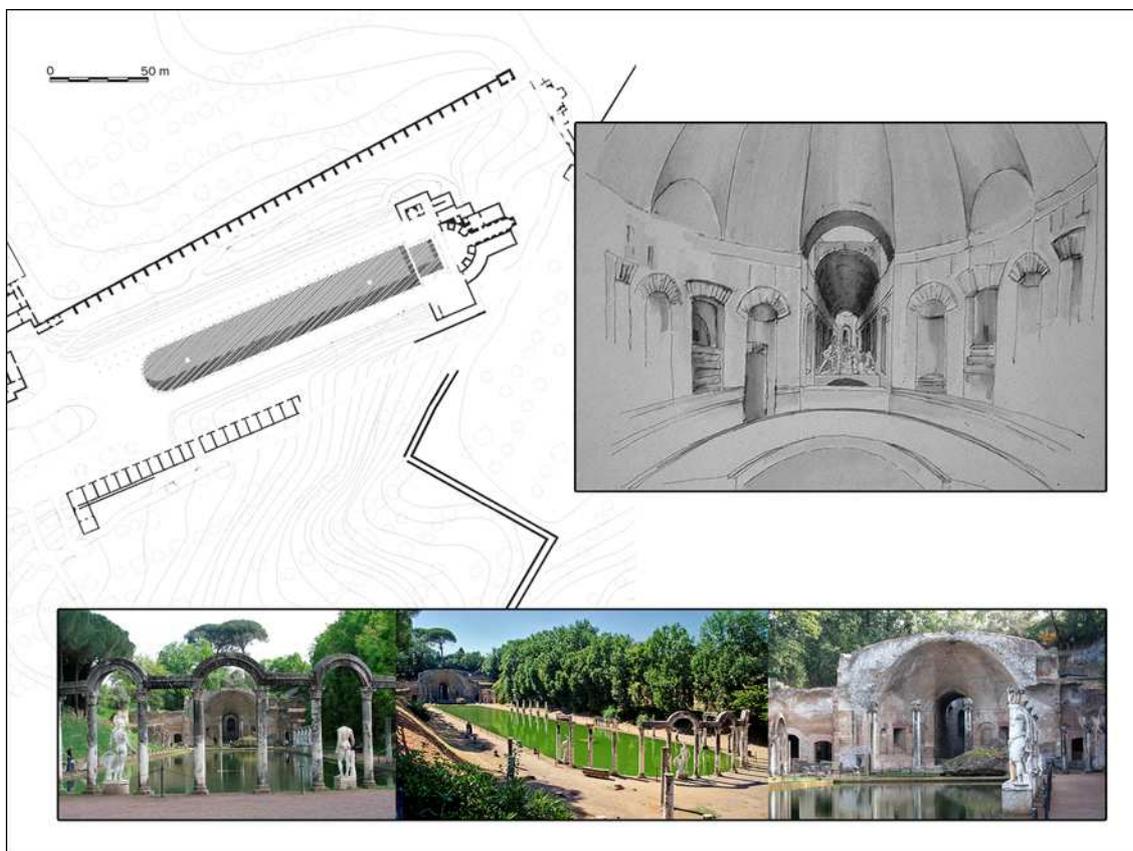


Fig. 9 – The ensemble *Serapeo-Canopo* of the Villa Adriana, Tivoli (ROMA), Italy. Up on the left: plant of the nymphaeum; up on the right: hypothetical arrangement of Polyphemus group inside *Serapeo* (Copyright: B. Andreae). Down: views of ensemble *Serapeo-Canopo*.

The digital survey

The Tiberius' Cave at Sperlonga and the ensemble of the *Serapeo-Canopo* of Hadrian's Villa in Tivoli certainly represent two extremely interesting case of study from the whole Italian archaeological heritage, for this reason approaching them starting from contemporary technologies like digital survey is a correct starting point.

The first digital survey campaign, took care of the so-called *Serapeo* in the Hadrian's Villa, it was carried out in 2007 using a *Cam2* laser scanner model *Faro 8080HE*.

The second survey, operated at the Tiberius' cave in Sperlonga, was carried out in 2008 in collaboration with dott.ssa Nicoletta Cassieri, from the *Soprintendenza Archeologica del Lazio*. During this campaign was carried out also the survey of two sculptural groups preserved in the Sperlonga Archaeological Museum both the groups once were part of the architectonic apparatus adorning the cave. In this campaign the tool in use was a *Zoller+Fröhlich 5003 Laserscan* (Fig. 10). Both the campaigns so were based on Phase-Shift laserscan technology, both the survey campaign were conducted under the scientific supervision of prof. Giorgio Verdiani from the *Facoltà di Architettura di Firenze*.

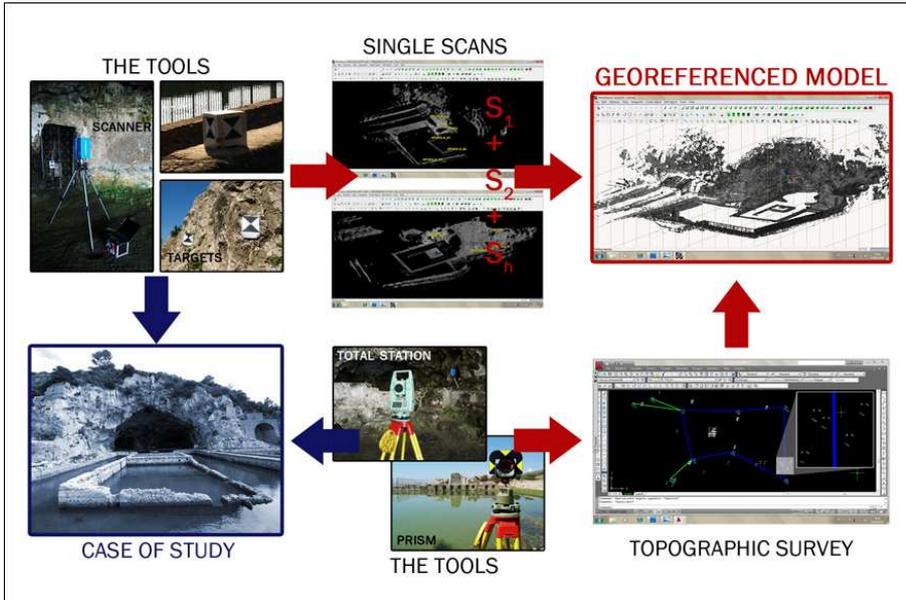


Fig. 10 – The main digital survey workflow.

For each scans a certain number of targets were positioned to allow registering the overall point cloud model. A specific topographic survey was associated the laser-scans operation, this was done to recompose each single scan into a single model and with an unique reference system.

The gathered data are presented in their point-cloud representation in a digital three-dimensional space so to show the exact shape and dimension of each surveyed object.

Starting from the point cloud model, composed by the assembly of each single scan, it is possible to extract plants (Fig. 11), sections (Fig. 12, 13, 14) and any other kind of drawing necessary for a deep study of the object.

The software used to develop this operations was *Leica Geosystems Cyclone* release 6.0.3.



Fig. 11 – Tiberius' Cave ground plan extracted from point cloud model.

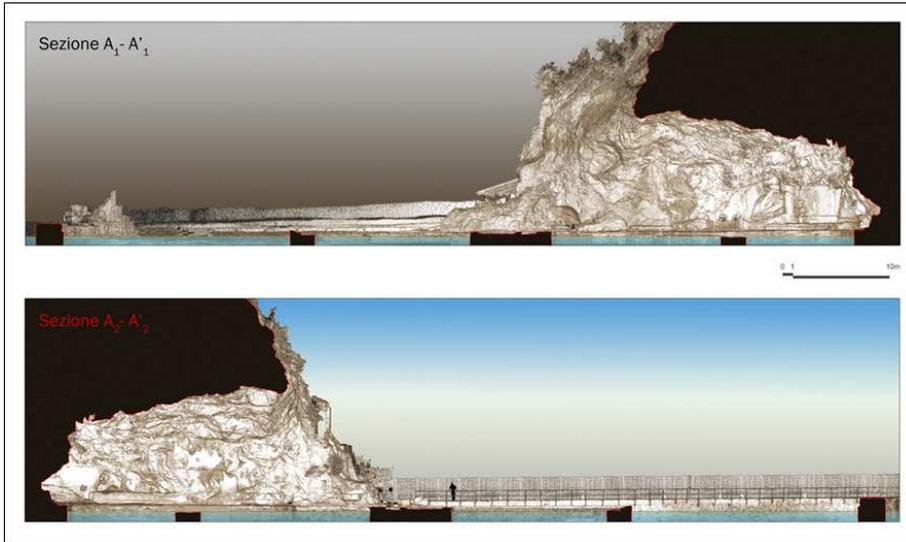


Fig. 12 – Central section of Tiberius' Cave extracted from point cloud model.

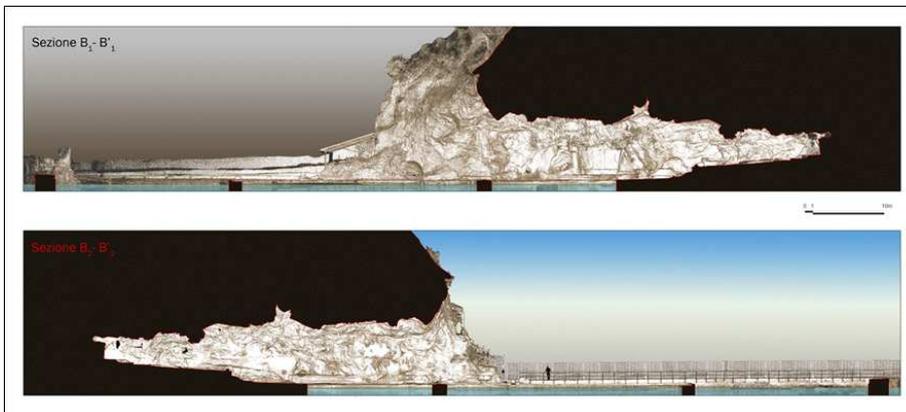


Fig. 13 – Sections B-B' of Tiberius' Cave extracted from point cloud model.

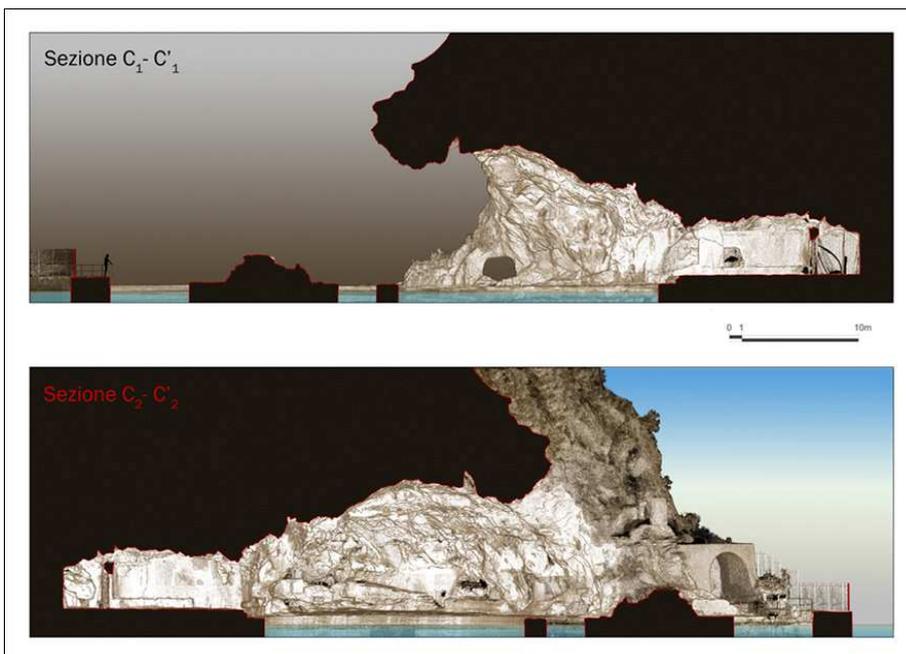


Fig. 14 – Sections C-C' of Tiberius' Cave extracted from point cloud model.

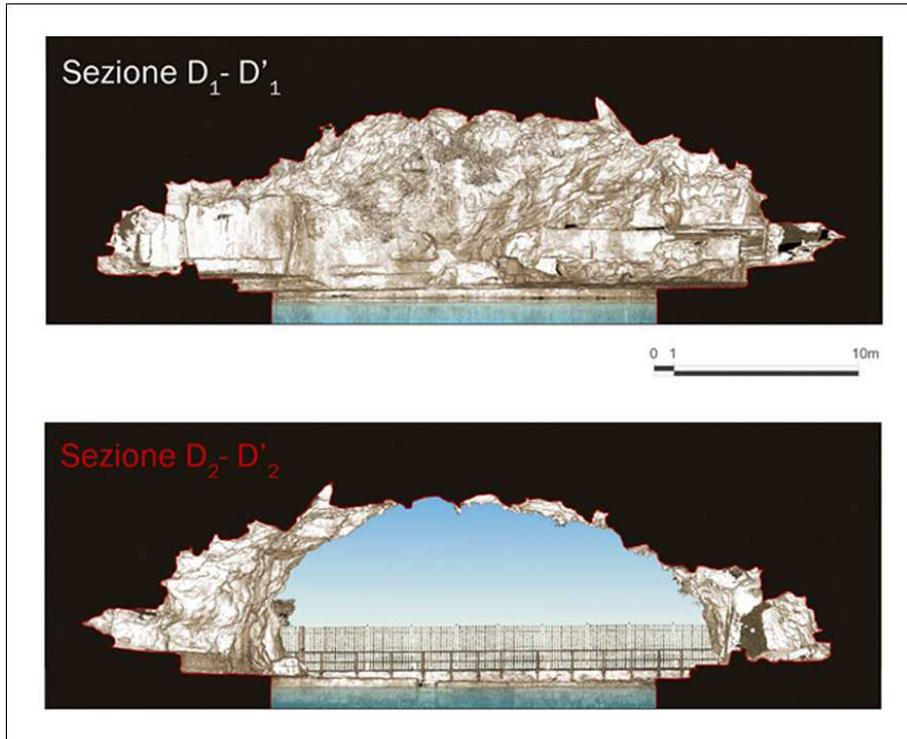


Fig. 15 – Sections D-D' of Tiberius' Cave extracted from point cloud model.

The question of the sculptures

The sculptures that one time adorned the *Antrum Cyclopis* at Sperlonga now are collocated in a different environment from the original (Fig. 16). Their arrangement within the museums has distorted the peculiar aspect of these place.

The digital survey and the next gathered data processing, trough the production of digital three-dimensional model, has allowed, for first, to virtually replace the sculptures in their ancient environment recreating the original scenographic of the *caenatio* at Sperlonga and demonstrating the effective presence of the sculptures in the place as hypothesized by the archaeologists (Fig. 17).

While the dimensional analysis (Fig. 18) led to reject the hypothesis, supported by some scholars, about the presence of a Cyclops sculpture, with the same dimensions of the sculpture of Sperlonga, in the *Serapeo* of Hadrian's Villa at Tivoli. «For first it is possible to establish that an eventual sculptural group inside the *Serapeo*, may not extend over the width of four meters and thirty centimeters: in fact the checked measurements inside the nymphaeum does not exceed four meters and forty centimeters. This metric observation is supported by perspective vision, that allows to exclude the arrangement of a statuary group within the depth of the nymphaeum, because the group will be barely visible by the views point, near and far, being, at the same time, a heavy occlusion to the niches around the sides of the same nymphaeum» (VERDIANI 2008).

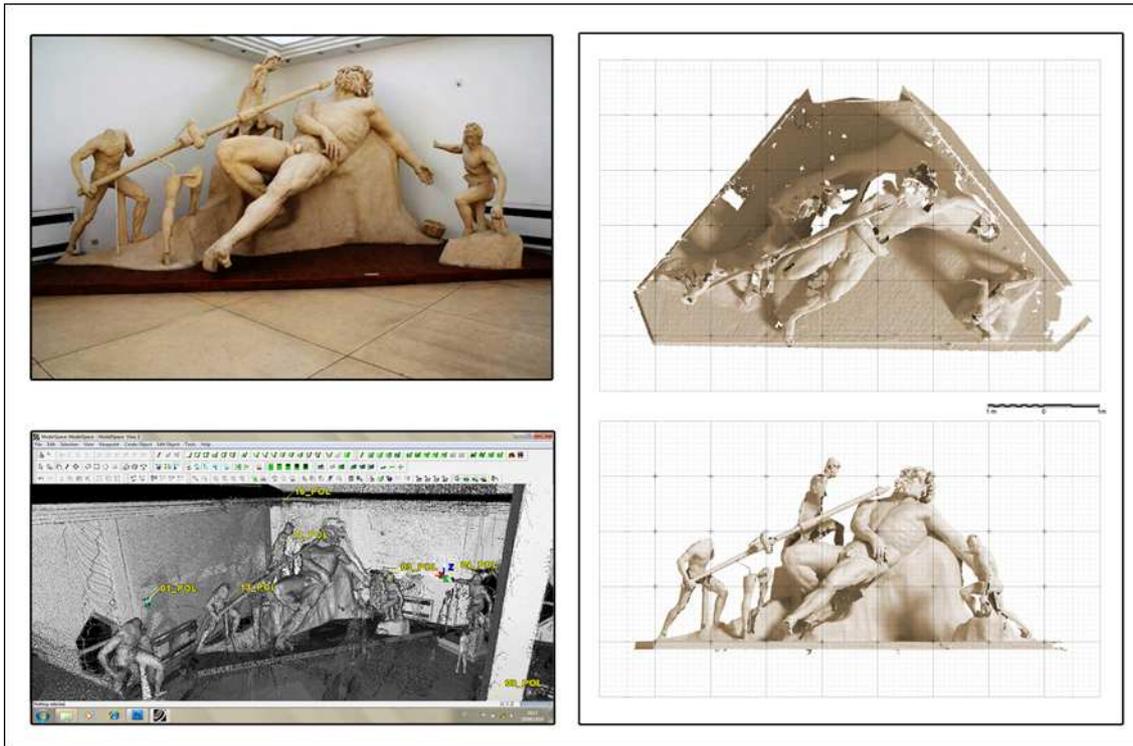


Fig. 16 – The sculptures that once decorated the *Antra*: the group of Polyphemus of Sperlonga. Up on the left: The archaeological remains preserved in the *Museo Archeologico Nazionale di Sperlonga* (Copyright: N. Cassieri). Down on the left: view of point cloud model. On the right: 3D reconstruction worked out by the architect Filippo Fantini.

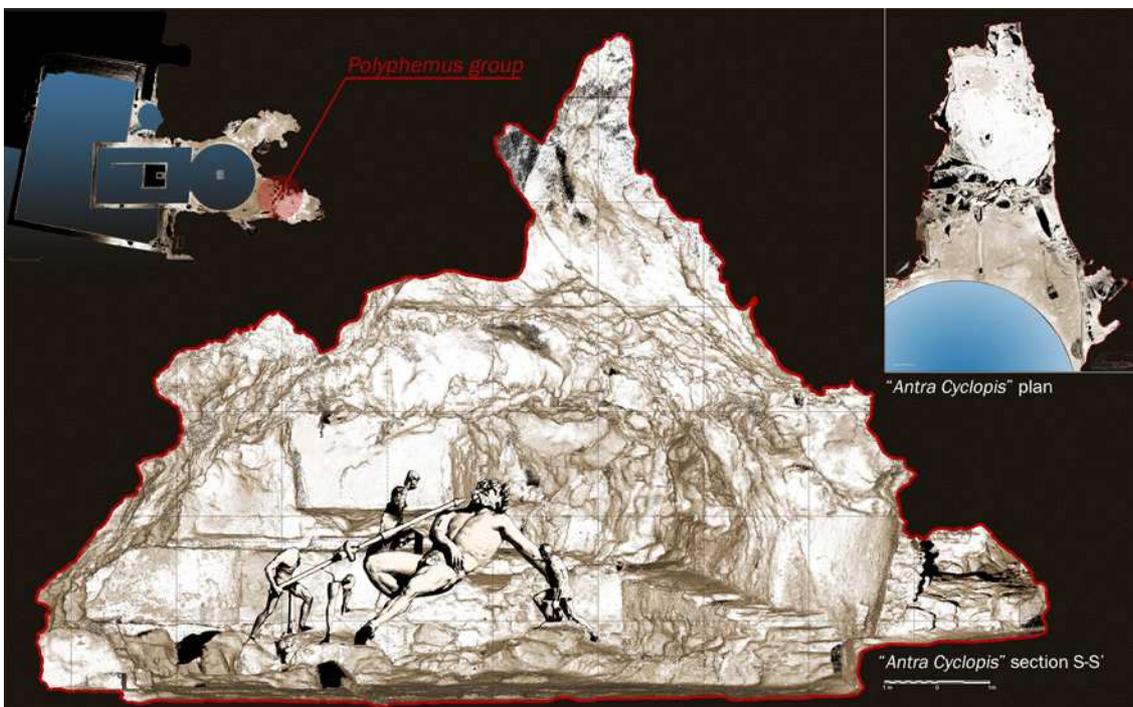


Fig. 17 – Relocation of Polyphemus group within its original context.

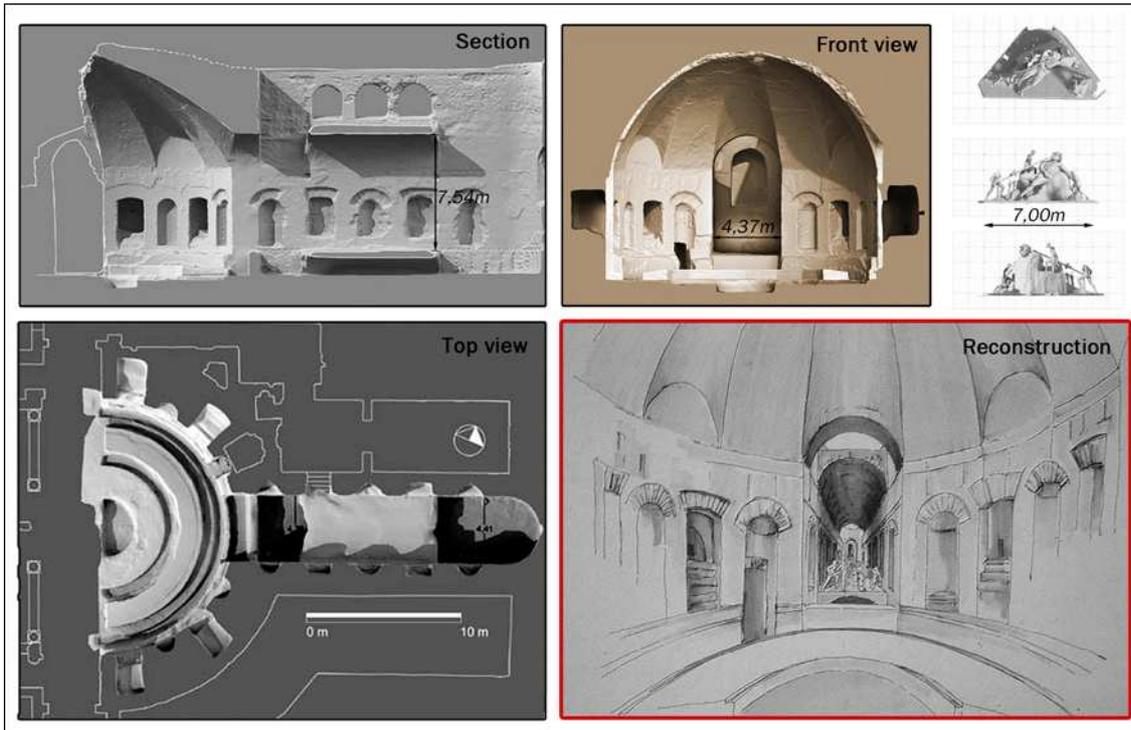


Fig. 18 – Section, front view and top view extracts from digital survey of Serapeo. Down on the right: reconstruction carried out by the archaeologist B. Andreae (Copyright: B. Andreae). This drawing shows the group of Polyphemos like Sperlonga one, fitted into the Serapeo of Hadrian's Villa. This reconstruction is clearly impossible for dimensional reasons.

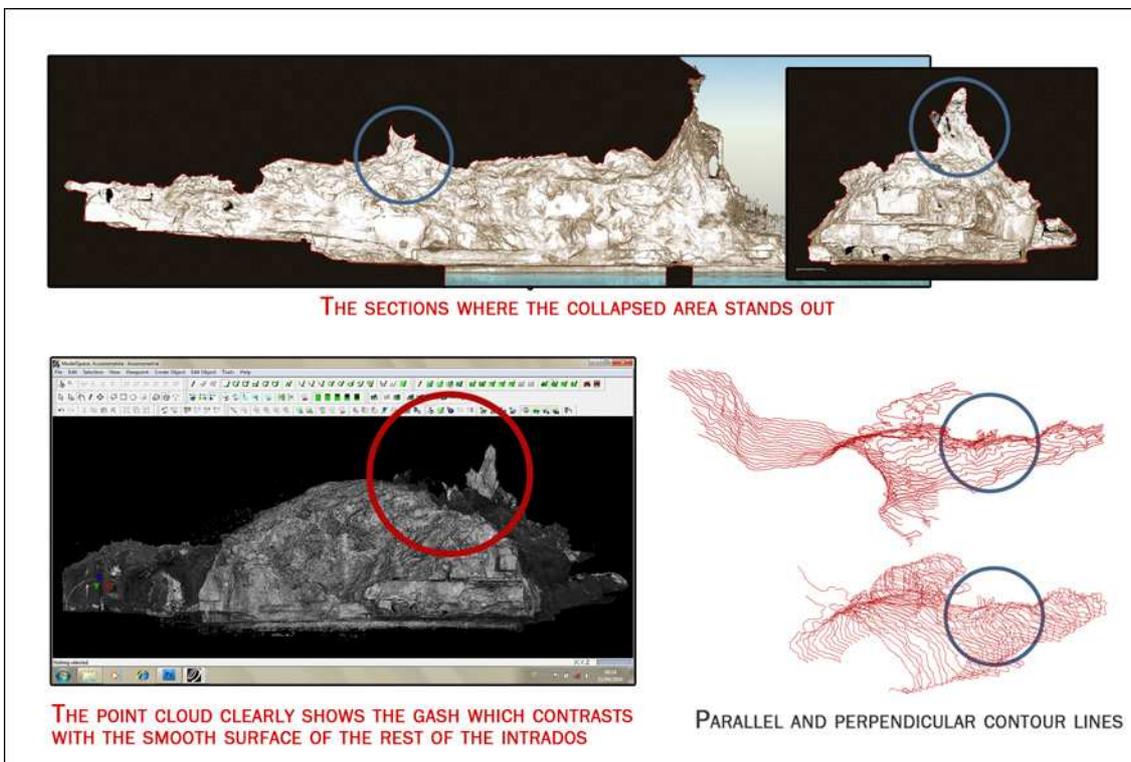


Fig. 19 – Individuation of a probably collapsed area.

The fall of 26 AD in the Tiberius' cave

The Tiberius' cave, because of its natural conformation, until now has been an very difficult subject to survey. So the laser scanner becomes, in this case, a very meaningful tool to make easy the gathering of dimensional data and to know exactly the object in each of its parts and in all its natural irregularity. In this way it was possible to deeply study, the architectural system integrated into the cave, as well as the cave in itself. In fact, the scanner allows to survey what is very difficult, and sometimes impossible, to physically reach, for example, the intrados of the cave, which has proved to be a very interesting study subject. Here, during the elaboration of the sections, an anomaly was found and this has caused an immediate curiosity. This strong discontinuity that interferes with the regular curvilinear profile of the natural vault (Fig. 19). In the point cloud model view, it is clearly evident the presence of a gash that contrasts with the smooth surface of the rest of the intrados.

To better study this issue two series of contours have been created, one in a parallel direction to the ground and the other in the perpendicular direction. Both the series show the presence of this irregularity. It's clear that the whole calotte, because of the irregular natural conformation of the stones, has many discontinuity points, but never extreme like in this area.

So it is possible to suppose that the area showing the gash has been interested by a collapse, maybe resulting by:

- A natural percolation phenomenon, the stones here is karstic, and so it is easily subject to this kind of accident
- A human intervention who, consequently to some building or restructuring operations, has inadvertently caused a stress inside the stones creating a dangerous instability.

At this point come the doubt about the collapse, Tacitus and Svetonius in their writings speak about it⁴. Now it, can be or not localized in the area identified during the elaboration of the gathered data during the survey. The authors tell that during a banquet, in the cave near the villa, a sudden rockfall from the intrados killed many people. Tiberius was saved only thanks to the intervention of his prefect Sejanus.

This area is located in the front part to the basement of Polyphemus and falls in the opposite point respect the one hypothesized by the archaeologists until now (Fig. 20).

A simple calculation quantifies the volume, and consequently the weight, of the detached rock.

If we consider the specific weight of the karstic rock (2500 kg/m^3), and we multiply by the volume previously obtained, we can find the total weight of the hypothetical fallen rocks.

Obviously it wasn't an unique rock to fall, but the entire volume crumbled in many different dimension stones, some of these stones had dimension and weight sufficient to kill a man. From the analysis we carried out his deep gash identified in the intrados surface of the cave, it would seem, having the requirements to be recognized as a likely area of the famous collapse of the year 26 AD. To strengthen this hypothesis there is the fact that no other missing parts can be identified in the rock of a consistency capable to cause a disaster because of their detachment.

⁴ The latin authors Tacitus and Svetonius tell us that during a banquet, in the cave near the villa, a sudden rockfall from intrados killed many people. Tiberius was saved only thanks to the intervention of Sejanus. *Tacito (Annali, IV 59,1-5)*, *Svetonio (Vite dei Cesari, Tiberio 39,2)*.

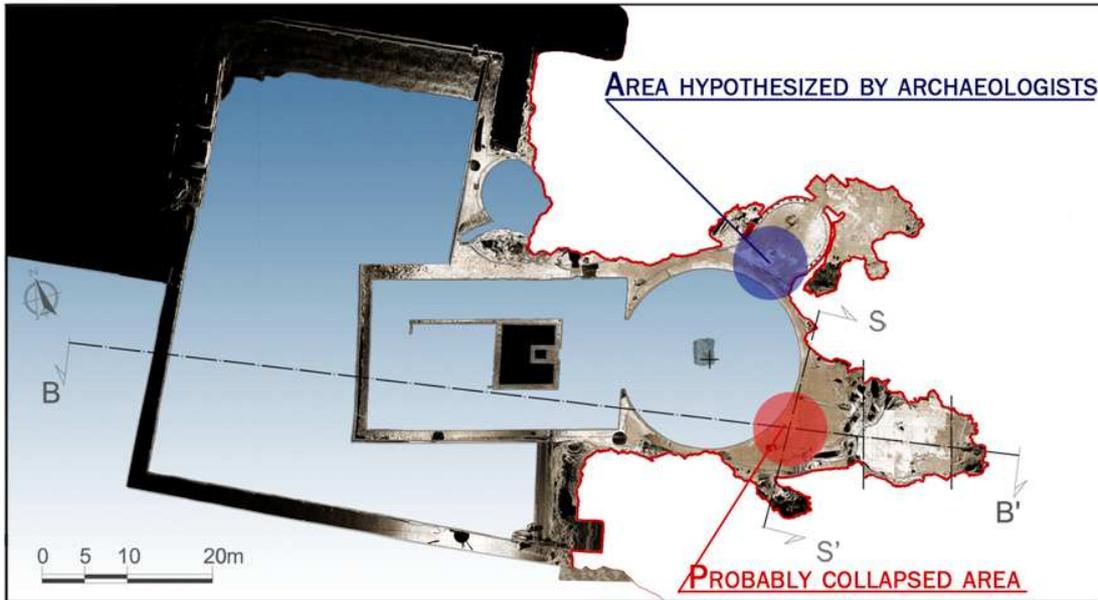


Fig. 20 – Localization in plant of probably collapsed area.

Acknowledgements

The survey of the Tiberius' Cave and of its statues was conducted 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 2008 was composed by G. Verdiani, F. Tioli, F. Fantini, S. Di Tondo. The laserscan survey tools were kindly granted by *Microgeo s.r.l.* All the survey and post processing operation were conducted thanks to the collaboration of the "Soprintendenza Archeologica del Lazio" under the supervision of dott.ssa Nicoletta Cassieri.

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Mainlimes Mobil – Presenting Archaeology and Museums with the help of smartphones

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Abstract: The technological development of mobile devices such as smartphones opens new possibilities for the presentation of scientific data. Short films, audio sequences, stills and text can be displayed in good quality.

Archaeology in particular provides many opportunities to play a pioneer part in the field of mobile information systems. You can find archaeology in the landscape, but also in museums. The idea of the project is to merge the landscape with the museum and vice versa. The information system provides archaeological content right at the current location (either in the museum or in the landscape). And the smartphones provide a true multimedia experience for the user: short films (i. e.: interviews or 3D Animations) as well as audio sequences or texts with pictures. Through GPS navigation the smartphone will alert the user when approaching a hotspot with archaeological information.

The application will run offline. Therefore an internet connection is not mandatory. This is especially important for remote regions and also for users from different countries (roaming costs).

In Bavaria the Limes along the river Main has been chosen for the pilot project. The 50 km stretch of the river frontier is clearly defined. Also there are previous projects such as a concept for signposting and a web data base. Therefore the region provides ideal conditions for the development of a prototype. The platform of the pilot system will be Apple iOS and the iPhone (plus iPod Touch and iPad), but it will be possible to migrate to other operating systems such as Android or Windows Phone 7.

Keywords: GPS, Mobile Information System, Video, Limes.

The development of an idea

Besides studying Roman archaeology (DOBAT 2009) and other scientific work Boundary Productions / Boundary Media has published several documentaries about archaeology and history in the last decade. Our special interest is the presentation of archaeological information to a public audience with the help of modern technology. The digital revolution in the last 15 years made it possible to produce high quality video content at reasonable costs. Therefore the implementation of moving images became a standard even in small museums. The medium DVD also allowed a distribution of high quality video data to an interested audience. In 2004 we started to work on a DVD about the Limes in Germany. We tried to stretch the DVD standard to its limits and created a DVD video with a partly interactive main documentary. While watching the main documentary the user had access to special short films about certain topics that were only mentioned in the main documentary. After watching a short film the DVD program returned automatically to the last sequence of the main documentary (WALKSHOFER and DOBAT 2005).

At the same time in 2004 slowly the first mobile phones with colour displays became available. Right from the beginning we experimented with video on mobile phones, but it became apparent that the user experience with video on small color displays was not exciting at all. However from then on the idea that in the near future the viewer would have the hardware in his pocket to view multimedia content anywhere has constantly been on our mind.

With the development of smartphones in the last few years the vision became reality. It is now possible to present videos, audio sequences, stills and text-information in high quality on mobile devices. Based on our experience with documentary films we can now distribute video content to the audience in new ways. It will be possible to produce for example interactive documentaries for the audience, but we have to develop new narrative techniques and explore the possibilities of the new technology (WALKSHOFER and DOBAT 2006: 125). Furthermore most of the smartphones today provide GPS navigation (WIKIPEDIA 2011a: GPS navigation device) and they have an integrated compass. This enables us to navigate users with his or her own mobile device to archaeological sites in the landscape and provide high quality information right on spot. Archaeology provides the perfect data and content to explore these new possibilities. It is possible to link an archaeological site with the museum, to link archaeological finds with the archaeological sites. These new location based services provide also a new experiences for the users. There is no need to rent technical devices from a museum or other institutions, it is possible to upload the information on your mobile device and use it as long as you want it. You get the information about a site, when you are at the site.

Archaeological Content: World Heritage Site “Frontiers of the Roman Empire”

Defining a test region

In 2009 we started to develop a concept for an archaeological information system on a mobile device. We started to think about platforms and technical requirements, but most important was to find a test region to develop a prototype. Together with the Landesstelle für nichtstaatliche Museen in Bayern and the CHC – Research Group for Archaeometry and Cultural Heritage Computing of the University of Salzburg (Austria), we were working on media content for the innovative web-based project www.museen-mainlimes.de. Within this project the archaeological information of the World Heritage Site “Frontiers of the Roman Empire: The Upper German Raetian Limes” in the region of the river Main has been gathered in a complex web data base. The web interface allows easy access to content and information. Because of the advanced data base behind the interface the content is always displayed in a unique way and there are also many cross references between different archaeological sites of the region (SCHALLER, EGGER and UHLIR 2010). The project provided already a lot of information about the Main Limes and we have already created a lot of footage for the media section of the website. Furthermore it is a clearly defined relatively small region and therefore it suited perfectly to produce a prototype (Fig. 1). Finally the Bayerische Sparkassenstiftung and the Landesstelle für nichtstaatliche Museen in Bavaria were convinced and we were able to start working on an archaeological mobile information system for the Main Limes. We then decided to concentrate on the Bavarian part of the Main Limes, the two northernmost forts of the Main region at Seligenstadt and Großkrotzenburg in Hesse were not included.

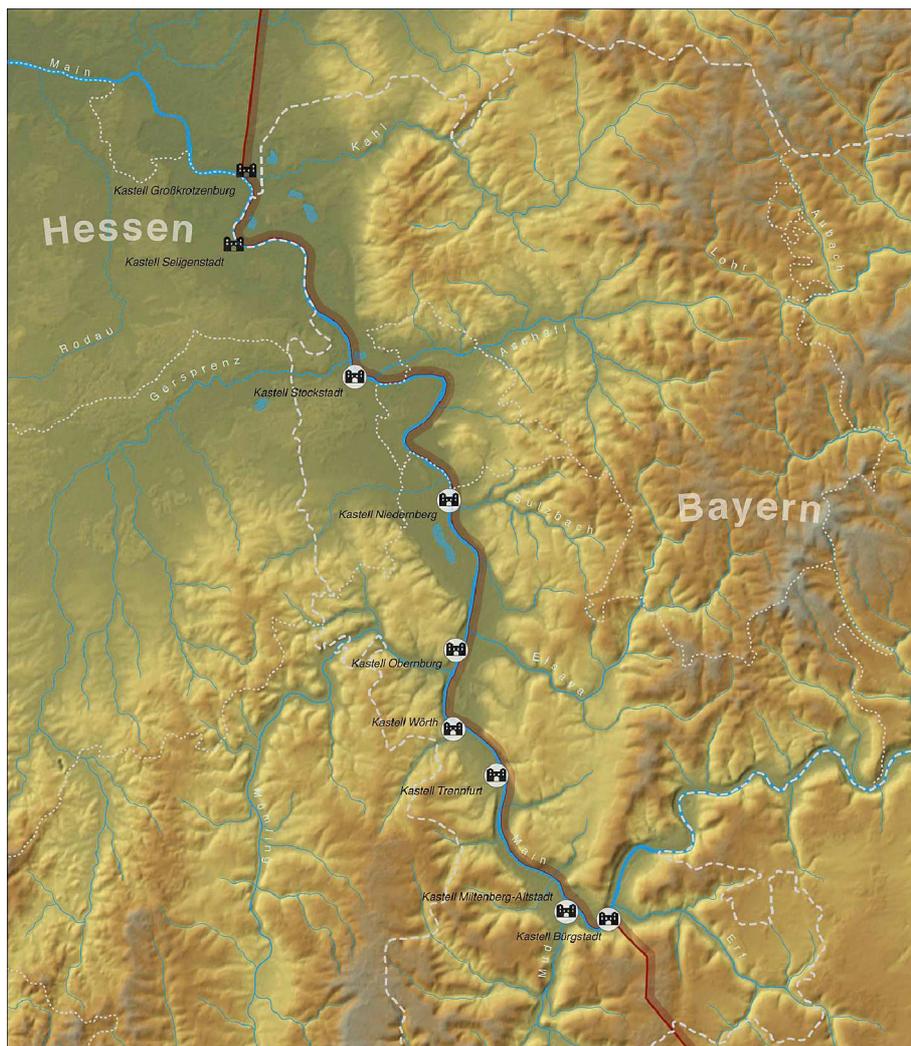


Fig. 1 – The Main Limes from Miltenberg to Großkrotzenburg (map by K. Schaller).

The archaeology of the Limes along the river Main (short description)

In 2005 the Upper German Raetian Limes became part of the UNESCO World Heritage Site “Frontiers of the Roman Empire”. The Limes in the region of the river Main (Main Limes) is part of the Upper German Limes. From Miltenberg in Bavaria to Großkrotzenburg in Hesse the river Main marks the frontier of the Roman Empire. Between the Odenwald forest and the Spessart forest the river runs for approximately 50 km from south to north.

Late in the reign of the emperor Antoninus Pius (AD 138–AD 161) the final course of the Limes was set in the Main region. The so-called Odenwald Limes was abandoned and the Main Limes was extended either from the fort of Obensburg or the fort of Wörth to Miltenberg. From Miltenberg the new artificial frontier line ran for approximately 80 km straight to the south where the Upper German Limes met the Raetian Limes in the Rotenbach valley next to Lorch.

The Main Limes was supervised by nine forts. The fort of Großkrotzenburg in Hesse and the fort of Miltenberg-Bürgstadt (Ostkastell) guarded the transition from the artificial frontier over land to the river frontier line along the Main river. Six forts were occupied by regular *cohortes* (Großkrotzenburg,

Seligenstadt, Stockstadt, Obernburg, Miltenberg-Altstadtkastell), while the three smaller forts were occupied by so called *numeri* (STEIDL 2008).

At present only two watchtowers just to the south of Obernburg have been discovered along the river frontier. Presumably most of the remains of watchtowers have been destroyed by floodings (Fig. 2). In general it is difficult to promote and demonstrate the remains of the World Heritage Site along the Main Limes. Usually the archaeology is invisible in the ground. In many cases modern towns have been built on top of the Roman forts and nothing can be seen today. There are only few sites where some archaeological remains are visible. At the so-called Altstadtkastell of Miltenberg for example the remains of the stone wall of the fort can be spotted in an orchard and the remains of the bath house of the fort have been preserved. The principia of the fort itself is not visible, but the remains of a medieval church built on top of the principia can still be seen today.



Fig. 2 – Flood of the river Main in 2011 with the town of Würth in the background.

The forts of Stockstadt, Niedernberg, Obernburg and Miltenberg-Bürgstadt have been overbuilt. The fort of Stockstadt has been destroyed by the construction of a modern factory on top of the Roman remains. The *numerus* fort of Miltenberg-Bürgstadt lies beneath a residential complex. The forts of Niedernberg and Obernburg represent the centres of the town and village. Even today the streets follow the patterns of the ancient Roman forts and by walking through these centres it is still possible to experience the dimensions of the Roman forts. The archaeology of Obernburg is especially interesting. Here a beneficiary station has been discovered. Extensive archaeological excavations revealed the ground plan, many finds and inscriptions.

Obernburg is the best researched beneficiary station in the whole Roman Empire. Of special interest are the inscriptions of the beneficiaries that allow to reconstruct a vivid picture of the Roman past in the region (STEIDL 2008: 108 ff.). Many inscriptions and finds are on display in the local Roman Museum and the Bavarian State Archaeological Collection in Munich (see below). The numeri forts of Wörth and Trennfurt are not overbuilt, they are located in a field and in an orchard. Nothing is visible above ground. The fort of Wörth is of special interest, because the north-western stone wall of the fort dropped completely into the ditch. This enabled the archaeologists to reconstruct the height of the fort wall quite accurately. It had a height of approximately 6,35 meter.

The forts of Seligenstadt and Großkrotzenburg in Hesse are located in the centres of the villages (BAATZ and HERMANN 2008: 325 ff., 477 f.).

Museums in the region

There are five museums with Roman collections in the region. The museums of Wörth, Stockstadt and Großkrotzenburg are relatively small museums. They open only once a week or on special request. The Roman Museum of Obernburg presents the epigraphic inscriptions of the beneficiaries and other finds from the fort of Obernburg.

The city museum of Miltenberg is currently the most important museum of the region. There is also a collection of Roman artefacts on two floors. Finds from the two forts in the region and from the Limes are presented.

The "Museums- and Communications Plan for the Limes World Heritage Site in Bavaria"

(http://www2.sbg.ac.at/chc/FRE_DOWNLOADS/LimesMusDevelopment_BY.pdf) recommends the establishment of a central "Main Limes Museum at an appropriate location at the Bavarian Lower Main".

The museums of the Main region are vital to present the World Heritage Site Limes to the public. They provide original artefacts from the region and therefore enable the people to identify with their history and archaeology (FLÜGEL 2008).

The archaeological information system tries to merge the archaeological site with its finds (that are usually located in the museum). The user will get information about finds immediately in the landscape, where it has been discovered. At the same time he gets the information where he can find the original artefact. The museums will probably also provide services such as WIFI connections to download the application in the region.

Technological requirements and distribution

At the beginning of the project we had to make a decision for a platform. There are two important operating systems for smartphones that seem to dominate the future in that field. On the one hand is the innovative Apple iOS and on the other hand is the open source platform Android, promoted by Google.

For our prototype we chose Apple iOS. The reasons for that decision were:

- easy distribution through the AppStore
- limited hardware versions
- many users

The application should be optimized for the iPhone, but it should also run on the iPodTouch and the iPad. All functions including GPS navigation will be available on the iPhone. Therefore the iPhone is recommended for the best user experience.

Important is also that a migration to other platforms is possible. Currently the optimal solution seems to be a production for Apple iOS and for Android. Currently about 50–60% of the smartphone users could then access the application (if both platforms are covered) and the tendency is that there will be an increasing number of users for those two operating systems (WIKIPEDIA 2011b: Smartphone).

We also decided that it is important to create an application that will work offline. The Limes sometimes runs through remote regions and therefore it is important that the internet connection is not mandatory. Especially videos and audio sequences would need a high speed internet connection to guarantee a good user experience. Therefore we integrated the content in the application, this ensures good video and audio quality everywhere. It is also important for international users, as data roaming costs in the EU are often very high. If there is an active internet connection the user will have access to additional content through the web click button on the top right. It provides access to the web data base www.museen-mainlimes.de (see above).

Realisation

Development of the content

Even if you are using the most recent and exciting technology that is available on the market, the content should remain the most important concern. The technological devices are just vehicles to promote the content about archaeology to your audience.

You have to think about the development of your content even more carefully as new technology also provides the possibility to adapt or change narrative techniques for the content. This is especially true for multimedia devices like smartphones. It is possible to wrap your content in a video file, an audio sequence or text-picture information. Also people will use it in different ways. They will access the information in different situations such as standing, sitting, in a cafe or somewhere in the landscape, etc.

You have to carefully think about the best media to transport your message in each single case. Certainly there are also financial limitations, a text-picture information is cheaper to produce than an audio sequence. And of course a high quality video sequence is most expensive. And even within a video sequence an animated 3D model is of course more expensive in comparison with a landscape shot with just panning or tilting in different directions.

Therefore we defined at first, what we wanted to achieve with this application. Our aim is to enable the user to access valuable and interesting archaeological information, when he is visiting an archaeological site in the landscape. The GPS navigation should help the user to verify the location of a Roman fort (that is not visible) in the landscape for example (Fig. 3). Therefore we defined 48 hotspots along the Bavarian part of the Main Limes from Miltenberg to Stockstadt. Each of these hotspots is related to an archaeological site or find or it provides important historical or epigraphical information. Then we had to define which is the best form of medium to transport the information for each of these hotspots. A descriptive example is the fort of Wörth, which is located in a field (see above). Nothing is visible today. Therefore the decision has been taken to implement an animated 3D reconstruction as a video sequence. The user is standing next to the field and

through the 3D model he is enabled to envision the Roman fort in the landscape. Another interesting example is a hotspot in Obernberg. The house with number 41 has a Roman inscription in its wall. It is at eye level and the visitor can easily read the Latin inscription. Instead of forcing the user to look at a video sequence or a text information, we produced an audio sequence. While examining the original inscription in the house wall, the users gets the necessary information via audio.

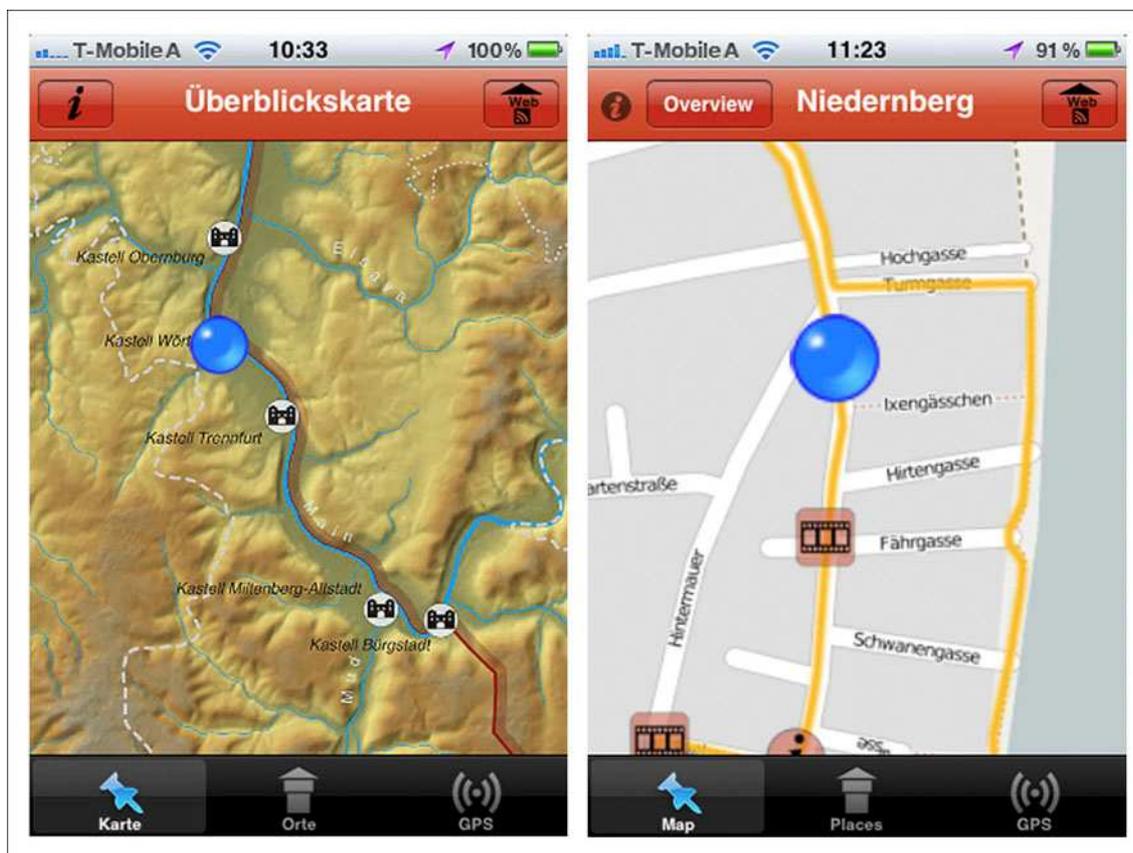


Fig. 3 – Screenshot with overview map and detail map. Blue GPS location marker.

The 48 hotspots of the Mainlimes Mobil application are:

- 16 video sequences (approx. length: ~ 01:00–03:00 min.)
- 14 audio sequences
- 18 text-/picture-information

Furthermore our aim was also that all 48 hotspots together describe the World Heritage Site Limes and the functioning of the frontier system. Therefore each of the hotspots focuses on different aspects of the frontier system. Together the hotspots form a picture of the Main Limes enabling the user to understand the function of a Roman frontier system based on current research.

Technical implementation

The production of content is already demanding, especially if you include video and audio. Nevertheless it becomes even more complicated with the technical implementation of the content into the application. At first we had to solve the navigation within the application. Georeferenced maps provide the main access to the content. An overview map shows the whole region and several detailed maps provide access to the

content. The maps are zoomable (pinch and zoom) and clickable. By choosing the fort of Wörth on the overview map, the user gets access to a detailed map of the city of Wörth. On this map the hotspots are available. By clicking on a hotspot the user gets direct access to the content of the hotspots. If the user has an iPhone, he can turn on GPS navigation. A blue spot marks his position on the map. It is now possible for him to explore the Roman archaeology in the vicinity of Wörth. When he approaches a hotspot an alert with a sound signal is triggered within 15 meters radius. The user can then decide, if he is interested in that particular information (Fig. 4). Additionally an alternative navigation in a table view is available for each town or village. This provides instant access and it is also a good overview. To guarantee an accurate navigation and a correct alert each of the hotspots is geo-referenced.



Fig. 4 – Screenshots from Miltenberg. On the left side showing the alert function.

Web Tool

The so-called Web Tool allowed us to gather all the information and connect the content with the maps and hotspots. Each hotspot needed the correct longitude and latitude, then it was connected to the correct map. Finally the content was attached to the hotspot and the programmers were able create the application. Certainly it needed a lot of testing. The most difficult part with a lot of trial and error was the correct location of the hotspots, when they were quite closely together (> 20 m).

The Web Tool also allows us to keep the application up to date. Once the geo-referenced hotspots are connected with the map and the content, it is quite straight forward to update the application. It is possible to integrate new results from scientific research at reasonable costs. For example we can envision the text-

picture information within the application as mobile wall charts. In contrast to wall charts in the landscape they can be updated quite easily. In the future a combination with wall charts in the landscape and text-picture information might be the best way to present a monument with the content well-matched on both media.

Additionally the content was planned from the beginning in two languages. The web tool provided the possibility to record both languages at the same time. Finally there will be two versions of the application, one in German and one in English.

Future developments

The archaeological information system Main Limes Mobil provides information about archaeological sites and finds in the region. It brings the museum with its finds into the landscape and it can also bring the landscape into the museum. An integrated GPS based alert system automatically informs the user, when he is approaching an interesting site with available information in the landscape.

The integration of different languages is very important within the European Union and we have integrated many languages in earlier multimedia projects (WALKSHOFER and DOBAT 2008). The mobil information systems on smartphones also enables us to use different languages. Therefore it is also possible with smartphone applications to promote an archaeological monument to an international audience.

In this version we have already integrated a riddle. If you are able to solve it, you will get a DVD about the Frontiers of the Roman Empire (BREEZE 2011: 76). The idea of the riddle is based on the popular geo-caching. It can only be solved, if you visit the sites. In a next step this geo-caching riddle will be integrated in the navigation of the application. It will be possible to monitor your progress in solving the riddle within the application. This feature is targeted especially on families spending a day or two in the landscape, discovering archaeological sites, solving a riddle and automatically learning more about the World Heritage Site.

Another important feature in future projects will be the implementation of augmented reality. With this technology it will be possible to mark archaeological monuments in the live view of the camera provided by the smart phones.

Those new features are planned for other parts of the World Heritage Site and other sites. Currently we are planning to extend the Main Limes Mobil application on parts of the Raetian Limes in Bavaria.

Certainly one of our future aims is to provide a version for Android and Apple iOS simultaneously.

The application has been completed in March 2011 and it will be available soon in the iTunes AppStore. The application will be presented by the Bavarian Minister of Science and Culture Dr. W. Heubisch, by the Bayerische Sparkassenstiftung and by the Landestelle für nichtstaatliche Museen in Bavaria in July 2011. Therefore the application will be available in the App Store for free in July 2011.

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Highly Accurate Photorealistic Modeling of Cultural Heritage Assets

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Abstract: Digital applications become more and more relevant in cultural heritage related management. Digital models of individual assets or of complete sites or excavations are commonly used to support documentation and visualization tasks. However, the requirements for those two applications differ significantly. While for documentation purposes special focus is drawn on proper and accurate geometric modeling, especially in visualization applications, the geometrical model is commonly generalized as far as possible in order to enable high performance rendering. This divergence in the requirements causes high costs if both applications are to be fulfilled as data and models captured for one are generally not applicable for the other purpose. To overcome this, we propose an automated processing chain for the generation of highly accurate, photorealistic models of cultural heritage assets. This method is based on processing point clouds acquired by laser scanning. It is not restricted to a certain instrument type or a certain scale. It has been approved for various documentation applications at different scales ranging from small pieces like a chalice or vases over man high sculptures up to objects of some dozens of meters in size like fountains or a staircase. It could be demonstrated, that the achieved geometric models are applicable for documentation purposes at millimeter scale. Within this contribution, we demonstrate its applicability for the generation of high resolution, photorealistic models. In comparison to models determined from images only, the results of the proposed processing approach are more accurate (from a geometrical point of view) and the interactive processing effort is reduced by approximately forty percent.

Keywords: Virtual reality, laser scanning, texture mapping, documentation, geometric modeling.

Introduction

Photorealistic, three-dimensional models have the ability to support various management tasks in cultural heritage preservation, documentation, and marketing. However, the requirements to fulfill these tasks are manifold. On the one hand, highly accurate models are necessary for reliable documentation purposes while on the other hand, for marketing and public relations – but for visual inspection as well – the visual representation is of major importance while, in those cases, the requirements on the geometrical correctness is less important. Hence, fulfilling the requirements for both tasks becomes a challenging task especially if economic aspects have to be considered. Additionally, the variety of devices for representing virtual models increased significantly in the recent past, now ranging from high resolution and large scale projection installations to small devices like iPhone or Android based phones. This multi-scale applicability of such models results in additional quality requirements.

For the acquisition of accurate three-dimensional geometric models, Terrestrial Laser Scanning (TLS) has proven to be an adequate tool. The variety of instruments ranges from low budget close range scanners

available from 1.000 € upwards to high-end instruments costing several 100.000 €. The achievable quality is dependent on the field of application and the measurement technique used. Close range scanners (i.e. up to several meter measurement distance) achieve 0.01 mm accuracy or even better. However, due to their restricted field of view, the acquisition of huge objects becomes uneconomical. For distances of up to 100 meters, phase-shift scanners achieve an accuracy of some millimeters and due to their panoramic field of view, they are well suited for numerous applications in cultural heritage documentation. For longer distances (up to several kilometers), pulse-round scanners are commonly used allowing for a ranging accuracy better than a centimeter.

TLS typically provides enormous point clouds (up to 1.000.000 points per second) which are – in general – not well suited for the above mentioned tasks. Hence, further processing is required in order to derive products fulfilling the specific requirements. The major post-processing steps are registration (i.e. transforming the individually captured scans into one coordinate system (e.g. RUSINKIEWICZ and LEVOY 2001; ULLRICH et al. 2003) and model generation. Most software solutions distributed together with the instruments and numerous commercially available post-processing software tools provide such functionality. In this contribution, we propose an automated processing chain for the generation of three-dimensional triangulation models from TLS-point clouds (DORNINGER and NOTHEGGER 2009).

The generation of visualization models from geometric models requires the mapping of adequate texture images. The requirements on the geometric foundation differ from documentation requirements. Therefore, if aiming at visualization applications only, image data is commonly used to derive the geometric model directly without an additional (geometric) data source. In this case, highly generalized geometric models, representing the coarse shape of the object are derived manually by, e.g., stereo analysis of images. In this case, small surface structures are generally not represented by the base geometry model directly but by so-called geometry texture maps which may be derived from image data as well (e.g. shape from shading (HORN and BROOKS 1989). Anyhow, such models are not well suited for documentation as they aim at proper visual appearance while considering geometric correctness as less important.

To fulfill the requirements for both types of application, we propose a workflow allowing for automated determination of triangulation models based on point cloud data. Based on this geometrically accurate foundation, visualization models are derived interactively using commercial software tools originally developed for the gaming industry. In the following we will introduce the major characteristics of our workflow and analyze the achievable results based on modeling a sarcophagus of the Pharaoh Tutankhamun. As demonstrated, the resulting virtual model can be used for documentation purposes at millimeter scale and for multi-scale visualization applications such as high-resolution renderings or within a Smartphone application.

Methodology and Related Work

So far, economical factors prevented an overall application of TLS based technologies in the field of cultural heritage documentation. Instead, traditional techniques such as image based documentation or map drawing were often used for data acquisition especially in the archeological context. Nevertheless, due to the achievable performance and accuracy, the market share of TLS based data acquisition grew significantly.

In the following, we distinguish two applications of geometric models: documentation and visualization. Documentation of cultural heritage sites is of major importance and accurate three-dimensional models are well suited to fulfill numerous tasks in this field. For visualization tasks such as web based representation, customer DVDs or on-site computer installations, the documentation aspect is commonly neglected while focusing on creating visually appealing models. Figure 1 compares the major characteristics of documentation and visualization models and their major fields of application. Due to the contrariness of these requirements, in general geometric models are either generated to fulfill only one task – i.e. either documentation or visualization – due to economical restrictions.

Documentation	Visualization
Geometrically accurate representation	Geometrically generalized to support rendering requirements
Geometrically rich in detail	Richness in detail through texture
Foundation for ... <ul style="list-style-type: none"> • Planning • Restoration • Monitoring • etc. 	Foundation for ... <ul style="list-style-type: none"> • Visual inspection • Marketing • Public Relations • etc.

Fig. 1 – Characteristics of documentation (left) and visualization (right) models.

To overcome this, several aspects need to be fulfilled in order to generate multi-purpose geometric models in an economically feasible manner. Figure 2 shows a processing chain for generating such models based on TLS (geometry) and image (texture) data.

Terrestrial Laser Scanning (TLS)	Image Data (Texture)
Data acquisition <ul style="list-style-type: none"> • point cloud measurement 	<ul style="list-style-type: none"> • image acquisition
Calibration – minimizing systematic errors <ul style="list-style-type: none"> • e.g. distance, intensity, angle 	<ul style="list-style-type: none"> • e.g.: radiometry, distortion
3D-filtering <ul style="list-style-type: none"> • minimizing measurement noise • data reduction (thinning) 	<ul style="list-style-type: none"> • resampling
Registration <ul style="list-style-type: none"> • transformation of scans into project coordinate system 	<ul style="list-style-type: none"> • manual image assignment • bundle block
Merging <ul style="list-style-type: none"> • minimizing remaining discrepancies 	<ul style="list-style-type: none"> • mosaicing
Modeling <ul style="list-style-type: none"> • e.g. triangulation, NURBS, primitive fitting 	<ul style="list-style-type: none"> • manual texture mapping • rendering

Fig. 2 – Processing chain from data acquisition to the virtual model. The TLS processing (left) is applied automatically. The image processing steps (right) are applied interactively using commercial software tools.

The proposed processing chain is based on highly automated processing of TLS point cloud data (DORNINGER and NOTHEGGER 2009). For data acquisition, we propose the application of phase-shift

TLS. However, close range or time-of-flight instruments are also applicable, depending on the purpose, and, especially the extension of the object to be captured. For the steps "3D-filtering" and "Merging", the same algorithm is applied. It is based on the highly robust estimation of local normal vectors which are used to determine the most probable local surface behavior. Based on this information, the most probable surface position within the noisy data is determined by density estimation (NOTHEGGER and DORNINGER 2009). The registration, i.e. the transformation of the individual scans into one project coordinate system is performed using a hybrid approach based on the iterative closest point (ICP) method while considering tie features as well. A similar approach is described by AKCA and GRUEN (2007). The triangulation model is determined using commercial software.

Based on the triangulation model, the visualization model is generated using commercial software tools (Maya and 3Dcoat for modeling and texture mapping and Zbrush additionally for texture mapping). Within this process, the coarse geometric model representing the major defining objects parts is reconstructed. Further on, UV maps are generated representing smaller details and controlling the surface rendering behavior. Finally, the UV maps and the radiometrically corrected images are projected onto the coarse geometry. The resulting visualization models can be used in their original resolution or a supervised resampling process may be applied to reduce them with respect to the expected output device.

Results and Discussion

In the following, we demonstrate the whole processing chain from TLS and image acquisition by means of a sarcophagus shown at the exhibition "*Tutankhamun – His Tomb and his Treasure*". This exhibition consists of reproductions of the objects originally found within the tomb of the Egyptian Pharaoh Tutankhamun. The objects were manufactured under supervision of the Museum of Egyptian Antiquities in Cairo and are produced using true to original materials. The data acquisition took place in Hamburg, Germany, using a Faro Photon 80 Scanner. This instrument applies the phase-shift measurement principle. During one night (approx. 10 hours), all bigger objects were entirely captured by 77 scans. Additionally, we tried to capture all smaller objects at least by one scan. Fortunately, glass cases did not influence the measurements significantly. Figure 3 shows a panoramic view of a single scan acquired close to the four inner sarcophagi of the Pharaoh. The modeling process of the sarcophagus seen left of the image center is discussed in detail in the following. The colors represent the intensity values captured by the scanner. Those represent the local reflectivity behavior of the scanned objects. Although we expected major problems on the surface of the sarcophagus due to the highly reflective gold leaf material, it turned out, that those remained controllable. The instrument accuracy is about 3 millimeter at 5 meter distance for single point measurement. Compared to the current Faro scanners (Photon 120 and Focus 3D), the scanner used had a lower repetition rate of 120.000 points per second. Aiming at high point densities, the average scanning time was approximately 6 minutes per scan.

Texture acquisition was performed using a Canon 20D with a variable focal length of 14 to 18 millimeter and took approximately 5 hours. Due to the time pressure, we were not able to use additional lightning. Hence, we had to cope with the original lightning conditions of the exhibition's rooms. This caused several problems such as specular reflections, which had to be retouched manually using image processing software.



Fig. 3 – Polar view of 360° panoramic TLS data acquisition showing a typical scenario of acquiring objects at a museum site. A part of this scan was used for generating the model shown in Fig. 4.

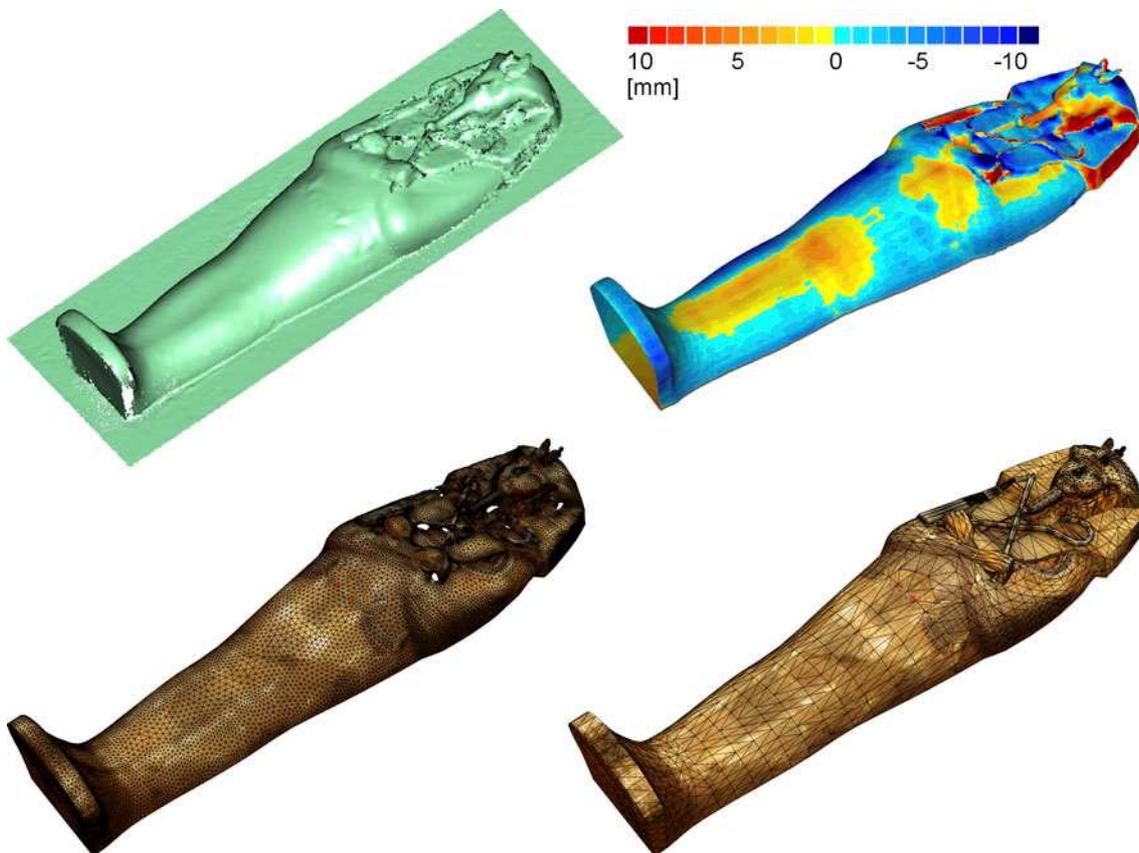


Fig. 4 – Processing steps from a TLS point cloud to textured models. Upper left: Shading of filtered point cloud; Lower: Automatically generated triangulation model (left) and interactively derived visualization model (right); Upper right: differences of automatically and manually derived geometry model.

The upper left image of Figure 4 shows the resulting point cloud after applying the following processing steps on the original scanning data:

- 3d-filtering of individual scans: data reduction by factor 5 \Rightarrow ~300,000 points
- registration
- 3d-filtering for merging individual scans \Rightarrow ~200,000 points

Afterwards, a triangulation was applied resulting in the triangulation shown superimposed on a rendered model in the lower left image of Figure 4 (~78.000 triangles). The manually reconstructed model consists of ~6.000 triangles and is shown in the lower right image of Figure 4. The differences of the manually

generated model (i.e. the visualization model) and the automatically derived triangulation (i.e. the documentation model) are shown in the upper right image of Figure 4. The major parts of the two models differ less than 3 mm. Bigger discrepancies (up to 10 mm) can be found in the regions of the insignia which were obviously not captured properly by the laser scan and had to be remodeled manually based on the image information. Further on, discrepancies occur along inner edges. This effect seems to be caused by reflectivity problems of the scanner on the golden surface. In this case, the accuracy of the documentation model is even worse than those of the visualization model as for this, the image data was used in order to fix the deficiencies of the documentation model based on laser scanning data only.

From all together eight selected highlight objects of the exhibition, three-dimensional visualization models have been generated. Those models were finally prepared for integration into an iPhone application. The memory restrictions of such devices define a tight requirement framework concerning the maximum complexity of virtual models to be displayed properly. Further challenging tasks are the implementation of a proper camera coordinate system and of a finger touch based navigation enabling zooming, panning and rotating functionality, based on finger tip gestures only. Figure 5 shows screens of the iPhone application "Tutankhamun – His Tomb and His Treasures".



Fig. 5 – iPhone application with 3D-content derived from TLS data. The high resolution documentation models were prepared for displaying on the smartphone device (lower, right).

Conclusions and Outlook

Within this contribution, we discussed an automated processing chain for the simultaneous generation of highly accurate documentation and visualization models based on laser scanning point clouds and additionally captured image data. The advantages of the proposed method are its capabilities in reducing the amount of input data (billions of points) significantly while preserving as much details as possible (adaptive, robust thinning). The capabilities of the 3d-filtering approach used have been already discussed in former publications. Hence, the major focus of this paper was drawn on the applicability of the resulting documentation models as basis for subsequent generation of visualization models.

For the investigated object, it could be demonstrated, that the visualization model fits to the documentation model with maximum differences of ± 3 mm for the majority of its surface. At some regions, maximum differences of ± 10 mm did occur. Most of those were caused by reflectivity problems due to the highly reflective golden surface of the sarcophagus. However, the model's accuracy could be improved by means of the image data in these regions.

Based on the given example, we demonstrated that the manual effort to generate high resolution visualization models can be reduced by approximately forty percent if using automatically generated laser scanning models for the subsequent interactive modeling process. This makes the simultaneous generation of documentation and visualization models economically more feasible. Hence, the overall production costs can be reduced significantly (i.e. the costs for the scanning campaign are significantly lower than the costs of a photo based production) and, by the way, the geometrically accurate documentation is ensured increasing the benefit of the results. Therefore, this offers new fields of application such as archeology, cultural heritage, virtual museum, and many more.

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Ad thermas: a system between private and public life in the ancient town

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Abstract: The realization of public baths represent one of the most important urban operation of the ancient town, it is used to qualify a district or a new settlement zone. Often the building was financed by the emperor or by a rich citizen with the intent of some politic propaganda. This kind of places was used for hygiene purposes, cultural, social and entertainment requirements. Beside at this big “house for the people” another private plant was erected, with a smaller dimension but with luxurious installation and decoration. The Hadrian's Villa, in Tivoli, with a whole set of noble and slavish structures, can be compared to a micro-urban system. In this place there are noble plants (Heliocaminus and Small baths) and popular plants (Great baths). This research moves from a digital survey, considered as the fundamental starting point of any documentation; then, using the gathered data to determinate technologies and typological analogies between these structures, and then to understand the design and the logic of composition of these amazing buildings.

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

The origin an diffusion of thermal baths

The emergence and spread of thermal baths in the ancient world was originated from hygienic necessities: running water was not always available in the houses, and therefore the need of facilities for cleanliness arose. In the Roman world smaller structures, the *balnea*, developed first; these were often narrow, with few chambers, and were heated by mobile braziers and organized with the bare essentials for bathing.



Fig. 1 – Foro di Ercolano, thermal baths.

Later, in the Imperial Age, the development of technology and heating techniques allowed the construction of larger and more complex facilities, the *Thermae*: these centres became real "people's buildings", with several rooms, enriched with saunas, chambers for massages and anointing. At the same time, the *Thermae* became increasingly a place for socializing or business meetings, and so libraries, game rooms and theatres were added to the bath core. The thermal path usually began with a slight warming of the body through gentle exercises or through a pause in the *tepidarium*, followed by a stop in the sauna, a hot bath in the *calidarium* and finally a cold bath in the *frigidarium*.

The Roman emperors, starting from Augustus, understood that construction of a new thermal bath or the reduction of the entrance fees (or even free admittance) would help them gain the favour of the lower classes. To achieve this objective, they realized huge facilities that could accommodate up to 3000 people at a time (Baths of Diocletian, 298 b.C.).

However, when comparing baths inside the villas of the wealthy Romans with those built by the Roman emperors for the people, substantial differences can be noted: these differences involve the architectural and decorative fields, but also the typology of the rooms.



Fig. 2 – Terme di Caracalla (Rome), a front view.

The Hadrian's Villa

The Emperor's Villa in Tivoli isn't really a town but a private space, but a comparison to the urban context is possible because of the size of the property, the number of people accommodated and especially the simultaneous presence of different social classes.

The Villa has three baths – the *Heliocaminus* Baths, the Large Baths and the Small Baths: since 2004 several surveys have been carried out on these buildings by means of laser scanning, referencing the scans on a common topographic network. The *Heliocaminus* and the Small Baths, both luxurious and small in size, were built for the emperor and his court in two different stages of construction, while the Large Baths, less rich but bigger, were built for the workers of the Villa.

To analyze these complexes we have to consider that Emperor Hadrian was a revolutionary architect for his time, and, furthermore, there were no limitations because he was working within the private space of his villa: it follows that in the two noble baths he experimented new architectural and technological techniques.

Starting from the surveys carried out, we tried to understand the functions and the degree of heating achieved inside each room by analyzing their exposure, size, insulation (due to the number and size of windows), the presence, number and size of the furnaces, the presence of cavities in the walls and ceilings for the passage of the fumes, the presence of steam in the air (introduced or derived from heated basins),

the number and size of the exhaust holes for the fumes. These parameters are used to distinguish the tepidaria, the calidaria, the sudationes (steam saunas) and the laconica (dry saunas).



Fig. 3 – Hadrian's Villa, thermal baths.



Fig. 4 – Various technological solutions in the thermal baths.

The Heliocaminus Baths

The Heliocaminus Baths are the most ancient thermal complex of the Villa. The path, deducible from the plan, started from three rooms located to the East, where the room for undressing was probably located. The path then led into two warm chambers (the octagonal *laconicum* and a *tepidarium*), into a grand circular *sudatio* (the so-called Heliocaminus) and finally to the two *calidaria*, characterized by basins. A *tepidarium*, equipped with a basin, mitigated the transition to the *frigidarium*, which had a small basin and a grandiose pool.

The Small Baths

The Small Baths show a similar path: the entrance, located to the North, gave access to a chamber for undressing; in addition, one *laconicum*, two *tepidaria*, one *sudatio*, and three *calidaria* can be recognised; and an octagonal room gave on to the paths leading to the warm chambers, the *frigidarium* and the gym.



Fig. 5 – Heliocaminus Baths, plant.

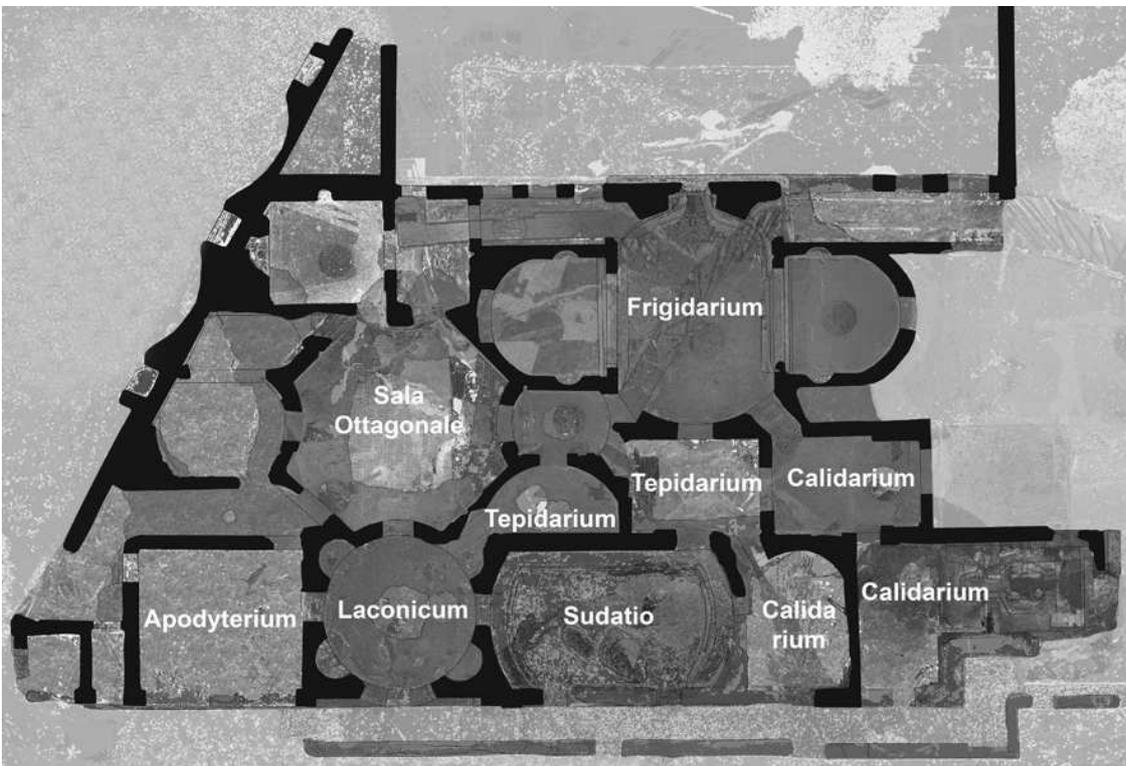


Fig. 6 – Small Baths, plant.

The Large Baths

The Large Baths, as already stated, were reserved for the workers of the Villa, and are divided into two areas, both accessible from the northern side of the gym. The so-called men's sector was characterized by a different path, if compared with the other two complexes: from the dressing room it was necessary to pass through the *frigidarium* to reach the heated area, constituted by one *laconicum*, two *tepidaria* and two *calidaria*. The so-called women's sector, located in the perimeter of the building, is characterized by the bare essentials for bathing, that is one small *frigidarium*, one *tepidarium* and two *calidaria*.

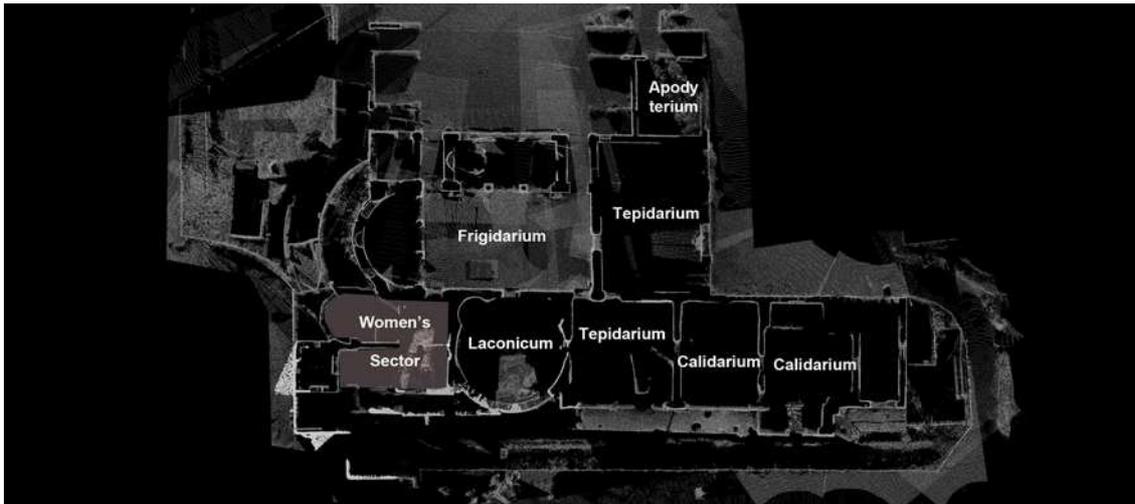


Fig. 7 – Large Baths, plant.

The research

The main purpose of this research, still ongoing, is the comparison between the three complexes and the search for differences and similarities among them.

There are more starting points of this analysis, but the principal base for this approach is a digital survey of the complex.

The survey

The first laserscan campaign was taken in 2004, with the survey of Great Baths, then in 2008 and 2009 it was the time to survey the complex of the Small Baths. Finally, in 2010, the Heliocaminus Baths were surveyed.

All the digital surveys were done with a phase shift laser scanner, except the survey of the Great Baths, that was done with a time of flight laserscan.

All the surveys was geo-referenced by a topographic survey, planned on entire area of the Villa.

The pointclouds coming from the surveys are the start of a series of 2D and 3D elaboration. In facts it's possible to extract plan views, sections, and frontal views of the buildings or create 3D surfaces and textured mesh. For the texturing it is necessary to realize a correct photomatching survey, using a calibrated camera mounted -especially in this case- on a versatile tripod, suitable for panoramic shooting.

Differences and analogies

The two noble complexes have a greater number of smaller rooms. The presence of multiple chambers with the same degree of heating can be explained by their original differentiations which cannot be reconstructed today (it is impossible, for example, to differentiate a room for massages from one for anointing). The limited number of chambers in the Large Baths can be explained with a reduced supply of services.

From an architectural point of view, the solutions adopted in the Large Baths are certainly more conventional, due to the arrangement of same-size chambers that are generally rectangular in shape.

The Small Baths, on the contrary, are the noble complex that best expresses an architectural study, joining small rooms and upper level chambers, using the first as a static support for the latter; the plans of the single rooms are articulated, as shown, for example, by the octagonal hall, that alternates straight and convex walls.

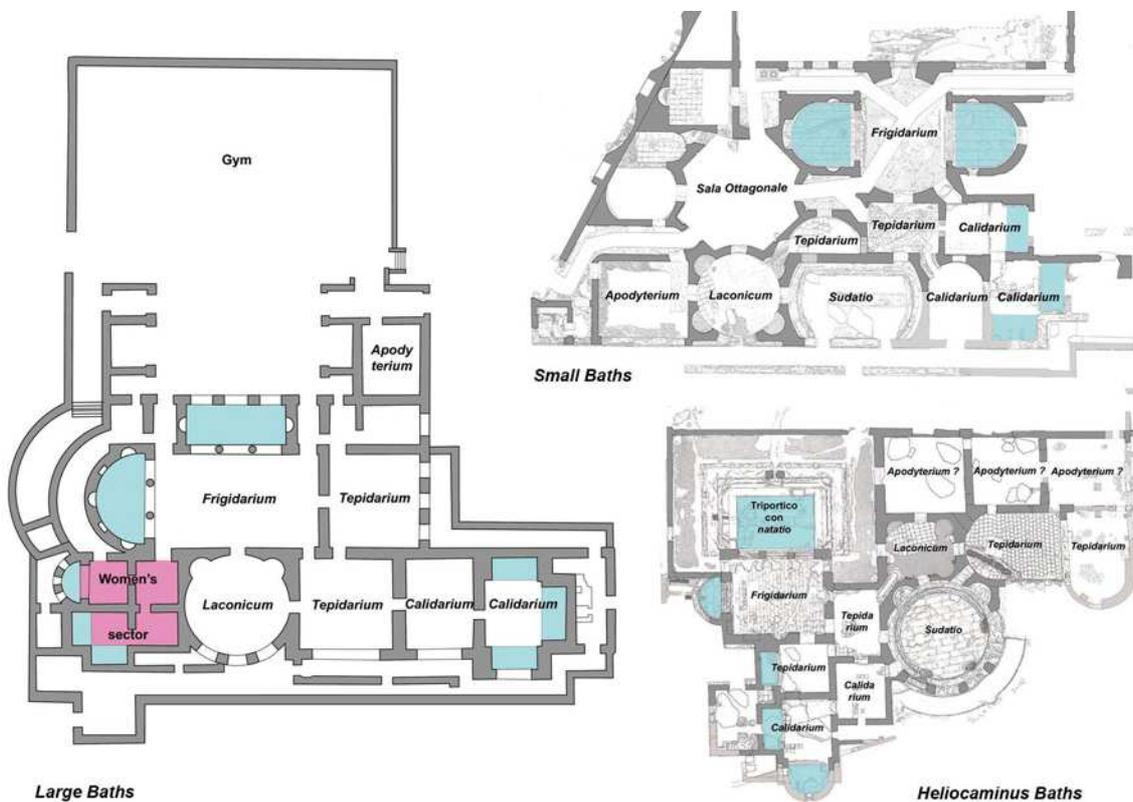


Fig. 8 – The thermal baths of Hadrian's Villa (small baths – Blanco, Mollo, Marzuoli; some elements of heliocaminus baths – Verduchi).

The two noble complexes are characterized by two *sudationes* (saunas): one is the so-called *Heliocaminus*, with a circular shape, while the second is a rectangular room in the Small Baths. These environments are well developed in height, with large windows to ensure a good insulation; the floor is entirely occupied by a basin, with steps around the perimeter, where people could sit. It is interesting to note that the steps are located only on the sides reached by the sun, confirming the function of the chamber.

In the Heliocaminus Baths, the *sudatio* was heated by four furnaces, with the heat circulating through the walls and the ceiling before going outside; in the Small Baths there were only two furnaces with analogous functions. We don't know how the steam was introduced into the chamber. In the *Heliocaminus* Baths there

are two small pipes, and it is possible to hypothesize the presence of two boilers *testudo*-shaped directly above the furnaces doing this task.

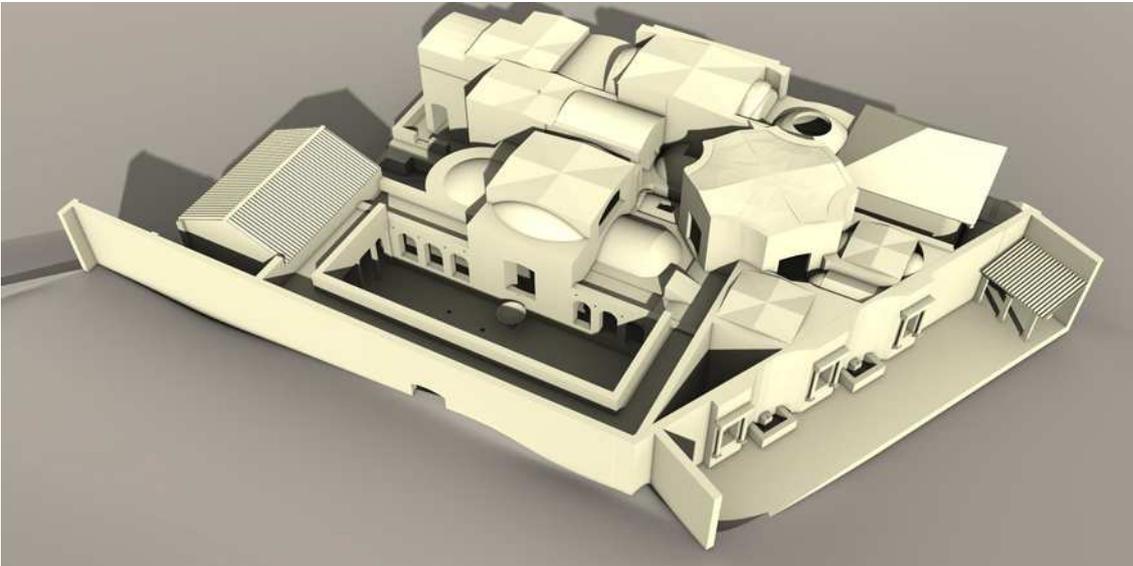


Fig. 9 – 3d model of the Small Baths.

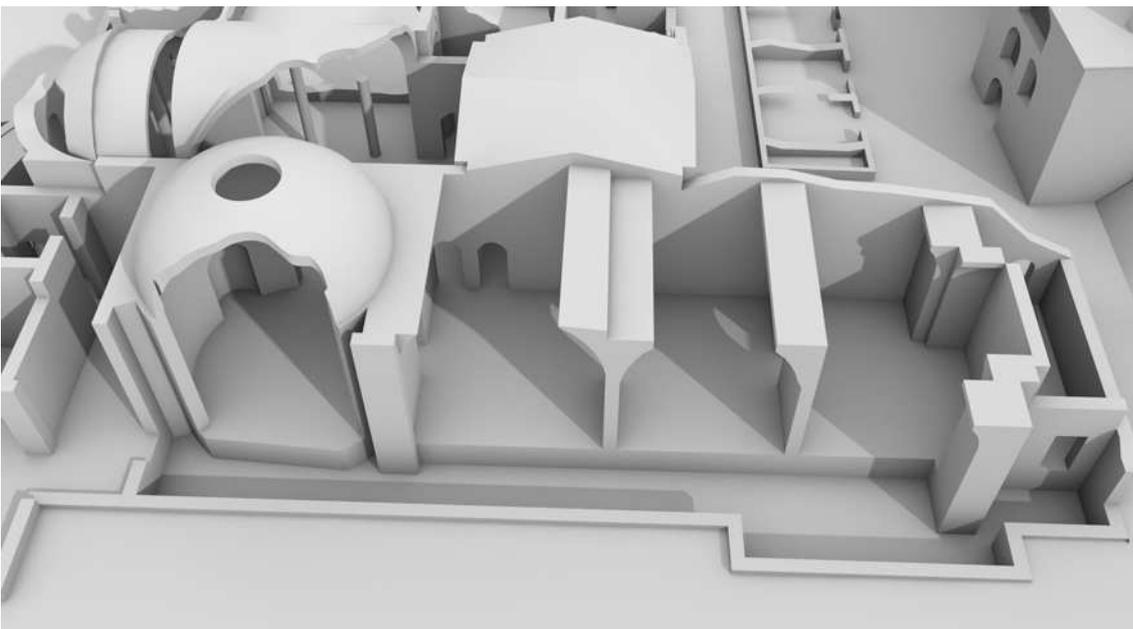


Fig. 10 – 3d model of the Great Baths.

The reconstruction of the side with the windows of the *Heliocaminus*, nowadays lost, is quite easy, because of the preservation: it can be imagined that the arched openings were topped by a jutting-out frame decorated with travertine corbels.

Reconstructing the side with the windows of the *sudatio* in the Small Baths, now collapsed, is more complicated: the remains are constituted only by an a pillar (with the rests of an arc and a collection for lintel) and two collapses of the roof. In the proposed solution, the only doubt is about the presence of the two side

windows on the upper level, which would have been closed, as would seem to be suggested by a similar architectural design in the Large Baths.

It is clear that an expensive system like a *sudatio* (considering the consumption of four furnaces) was a luxury granted only to the Emperor and his court: the attempt to recognize a *sudatio* in the circular chamber of the Great Baths is a mistake, because of the large dimensions of the room and the presence of a single furnace.



Fig. 11 – rendering by a textured mesh of the sudatio room of Heliocaminus bath.



Fig. 12 – the reconstruction of the sudatio room of Heliocaminus bath.



Fig. 13 – rendering by a textured mesh of the sudatio room of Small bath.



Fig. 14 – the reconstruction of the sudatio room of Small baths.

Having analyzed the differences found in the social statuses of the three baths of Hadrian's Villa, it is necessary to understand why there are two complexes for the Emperor and his court.

The first difference is chronological: the *Heliocaminus* Baths are, without any doubt, the oldest facilities, as evidenced by the topographic position (they are close to the oldest part of the Villa); the Small Baths, instead, follow a more recent expansion of the axis, developing from the *Pecile* to the *Serapeo*.

On an architectural and planimetric level it can be noted a great differences in construction: the heated rooms of the *Heliocaminus* Baths are arranged "in staircase", to ensure the insulation of all the chambers. In our view, a major planning error consisted in the placement of the heated rooms in an internal position of the building. To heat these two chambers, the architect was forced to create an underground corridor, with several small furnaces placed on each side. It is easy to understand that the workers encountered many difficulties to feed as many as seven furnaces in a narrow space with no air vents. The lack of traces of wear, blackening or fire damage could mean a renunciation to their use in ancient times.

Another characteristic of the Heliocaminus Baths is the presence of architectural diaphragms: in the eastern sector pillars and columns were used along the perimeter, both to create well illuminated rooms and to divide different environments. In the *frigidarium*, two columns gave access to the nearby *natatio*, allowing one side of this environment to always be open and without fixtures. During the construction of the building several changes were made, among which the abolition of these architectural elements that were probably proper for warmer countries: in the eastern sector the spaces between pillars were filled in, while in the *frigidarium*, instead of an open *natatio*, a covered basin was built.

These and other changes made during the construction of the building revealed, on the one hand, a great willingness to experiment, and, on the other, several construction problems, probably followed by significant delays in finishing the building. For these reasons the Emperor could have been pushed to begin new projects before ending the earlier one.

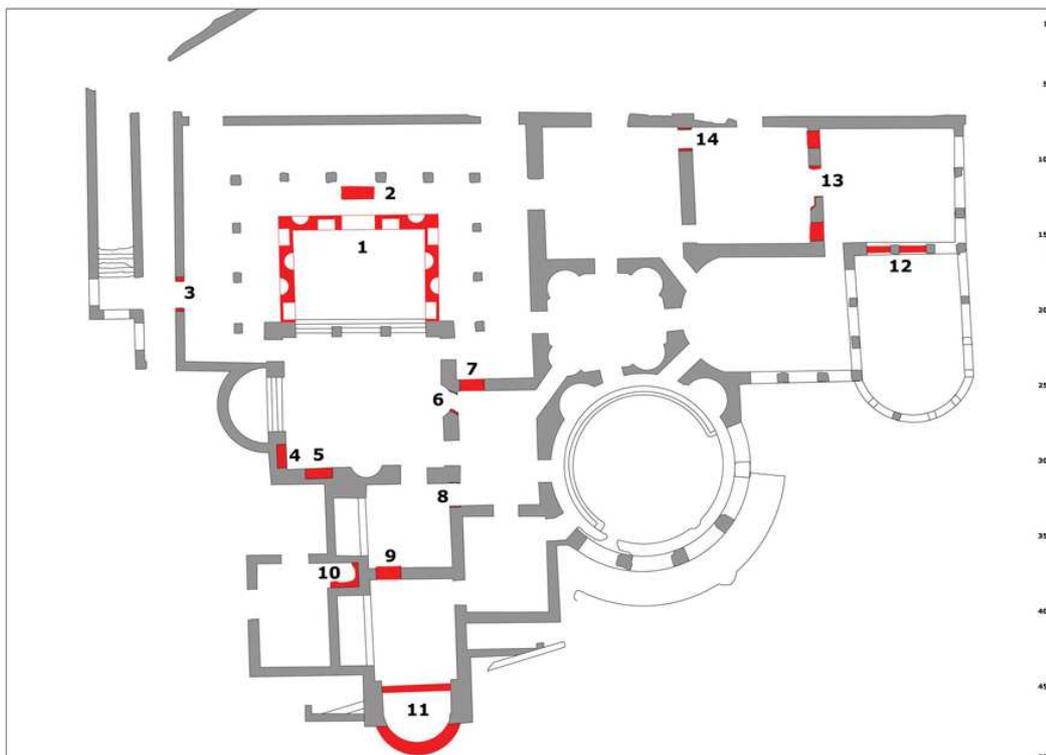


Fig. 15 – the Heliocaminus baths, in red the changes.

In fact, in the following construction of the Small and the Large Baths, the architectural design of the *Heliocaminus* Baths was abandoned: the heated rooms are arranged along a straight axis, with a simple and effective solution. The furnace corridor is straight and located along the perimeter of the hot rooms, so that it was possible to place air vents in the ceiling. With the hot environments in an external position, the inner warm rooms received the heat indirectly from the neighbouring areas, preventing the realization of underground passages.

Unlike the *Heliocaminus* Baths, the Small Baths lack in traditional architectural elements (columns and pillars), even in the basins, entrusting both the static and decorative functions to the walls.

In conclusion, in our view, it seems that the construction problems encountered in realizing the *Heliocaminus* Baths led to the building of a new thermal structure inside Hadrian's Villa. The earlier structure was certainly finished and used for a long time, as evidenced by building interventions of the later period.

A last doubt is about the final destination of the complexes. We cannot know for sure for who should be the final user to these two noble facilities (Hadrian? Sabina? the Emperor's court?) and if there were changes of the recipients, but certainly the scenario here outlined would seem to confirm the hypothesis that the Small Baths were used by the Emperor Hadrian himself.

Acknowledgement

The survey of the small baths, the great baths, *heliocaminus* 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.

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SESSIONS

How Archaeology Survives in Big Cities: Structures of Urban Archaeology

Archaeology is part of culture!

Reflections on the subject of archaeology and the public

Armand BAERISWYL

Abstract: Archaeology is popular and quite present in the minds of the public. But the cultural establishment, politics and the administration are not aware of that fact. Targeted and comprehensive public relations efforts are therefore vital. The overall objective has to be the establishment of archaeology in the mind of the the cultural establishment, politics and the administration as part of the national cultural heritage, deserving equal attention and appreciation as museums, concert halls and opera houses.

Keywords: Acceptance, Public, Archaeology and Culture, Canton of Berne, Public Relation.

We archaeologists working in state, communal or regional departments in charge of the preservation and care of archaeological monuments are well advised to think about the various sections of society that are relevant to our work and about our relationships with them. It is, after all, their acceptance or rejection which more or less directly defines the legal, financial and staffing resources available to us.

As a matter of course, it is generally understood today that we can increase this acceptance by means of targeted and proactive public relations. However, we must first ask who our target audiences are. What sections of society are we talking about and what is their relationship with archaeological research? I would like to stress at this stage that the following remarks are based purely on my own experiences within the scope of my work:

I work in the state-run department of archaeology for the Swiss Canton of Berne, the Archaeological Service of Canton Berne (<http://www.erz.be.ch/de/index/kultur/archaeologie.html> [20.12.2010]). Canton Berne extends over 6,000 square kilometres and has a population of about 1 million inhabitants; from a political point of view, a canton is comparable with a federal state or county. Due to the fact that the political system in Switzerland is federally structured, the cantons are largely politically autonomous.

Back to the question concerning the sections of society and their relationships with archaeology. The first group to mention are our direct clients, the investors, builders, construction companies, architects and planners. It is easy to understand why they are not too keen on archaeologists, since we are a source of interference – however, we generally find that the relationship greatly improves once it emerges that archaeologists are reliable partners. But this is not my topic today.

Our second group of clients, the public, is completely different: they are usually interested if not fascinated to a degree that surprises us time and again. At open days or archaeological festivals huge crowds of people wait patiently for their turn to take a tour and are fascinated by our explanations regarding modest little foundation walls, barely visible post pits and unsightly potsherds.

Thirdly, politicians behave in a completely different manner. Apart from a few exceptions, politicians are not at all interested in our work. They are often not even aware of the fact that the public is interested in archaeology and that potentially this could generate more votes. At best, politicians might regard archaeology as being nice but irrelevant; at worst they see it as an impediment to the economy and

progress. Perhaps this is linked with politicians' profession or vocation: the ethical approach would perceive a politician's basic motivation in politics to be the bringing about of sound political decisions leading to solutions for the problems of the present and future either of a region or the entire country. This means that politicians do not deal with the past because they perceive it as being irrelevant. This is a mistake, but a common one.

Even within the administration, no matter where archaeological services are actually placed – planning, culture, education, internal affairs – the interest in and appreciation of archaeology and its methods are limited: builders see us as a hindrance, educators find us too exotic and the arts see us as lacking in aesthetic value. A certain degree of envy – we do get a lot of media attention – may also play a role. Lastly I would like to mention the media. They alternate between fascination and a lack of understanding. Definitely a central issue in my view is that the media only view us in terms of local interest and that they – perhaps spoilt by Indiana Jones and similar movies – are always looking for sensational discoveries. Public relations must be tailored to these different target groups. The public, the people who are interested in archaeology, in history and in their community's past, can be reached by applying the classic tools used in public relations: Guided tours, open excavation days, festivals, lectures, exhibitions, Information plaques, Educational trails, Information brochures or flyers. all kinds of publications and so on and so forth. Schools are an important subgroup. In addition to the means mentioned, an educational programme must also be made available, which would allow teachers to convey archaeological subjects without having to invest too much time. Therefore, the material on offer should be made as ready-to-use as possible. Studies made in Switzerland have revealed that this kind of public relations does indeed work. According to a representative survey made in 2008, visiting monuments and historical or archaeological sites is one of the most popular cultural activities pursued by Swiss people, ranking a close second to attending concerts and even outranking visits to museums, the theatre and festivals

(<http://www.bfs.admin.ch/bfs/portal/de/index/themen/2102/ind32.indicator.70508.3205.html?open=1#1> [20.12.2010]).

As I said earlier, politicians are a completely different problem. Of all sections, this one is crucial for us in terms of the general resources and it is the least interested in archaeological research. In my opinion, this situation will remain the same as long as the term 'archaeology' is equated with the preoccupation with exclusively local and past issues. Therefore, public relations using the classic methods mentioned are not enough in this case. A much more fundamental approach must be employed: we must find a way to make people think of archaeology as being a part of the culture of our country, of our nation, a part that has the same right to exist and is held in the same esteem as museums, concert halls and opera houses – and in contrast to these institutions costs much less, although I do not wish to play one off against the other. I am aware that this is more easily said than done and I cannot offer any quick or easy solutions either. All I can do is tell you about a project that is currently being initiated in Canton Berne, which may make a contribution towards the goal. Last year, the Minister for Education of Canton Berne launched an initiative with the telling name 'Education and Culture'. The aim of the project, in summary, is to emphasise the importance of the artistic and creative subjects in education, to involve more artists in the teaching and to improve and coordinate the educational programmes provided by people and institutions involved in culture and the arts while also raising teachers' awareness of these programmes.

We as archaeologists saw the initiative as an opportunity and got involved in the project groups. And we have achieved a lot. While the specifications of the project often mention theatre and film directors, drama educators, singers, musicians, painters and other people involved in the arts, one particular measure is outlined as follows:

Within the Office of Cultural Affairs, the departments of archaeology and of the conservation of historical monuments together with their partners (architectural organisations, heritage protection, museums, institutions of higher education, experts in the field) provide an educational programme on archaeology, monument conservation and building culture. They define goals and set standards, and basically award contracts for their implementation to third parties as well as supporting external programmes.”

(ERZIEHUNGSDIREKTION 2009)

The summary of the project proposal includes the following statement: with the Education and Culture Initiative,

... learners of all ages will have better access to creative works, cultural productions, architecture, high-quality building culture and archaeological remains (ERZIEHUNGSDIREKTION 2009).

In concrete terms this means that we can create and make available dossiers for tours, educational folders, archaeological suitcases, teaching materials and similar items with funding from the Education Directorate. In addition, and perhaps of more importance in the long run, we are on the list of cultural programmes for schools, as an accepted part of culture. This list will be available on an Internet platform.

The project is still at the planning stages; the Bernese parliament has put up a lot of resistance to it. It may not even be implemented. However, we as archaeologists have already achieved a decisive victory: the planning of the Education and Culture project made it necessary to redefine the cantonal cultural strategy in general and we were able to actively participate. According to this new cultural strategy which is now in force, culture is a collective term for the arts and other forms of cultural expression:

The term culture denotes mainly music, literature, visual arts, photography, drama, dance, film and design, but it also encompasses interdisciplinary projects, folk culture of all kinds as well as archaeology and history; furthermore, built cultural heritage and convincing achievements in modern architecture are also an important element of cultural diversity (ERZIEHUNGSDIREKTION 2009).

This signals a change in values which in my opinion is fundamental. If we manage to make people perceive the past in the broadest sense of the word, history, art history, architectural history and likewise archaeology as being parts of culture and constituents of our lives, which according to Kierkegaard must be lived forwards but can only be understood backwards, we have won the battle (KIERKEGAARD and GOTTSCHED 1905).

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The urban archaeology of the London Crossrail Project

Approach, organisational management, challenges of integration

Jay CARVER

BaHons / MIFA, Crossrail, Project Archaeologist

Abstract: Crossrail is a brand new metro railway across central London, UK. It comprises 118 km of new and refurbished line, 37 stations including six new stations in central London. The project started its life as a Cross London Rail Links, a joint venture between the Mayor of London's transport authority, Transport for London (TfL) and the UK Government Department for Transport who each held a 50% stake in the organisation. In 2008 Crossrail Ltd (CRL) became a fully fledged subsidiary of TfL. Crossrail is therefore a public works project but it includes significant financial contributions from the private sector.

The new railway passes through the heart of the West End of London and along the north edge of the Roman and Medieval city where deep construction for several new stations has required the careful assessment and evaluation of the archaeological sequence at some key historic locations. Important historic buildings and industrial archaeology sites are also being investigated.

This paper provides a description of the organisational framework that the archaeology programme operates in and looks at the project design, management structure, access and programme risk constraints that have affected the project planning. I will look specifically at how the various stakeholders have agreed to control impacts on archaeological sites, the coordination of the multiple consultants teams and contractors who are undertaking archaeological works for the project. Results so far and some of the key challenges are also discussed.

Keywords: Crossrail, archaeology, project design, Public/Private sector, programme risk.

Introduction to the project

This paper was presented to the conference to contribute to a session on how archaeology in our European towns is organized for major infrastructure projects and to look at how we can address issues surrounding archaeology and construction. This paper takes a lead from earlier studies such as work by the Council of Europe (COE 2001) and the transnational project Discovering the Archaeologists of Europe (AITCHISON 2009). Crossrail is a UK example project which demonstrates how the public and private sector can combine to achieve a balance between successfully addressing the needs to respect the archaeological heritage and historic buildings, and the needs to protect public and private expenditure associated with project delays.

The Company

Crossrail was originally established in 2001 to promote and develop a new London rail transport link to meet the needs of people and businesses throughout the South East of England (Fig. 1). It is now a fully owned subsidiary of Transport for London (TfL), the public transport body of the city authority, which is promoting the project through a combination of public funds and private sector partner funding.

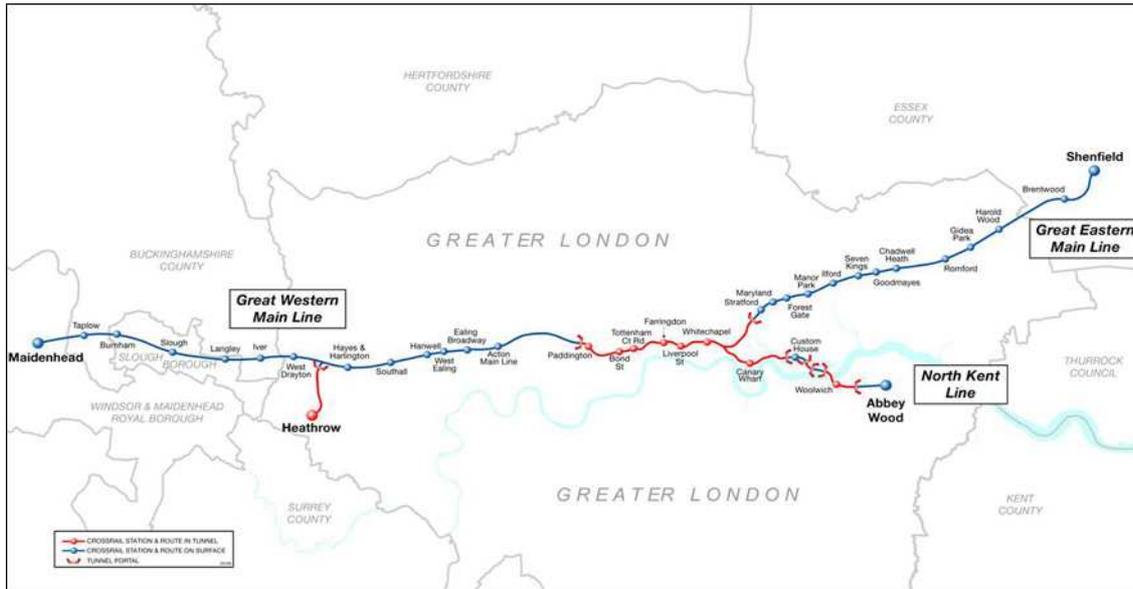


Fig. 1 – Crossrail Route Map (Copyright: CRL Ltd).

Project Funding

The funding framework was put in place in October 2007 when the then Prime Minister, Gordon Brown, announced that Crossrail's cost will be met by Government through Department for Transport, Transport for London and London businesses. A third of the cost is being met by a grant from the Department for Transport and London businesses will contribute through a variety of mechanisms, including the Supplementary Business Rate. There are also considerable financial contributions from some of the key private sector beneficiaries of Crossrail including The City of London Corporation and BAA Plc (owner of London Heathrow Airport). The Canary Wharf Group and Berkeley Homes who will also each contribute to new stations built on their land in London Docklands and at Woolwich.

The £15.9 billion budget for the project is a fully inclusive cost, allowing for both contingency and expected inflation. In terms of management of archaeological costs, although the assigned budget is a small proportion of the overall direct costs, the funding arrangement puts pressure on archaeologists to ensure processes are in place to manage the archaeology budget carefully. Archaeological evaluation is central to identifying high risk areas, although unexpected finds can still have an impact on tightly planned construction programmes. The following sections will look at how the project design contributes to these objectives and looks at some of the organisational tools used to manage these risks.

Getting Approval

The project approval and planning process operates outside of the normal UK planning framework. The Crossrail Hybrid Bill required to construct and operate the railway was introduced to the UK Parliament in February 2005 and like all UK legislation was fully considered by the House of Commons and the House of Lords. The Bill contained a description of the works to be done and where they are to be carried out, and identified the land needed temporarily or permanently.

The Crossrail Bill was a so-called *hybrid bill* which is used by the Government on behalf of railway companies and transport agencies to obtain authorisation for major projects deemed to be in the national

interest, but which would also affect a large number of private interests. Such bills have been used periodically for other major infrastructure projects such as the Channel Tunnel, the Channel Tunnel Rail Link and the Dartford Tunnel.

The procedure adopted gives individuals and bodies, such as businesses, local authorities and lobby groups an opportunity to oppose the bill or to seek its amendment before a Select Committee in either or both the House of Commons and House of Lords.

Consultation and information

Consultation exercises have been carried out at key development stages of the Crossrail project and information has been made available through a range of communication media before and during the Parliamentary phase.

Crossrail carried out extensive stakeholder and public consultation in advance of the Parliamentary process. In 2003 and 2004 exhibitions were held to explain the proposals at over 30 different locations. Over 200,000 invitations were distributed to the properties of residents and businesses along the proposed route, information was provided for schools, a 24/7 telephone helpdesk and a web site were established, and Crossrail staff attended meetings with councilors, local residents associations and businesses to discuss specific local issues which may arise out of construction of the railway.

Crossrail Bill Supporting Documents

To support the Bill, Crossrail produced an Environmental statement (CROSSRAIL 2005a) and a series of information papers that set out the likely impacts on key environmental topics including archaeology and the built heritage environment (CROSSRAIL 2007a; 2007b) The existing archaeological evidence was summarised in a specialist technical report (CROSSRAIL 2005b) that defined the archaeological map through which the route of the metro would pass and highlighted the key receptors likely to be affected, including all historic buildings, conservation areas, areas of archaeological priority and ancient monuments (Fig. 2). In addition many of the hundreds of boreholes drilled to inform the route for the underground sections of the railway were archaeologically monitored and analysed to build up a detailed deposit model for the key locations affected by buried archaeology (Fig. 3). This gave us the opportunity to begin to enhance the known archaeological histories with detailed level information for archaeological survival and represented the first phase of site evaluation.

Similar to development control conditions usually applied by local planning authorities, the Crossrail Bill introduced a set of Environmental Minimum Requirements (EMRs) (CROSSRAIL 2008), to govern the construction of Crossrail. These comprise a series of documents setting out the General Principles of the Construction Code, the Planning & Heritage Memorandum and the Environmental Memorandum. Together these provide a series of controls which contractors and others working to build the railway will work under. The EMRs were developed by CRL in liaison with the Local Authorities and Statutory Agencies responsible for environmental regulation in the UK including English Heritage. The Planning and Heritage Memorandum has been signed by eighteen local authorities that wished to become qualifying authorities for the purposes of the Act.

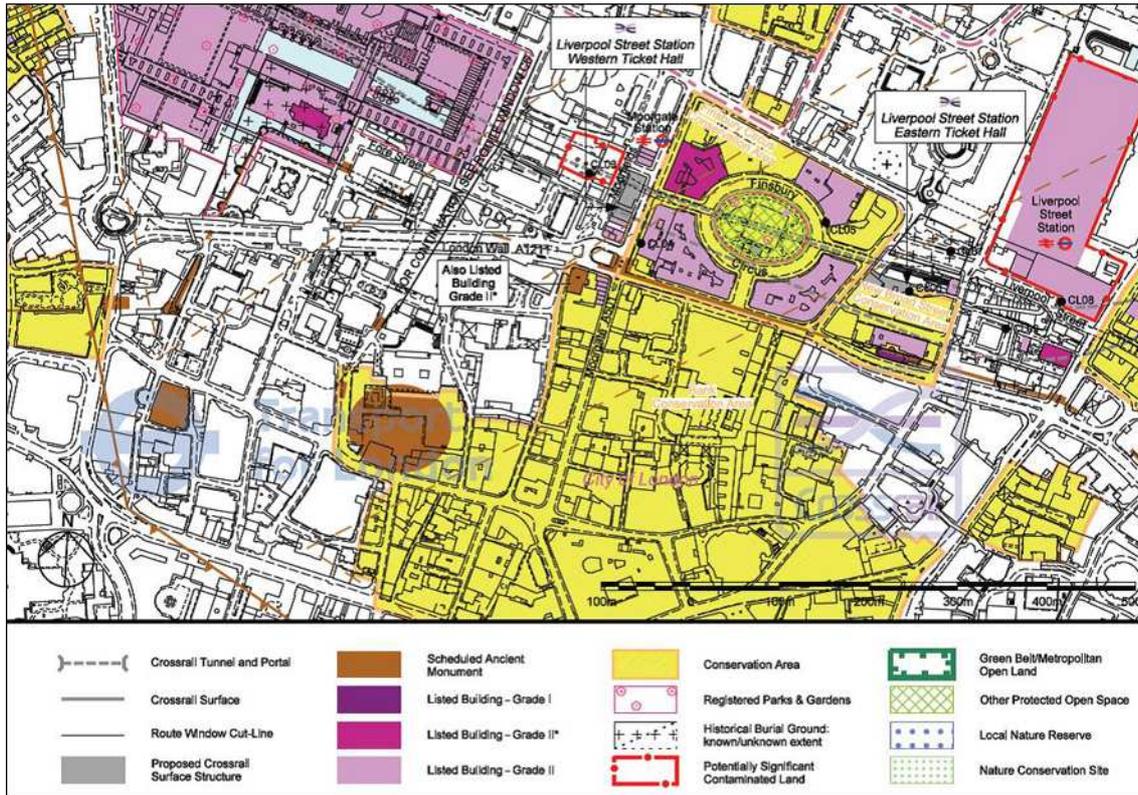


Fig. 2 – Crossrail ES route mapping example (Copyright: CRL Ltd).



Fig. 3 – Archaeologist logging sequence and recovering samples from geotechnical borehole Crossrail works Liverpool St (Picture by Maggie Cox -Copyright: CRL Ltd).

A Register of Undertakings and Assurances also forms part of the EMRs and provides an undertaking that "any nominated undertaker" of the project will be contractually bound to comply with the controls set out in the EMRs.

To manage and implement the environmental requirements of the Crossrail Act the project has adopted an environmental policy backed up by environmental objectives, and an Environmental Management System (EMS). The EMS is consistent with the principles of ISO14001, the international EMS standard, which helps us to manage our environmental responsibilities and risks.

The EMS incorporates Archaeology as one of eight topics for active management within the design and construction of the project. Central to the management of archaeology is a strategy, known as the generic Written Scheme of Investigation or WSI (CROSSRAIL 2009) that sets out how archaeology shall be designed, programmed and implemented. This project design document has been prepared by Crossrail in consultation with English Heritage and relevant County and local authority archaeologists to ensure a consistent approach across the route and throughout the life of the project.

Project Design

Description of the project research agenda

The Crossrail route central section (Fig. 1) comprises construction of a new underground railway through the centre of London. The archaeological research context for the project allows us to identify 5 key geographic zones along the project route (Fig. 4). Each zone is associated with a predominant deposit model and specific types of archaeological remains that are likely to be encountered. Although of course there are overlaps, the model allows us to focus investigation on clear objectives. The project is likely to encounter most periods throughout prehistory, the Roman and medieval town, the later post-medieval expansion of the city and the origins of the industrial age. Specific research objectives have been guided by the research framework for London archaeology (NIXON et al. 2003).

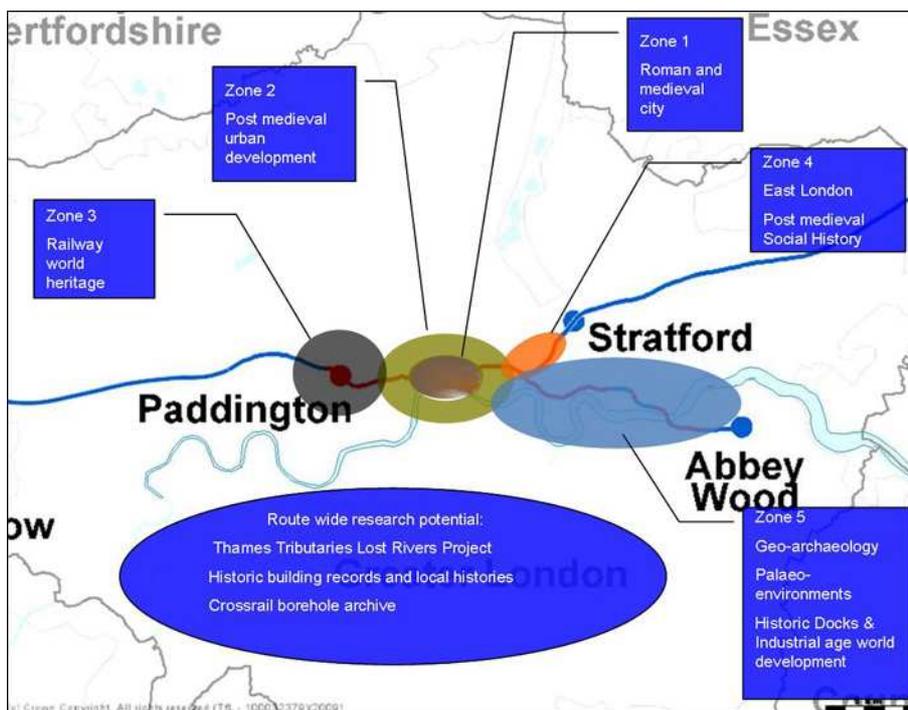


Fig. 4 – High level research themes and geographic zones (Drawn by Jay Carver -Copyright: CRL Ltd).

Zone 1

In London's historic core the best preserved locations lie within the Roman and medieval city walls where archaeological deposits survive in a stratified sequence up to 9.0 m in depth. The city initially developed on areas of higher gravel terrace to the east of the River Fleet and on either side of the Walbrook, two Thames tributaries draining into the north bank of the River (Fig. 5). Here we find up to 2.0 m thickness of 1st–4th century AD Roman deposits which are overlaid by c. 1.0 m of post Roman dark earth, overlaid by 2–3 m thickness of medieval and post-medieval urban deposits.



Fig. 5 – Roman London drawn in 1810 AD by John Britton. The plan shows the Roman wall, gates, street plan and road network, with some prominent architectural and geographical features presented pictorially. The Walbrook and Fleet Rivers are running North/South in the centre and left of the map (Source British Library No Copyright restriction).

Although the Crossrail route does not enter the historic core it does follow an east/west line immediately north of the city wall. The project research focus in this zone is the potential for disturbing Roman and medieval burial grounds, the marshy extra mural zones of Moorfields and busy road site activity along the routes leading beyond the city limits. Construction works will also coincide with the historic locations of two of London's medieval religious houses. Charterhouse, a Carthusian monastery founded in 1371 AD (BARBER and THOMAS 2002) at Farringdon, and the burial ground of the Priory and Hospital of Saint Mary Bethlehem, founded in 1247 AD (Fig. 6) at Liverpool Street, that will require investigation of two areas of cemetery dating to the 16th and 17th centuries AD.

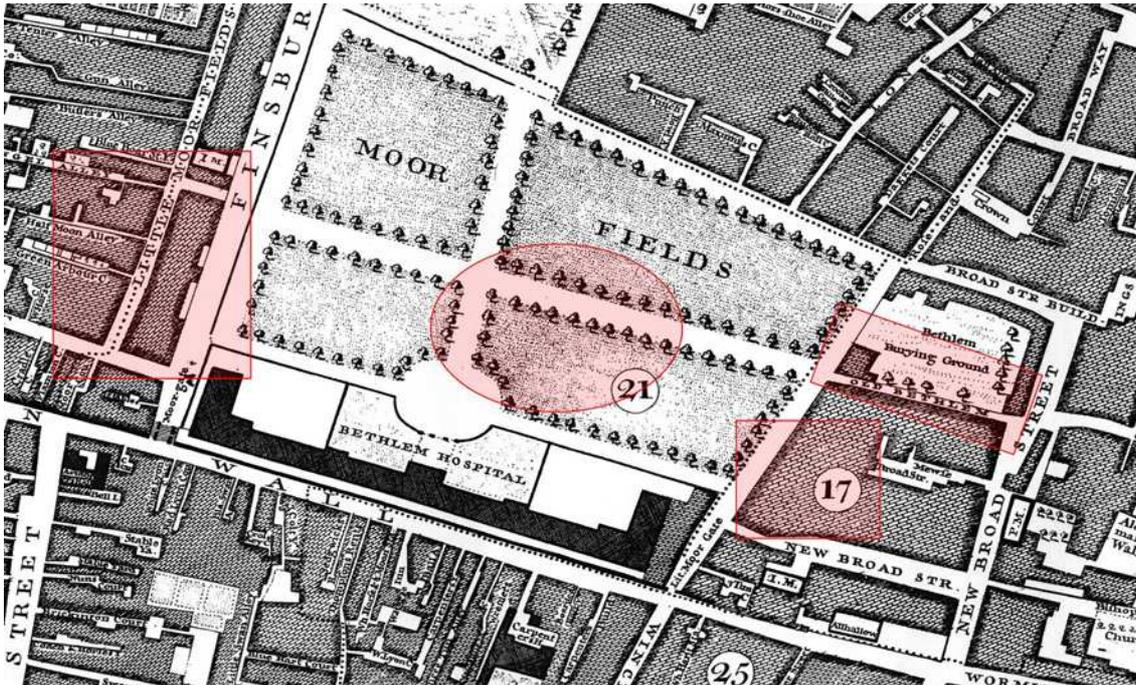


Fig. 6 – The Bethlem ‘Burying Ground’ on the right of the picture coincides with works for Crossrail at Liverpool Street (red highlight). Map detail is from Rocque’s 1748 map of London. The burial ground was set aside for the use of the Priory and Hospital of Saint Mary Bethlehem, founded in 1247 AD (Source British Library No Copyright restriction).

Zone 2

Within the outer core zone the deposit model predicts less dense Roman and Medieval extra mural transport networks and, agricultural and industrial activity (such as brick-making). Our research focus is aimed at understanding the suburban expansion from the mid-16th century AD onwards as nearby villages were subsumed into an expanded capital (Fig. 7). For the next two centuries development in this zone is characterised by a range of domestic and mercantile accommodation, rather than a city sprinkled with major *foci* such as the religious houses and other public buildings.

By the end of the 18th century AD the suburbs were flourishing and the establishment of the street layout, domestic, merchant and industrial architecture and processes are the focus of the archaeological investigations in this zone.

Moving to the western part of the rail route (Fig. 4, Zone 3), our attention turns to west London’s Paddington Station and the depots and goods yards of Brunel’s Great Western Railway (GWR) established in 1840 AD. The GWR is currently being promoted as a UK World Heritage Site nominee. Several of the main station buildings and many of the original bridges and tunnels between London and Bristol are protected by listing under the Planning (Listed Buildings and Conservation Areas) Act 1990 due to their historic significance (CROSSRAIL 2006). Parts of the Grade 1 listed station and associated archaeological evidence for the development of the rail transport network shall be altered in places to accommodate the new Crossrail station and depots. A programme of detailed building recording and archaeological investigation is taking place to ensure that elements of the historic railway are identified and recorded and where possible salvaged for reuse (Fig. 8).

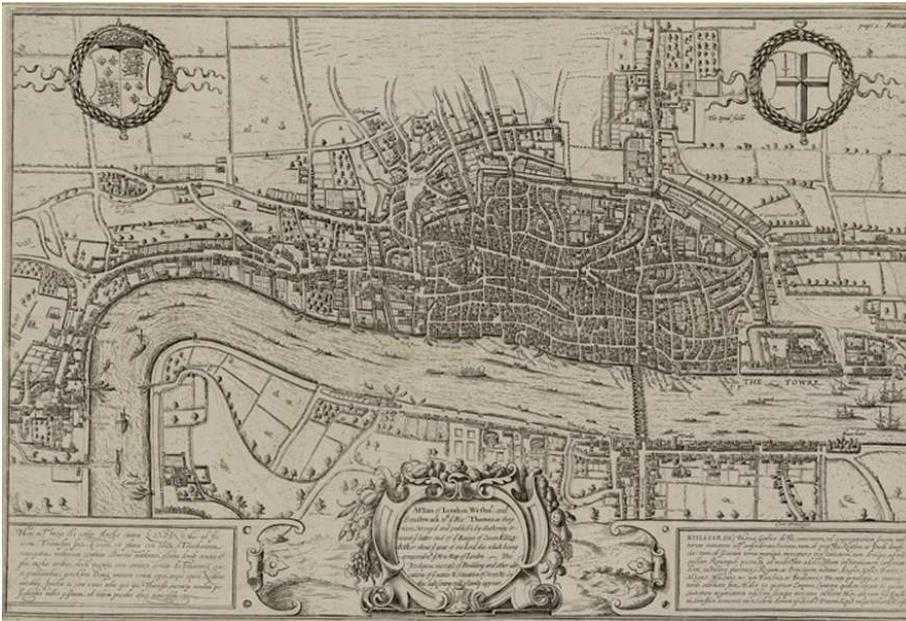


Fig. 7 – London around 1600 AD by Braun and Hogenberg. Significant development beyond the city walls is evident (Source British Library No Copyright restriction).



Fig. 8 – A former engine turntable leaves the Old Oak Common rail depot for a new home with a private steam railway in southwest England. Established in 1906 AD the rail depot has been fully recorded and many historic items salvaged for potential reuse and museum presentation (Copyright: CRL Ltd).

The eastern central sections of Crossrail focus on two zones. To the east of the city centre, the route from Whitechapel to Stratford (Fig. 4, Zone 4) passes along the line of a Roman Road and through an area important for post-medieval and recent social history. This includes Stepney Green where the remains of Worcester House, a Tudor mansion of 16th-century or earlier date, has been identified through documentary research and excavation. In the mid-17th century, the site subsequently became a focus for religious non conformists with the construction of a Baptist College and non conformist meeting house (Fig. 9). The archaeological sequence here continues right up to the bombed out remains of Victorian terrace housing, demonstrating some 400 years of continuity and change, from wealthy suburb to abandoned inner city slum

housing. The heritage values of these types of investigations are being used by the project to contribute to community and school education through a series of events and publications.



Fig. 9 – Evaluation investigations at Stepney Green. Mid 16th century AD Tudor foundations of the tower gate of Worcester House (Photo by Maggie Cox, Copyright: CRL Ltd).

Finally, the south-eastern section of Crossrail provides our fifth major research area centred on the prehistory and recent history of the River Thames valley, estuary and London Docklands (Fig. 4, Zone 5). Two themes predominate in this zone. The preserved prehistoric landscapes buried in the deep peats and clays of the alluvial soils of the floodplain of the River Thames and its tributaries are often buried below several meters of later alluvial silts and clays. The excavation of several large tunnel portals (where tunnelled sections join the surface rail sections) for Crossrail provides the opportunity to reveal this full sequence over large areas which are not commonly exposed for archaeological research. Geo-archaeological boreholes are combined with the many engineering borehole results to develop detailed subsurface topographic maps which we then use to identify priority locations for archaeological evaluation, such as former islands and gravel ridges that in prehistory were the focus for exploitation of the rich marshland environment (Fig. 10). The second research theme in Zone 5 is focussed on the development of London's docklands, ship building and industrial sites from the mid-17th century onwards. At the Limmo Peninsular, where the River Lea meets the Thames, Crossrail is constructing tunnel access shaft on the site of the former Thames Ironworks (established 1837 AD). During the 19th century and early 20th century the company built ships for nations across the world including the world's first iron hulled war ships. Our investigations are focussed on evaluating what survives of the yards and slipways which were abandoned when the works closed in 1912 AD, and subsequently covered over with waste soils up to 5 m in depth (Fig. 11).

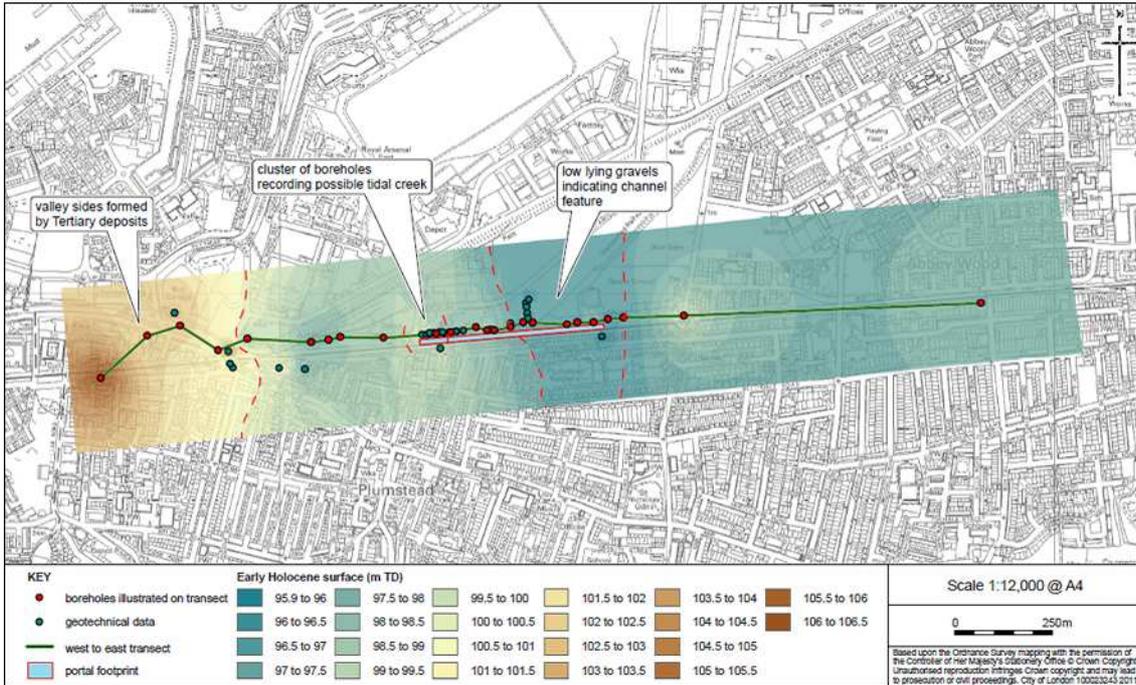


Fig. 10 – Extract from digital deposit model prepared for Plumstead Portal showing the early Holocene template and topographic interpretation (Copyright: CRL Ltd).



Fig. 11 – Evaluation trenches excavated to investigate the Thames Ironworks at Limmo. Left: general view showing workshop foundations foreground and yard railway to centre of trench. Right: Recording the remains of a forge. (Photos by Maggie Cox. Copyright: CRL Ltd)

Project organisation

Archaeologists are integrated into the Crossrail project organisation in several specific roles (Fig. 12). The client company has appointed a project management team from the private sector to supervise the design development, planning consents and construction of the railway. This is a consortium of private engineering companies experienced in rail design and construction led by three companies: Bechtel, Halcrow and Systra. The project archaeologist is appointed as part of this project management team and is responsible for the supervision of the design and managing the contracts for archaeological programme of investigations and historic building recording. The design work has been carried out by a supply chain of private sector engineering design teams, each of which include an archaeologist, to develop the scope and specification for packages of archaeological work integrated with the engineering designs for particular stations, portals or shafts. There are 8 archaeologists currently working in the design teams. The scope and specifications are prepared to a set of common standards developed by the project archaeologist for Crossrail which form part of the strategic level project design.

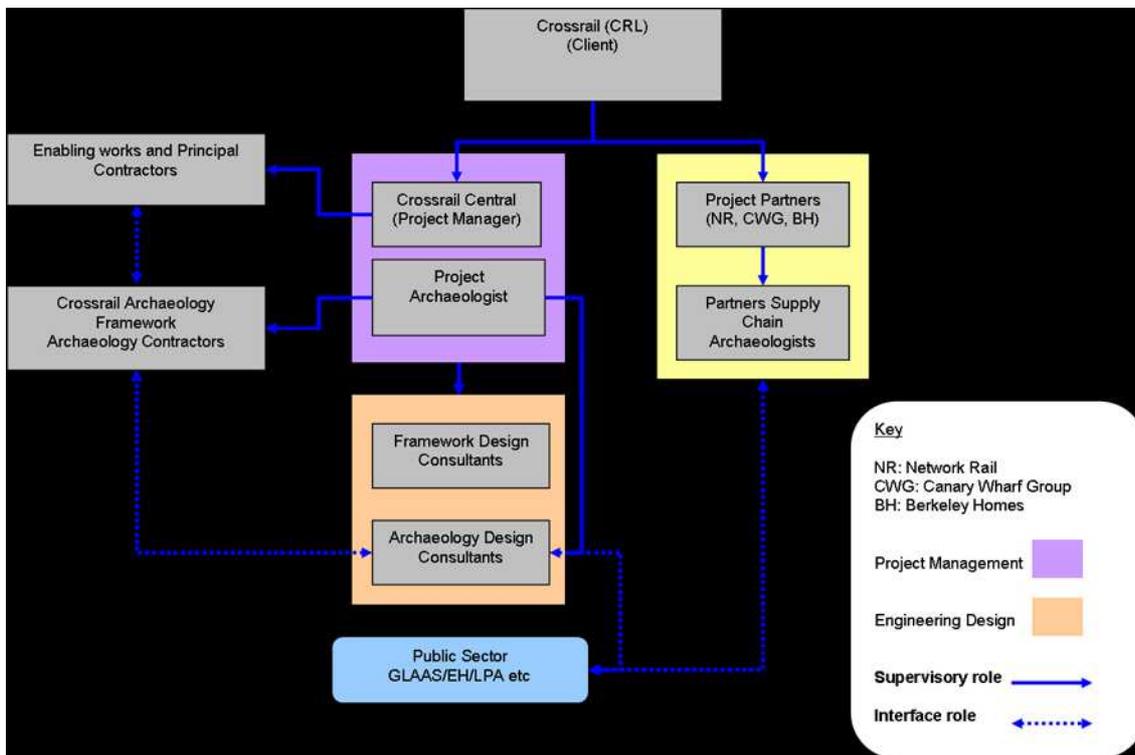


Fig. 12 – Project Organisation. Showing the relationship of different teams and curator. The yellow box on the right of the drawing indicates the separate teams appointed by project partners who are delivering parts of the Crossrail project (Drawn by author, Copyright: CRL Ltd).

The public sector role is to provide advice on the scope and specification of the planned works. The UK government department of Culture, Media and Sport, delegates development control in Greater London to English Heritage, a statutory agency, that delivers advice through the Greater London Archaeological Advisory Service (GLAAS) to the London boroughs, excepting those local authorities who appoint their own archaeologist (*i.e* for the City of London, the City Archaeologist).

The design teams submit their proposals regularly to GLAAS and the City Archaeologist for any comments and they meet prior to commencement of archaeology works and during the investigations to discuss the implications of the works, and to ensure that the agreed minimum standards are maintained. The public sector role is also to provide suitable museum space for the archiving and presentation of the finds and site records; in the Greater London region this service is provided by The Museum of London.

The actual archaeological building recording, site evaluation and excavation works are again provided by the private sector. Crossrail announced a tender competition to provide archaeological contracting services for the project in 2008 and advertised the opportunity in the European Journal. Following a tender process, that first established that companies could demonstrate the desired level of expertise and quality benchmarks, five archaeological companies were appointed to a ten year Framework contract in 2009. These contractors are supervised by the project archaeologist and liaise closely with the design archaeologists and the principal or main contractors undertaking the construction works.

Procurement

Competitive tendering for archaeology works has been the main route for providing archaeological services to the construction industry in the UK for the last 20 years. This market deregulation followed the publication of PPG16 (Department for the Environment 1991) in the early 1990's and we have seen the gradual phasing out of public sector archaeological services, provided by local government, since that time. Today, the vast majority of commercial archaeology in the UK is undertaken by private companies (AITCHISON 2009). The investigation of below ground remains, with its strong element of risk and unknowns, is not ideally conducive to a purely commercial form of procurement, and so it is important that the tender process allows for a competition that is jointly based on quality of delivery and economic value, and is capable of adjustment to suit actual ground conditions.

The Crossrail project has adopted the New Engineering Contract (NEC 3 2008a) for all contracts and the short form contract has been selected for the archaeological contracts (NEC3 2008b). This provides a model for costing based on priced items and rates and a transparent mechanism for the contract to either increase or decrease in value, depending on outcomes of fieldwork investigations. The five archaeological contractors who won a place on the framework were then invited to submit quality and commercial tenders for each of four packages of work that divided the route of the railway into 4 geographic areas. The scope of each package is to provide archaeological field and post-excavation services for a specific area, ensuring that continuity exists between the investigations and the eventual reporting phase. The quality/commercial weighting of the tenders followed an industry standard pre-published evaluation procedure allowing suppliers to compete equally on quality, alternative project designs, innovative methods and value for money. Tender evaluations were assessed by a multidisciplinary group within the project management team comprising project management and programmers, cost engineers, and technical assessment by a panel of archaeologists, and environmental specialists employed by the client.

The tender packages set out the evaluation phase investigations required at each site location. For example, 10 trial pit excavations of a stated size and depth; which buildings needed recording prior to demolition, and so on. All available desk study information was made available and contractors provided their prices and rates for undertaking the works against a bill of quantities. Although the outcome of the evaluation and scope

for any further detailed excavation was not known at the time, the pricing model also asked tenderers to provide rates for day rate works for various grades of staff together with other activities that can be quantified e.g. laboratory based works for different classes of artefact and environmental sample analysis and reporting. The amount paid to the successful contractors will be assessed according to the bill of quantities versus actual quantities completed. This procurement model spreads the risk between archaeological contractor and the employer. The contractor is responsible for accurate estimating and the employer is responsible for judging the likelihood of unexpected discoveries (BARBER et al. 2008) and providing active management and supervision.

Project Documentation

Because the Crossrail project is wide in both geographic scope and complexity and being delivered by multiple organisations, we established a common project design to help deliver consistent scope, specification and post-excavation outputs. This was developed with reference to a number of best practise guidance papers published by the team at English Heritage (GLAAS 2009) and those published by the UK Institute for Archaeologists (IFA various).

As referred to above, central to the project design documentation is the generic Written Scheme of Investigation, a strategic plan that sets out the types of assessment, and evaluation and mitigation methods that will be used to investigate and report on archaeology and buildings during the course of the project. This document forms a formal agreement between Crossrail and UK parliament and the local authorities. Based on the generic WSI a series of detailed desk studies and other surveys were completed by the consultant teams to inform Site Specific WSIs for each affected location. This work further developed the summary information provided in the Environmental Statement, and included additional local data such as borehole and trial pit observations to build a detailed deposit model for each site.

Programme Risk

From early on in the project lifetime archaeology was recognised as a key risk to the construction programme. The approach to phasing is to divide the project into a series of stages (Fig. 13). Our methods are influenced by our experiences on the Channel Tunnel Rail Link project (ADS 2004) and major road scheme projects in the UK. It follows industry guidance such as a due diligence risk assessment process for assessing and dealing with contaminated land (CARTER and WILDE 2004) and from research undertaken by the author for CIRIA (BARBER et al. 2008).

The premise is that given adequate forward planning, archaeological impact on construction programmes can be managed through:

- early and thorough investment in detailed desk study and deposit modelling
- multi-disciplinary direct working with archaeologists firmly embedded within client teams from the early project planning stages
- development of clear terms of reference for all parties
- early integration of archaeologists into the detailed design for construction to ensure engineering and access constraints fully understood (for example: ground water issues and the effect of excavation prior to dewatering works; ground and property stability issues around excavation; programme integration and

communication; understanding of construction phasing and site space constraints between engineer and archaeologist)

- early procurement from the private sector of the archaeological resources necessary for rapid archaeological investigation
- adoption of construction industry standard contracts and project management techniques

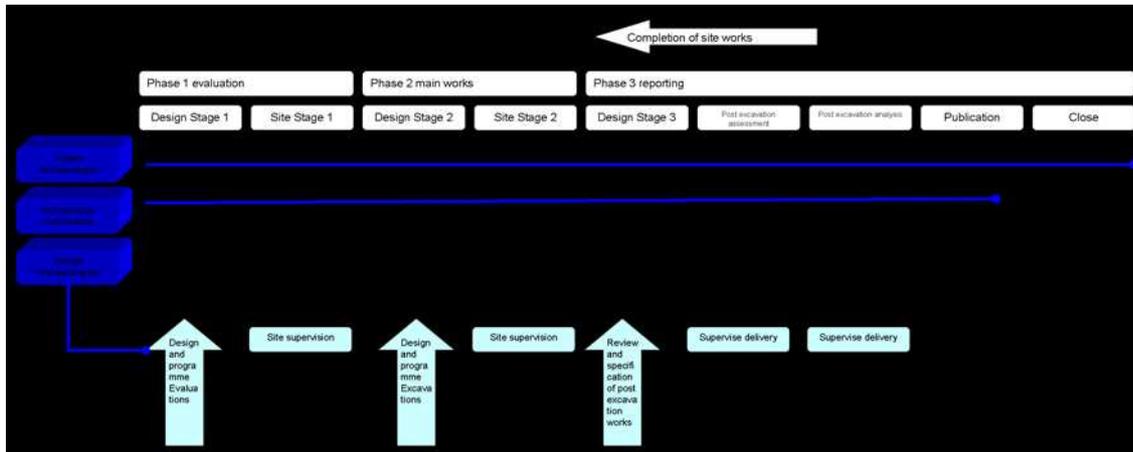


Fig. 13 – Project Phasing (Drawn by author, Copyright: CRL Ltd).

An initial Programming Assessment was prepared by the archaeological consultant carrying out the ES to provide early guidance on the time that should be allowed for in the project construction programming to undertake archaeological investigation and excavation. Individual locations were graded A to D, with A being on the critical path in the programme, and D being low likelihood of causing a delay. The usefulness of this exercise early on in the detailed design phase is to highlight certain locations and put timeframes in engineering teams' minds: "Archaeology will be an issue here". However since many of the assumptions will change as design and constructability assessment progress, such a document will only be effective in the longer term if the messages in it are constantly revisited and refined between engineering teams and archaeology colleagues.

Our next phase, of more detailed planning, was to incorporate a detailed consideration of programme risk into each site specific WSI (Fig. 13, Design Stage 1). This exercise should be based on actual and precise scope for archaeological evaluation setting out detail on: how many investigations required of what type, dimensions and how are they to be achieved (excavation methodology/constraints), what the main works contractor undertaking other works at the site needs to provide (for example, plant, accommodation, temporary works, labour etc.) and estimates for the time required by the archaeological contractor to complete their recording and sampling work. The availability of this level of information 'in time' to be included in the tender works information for each main contractor is essential, and its contents clearly communicated are essential if the management of archaeological programme risk is to be effective. In practise, within very large projects, communicating these details is not always successful all of the time. On one hand archaeological design teams need to have taken on board that, in order to be listened to by the construction sector, they must come up with a *specific and measurable* scope of work for the main works contractors to price and programme into their own schedules. Without this quantifiable baseline we have

found that engineers will put the issue aside in a 'may never happen' list, sadly missing the opportunity to manage and plan that risk effectively.

Archaeologists working in construction need to have the courage of their convictions. It is not sufficient to say "we don't know enough yet to tell others what investigations we need, how many and where, nor how long it will take ...". Within the NEC type of contract, effective integration is assured if you say "we need 10 excavations in this location of this size, of this depth and it will take this long to do". In the construction contracts, change to any of those parameters can be tolerated and accepted. What cannot be tolerated is a message from an archaeologist that is uncertain and unquantifiable in cost and time. So at design stage 1 it is also essential that time and quantities for detailed excavation works, that 'may' be required in phase 2 on site, are also clearly highlighted. Often the important issue here is to make a professional judgement based not on worst case, but on a realistic outcome, hence the importance of the early and thorough understanding of the site gained through desk study and other survey types. These assumptions are then revised at design stage 2 when the results of the first trial excavations can and should provide sufficient data for the designer to fully set out the requirements for any further work in phase 2 (Fig. 13).

In practice of course difficulties are faced when access for appropriate evaluation prior to taking ownership of sites has been delayed. There is a need to carefully co-ordinate evaluations whilst buildings are being demolished. Much of the evaluation work on Crossrail has been carried out through the base slabs of the existing structures (Fig. 14), the demolition then completed and any further investigation completed prior to piling contracts starting for the main station boxes and shafts.



Fig. 14 – Numerous evaluation trial pits for archaeology have been excavated within the basements of existing buildings in advance of main demolition phase to test the deposit model predicted by desk study (Photo by Oxford Archaeology, Copyright: CRL Ltd).

Close liaison between the archaeological teams and construction teams has been essential to identify the critical risk areas. For example, the impact of archaeological excavations taking place during the demolitions

contracts is significantly less than if excavations were to be programmed during the piling contracts or station box excavations. So, wherever possible, excavation works have been planned and completed as soon as possible in the programme (Fig. 15 and 16). That decision may have meant additional temporary works being implemented at additional cost. However, programme delays due to archaeology on enabling works packages may cost the project £20–40k per week. Apply the same delay to a main works tunnelling contract worth £1 billion, and daily delay damages could cost the project up to £1 million per day. The NEC contracts can include delay damages to be imposed on the archaeological contractor to control poor performance in completing the archaeological works on time. Likewise the main contracts include an undertaking written into the Crossrail Act (2008) that main contractors must allow sufficient time to allow archaeological works to be completed, and a minimum 28 day period allowed for excavation of unexpected discoveries.



Fig. 15 – Excavations at Bond Street Station site following demolition of buildings (Photo by Oxford Archaeology, Copyright: CRL Ltd).

Dissemination, community involvement and education

The Crossrail project has a proactive approach to public relations and in particular community relations. In respect of the archaeology programme one of the core objectives is the successful dissemination of archaeology information to the wider archaeological community together with a focused education and outreach programme for local communities in line with UK heritage policy and best industry practice (DCLG 2010, CARVER and KING 2008). Environmental issues are also promoted to the project teams to raise awareness of the projects commitments to archaeology and heritage. Crossrail is developing a series of initiatives to address these aims.

Project staff

Within the project a series of tool box talks and learning seminars is being developed for all project staff. These are held at various project offices to communicate generic information on the background to the archaeology programme, what are key commitments we have made our stakeholders, and what we each need to do to ensure we meet the minimum standards. Individual topics for specific locations are also being communicated through project newsletters prepared by our stakeholder communications team for each major construction site. In these we are able to highlight the particular archaeology facts and what needs to happen, and when.



Fig. 16 – Excavations at Tottenham Court Road Station site following demolition of buildings (Photo by Oxford Archaeology, Copyright: CRL Ltd).

Public information (on-site)

To communicate information to local communities on what works are taking place at each major construction site, our media team is preparing posters for the site hoardings, and community newsletters which contain updates on the archaeological finds. Project visitor centres are opening at two locations in the city and we plan to present temporary exhibitions of finds at these, as well as delivering a series of lectures to residents, local businesses and community groups. School visits to archaeological excavations have been organised which provide a mixture on hands on educational activities, such as the Museum of London Dig Box (Fig. 17), and tours of excavations provided by our lead archaeologists (Fig. 18). These events have so far been well received and generated positive media interest and public relations for the project as a whole.

Academic outputs (the project records)

The results of the archaeology programme are to be communicated through interim and final fieldwork reports initially, that will be submitted to the London Archaeological Archive Research Centre (LAARC). Once field investigations are largely complete a formal post excavation project shall be carried out to ensure that the combined results across the research themes discussed above, contribute to a genuine research output

for the project. The project archives, including finds and environmental evidence will be assigned to the museum of London for long term safe storage and possibly presentation within specific exhibitions planned by the museum. We also aim to develop a dedicated project digital archive with an institution such as the UK Archaeology Data Service (ADS). Summary articles will also be prepared for professional journals to alert researchers to the summary results and contents of archives.



Fig. 17 – Left, school pupils discover finds in the Dig Box and Young Crossrail mascot 'Digby the Mole' makes an appearance. Right: Archaeologist discusses finds from the Dig Box with pupils (Photos by Juliet Whitcombe, Copyright: CRL Ltd).



Fig. 18 – School pupils are given a tour of the excavations at Stepney Green by the excavator Dave Sankey from the Museum of London (Photo by Juliet Whitcombe, Copyright: CRL Ltd).

Presentation of archaeological remains

Finally, wherever possible we are retaining and reusing historic assets within the final design of the scheme (Fig. 19) and carefully looking for opportunities to design-in presentation of archaeological finds in the finished station areas. To achieve this we are liaising with the projects art and architecture teams to identify where the rich history of the project sites revealed by archaeological and historical research can be permanently celebrated in the finished railway.



Fig. 19 – The Connaught railway tunnel was built in 1878 AD is now abandoned. It will be restored and reused by a section of the Crossrail rail route in east London (Copyright: CRL Ltd).

Public benefits such as these are not easy to achieve with private sector funding alone and the application of industry proven business management and risk management may be missing from the public sector when planning for archaeology and infrastructure. Crossrail demonstrates that a combined public-private sector venture can provide significant opportunity to marry public goals for the protection and promotion of learning and history of our common heritage with the tools and technical abilities of private sector providers focused on efficiency, value for money and sound business practice. The private sector may often be wary of allowing or funding public archaeology. However, when driven by a strong public sector commitment (see also work done by the National Road Authority in Eire and Highways Agency in England, and CARVER 2009) the shared input of expertise and resources can truly provide public benefit in terms of research output and increased public knowledge of archaeology work carried out in the infrastructure and development sector.

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Rijeka – Pul Vele crikve

Archaeological research of roman baths in the old town of Rijeka (Croatia)

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Abstract: During 2008/2009 the Croatian Conservation Institute performed a rescue archaeological research at the site Pul Vele crikve (*By the Great church*) in the old town of Rijeka.

The oldest finds of this multilayer site are the remains of Roman baths from 1st to 4th/5th century AD. Two construction phases have been identified. The old baths were built during the Flavian age and are less preserved. Based on discovered walls and floors, only six rooms have been identified but their exact purpose remains unknown.

During the second half of 3rd century the baths were expanded or rather rebuilt in the same place. The old baths were levelled, and the new ones were built larger and improved with underfloor heating system. 10 rooms have been identified, as well as the purpose of some of them. The wall and underfloor heating system implies warm and hot rooms, i.e. two *caldaria* and one *tepidarium*. There is a *frigidarium* with a large pool of cold water to the east of the heated area.

Since the site is located within the Old Town urban complex and has protected cultural heritage status, it was necessary to perform archaeological research along with the scheduled replacement of existing municipal infrastructure. The area and the dynamics of research were considerably tailored to the needs of the construction works. An additional difficulty was the fact that this part of the Old Town's pedestrian zone is exceptionally crowded; therefore a permanent pedestrian passage through the site had to be provided. In order to preserve the statics of surrounding buildings, larger excavated areas could not be left open for a longer period of time. Every few researched and documented quadrants had to be backfilled in order to proceed with the research.

Keywords: Roman baths, Rijeka – Tarsatica, rescue archaeology, urban archaeology.

The site Pul Vele crikve

Rijeka is situated in the Western Croatia, on the northern Adriatic, overlooking the Kvarner Bay. During 2008/2009 Department of Archaeological Heritage of Croatian Conservation Institute performed a rescue archaeological research at the square Pul Vele crikve and eastern part of Užarska street in the old town of Rijeka (Fig. 1).

The site is located within ancient roman and medieval settlement, and this part of town has protected cultural heritage status. Because of that, it was necessary to perform archaeological research along with the scheduled replacement of existing municipal infrastructure. The size of excavated area was approximately 1100 m².



Fig. 1 – Old Town urban complex with the site Pul Vele crikve and the position of roman and medieval walls (Copyright: Croatian Conservation Institute).



Fig. 2 – Rijeka – Pul Vele crikve from 1st to 20th century (Copyright: Croatian Conservation Institute).

Diversity of historical periods is represented on this multilayered site which enables us to trace the history of Rijeka from 1st to 20th century (Fig. 2). The youngest finds belong to the sewer system and few structures from 19th and 20th century as well as to the modern age architecture. Chapel north of the tower (dated to the 16th to 18th century) was placed directly on mosaic floor of basilica. Grave architecture is placed south and west by the church of st. Marys Assumption. The whole cemetery (most of the graves are without architecture) is dated from 14th to 18th century. Early Christian basilica, dated in 5th and 6th century, is placed in front of and beneath the church. It has three naves and nartex in front of them. It had multicolored mosaics which were conserved, protected and left *in situ* because of the planned presentation. On the southeastern end of the site, remains of the rampart from the 4th century were found. The oldest finds belong to the roman baths which were used from 1st to 4th/5th century.

Roman Baths

The remains of Roman baths were placed in the southeastern part of roman Tarsatica, near the water source (stream Lešnjak). Baths (as well as basilica and nowadays church) are oriented NE-SW, parallel with the main roads of the roman Tarsatica. Two construction phases have been identified. First one dates to the 1st century when they were built during Flavian age. Second one dates in the second half of 3rd century when they were expanded or rather rebuilt (MATEJČIĆ 1968 and 1988; BLEČIĆ 2001). Baths lost their function at the end of 4th or the beginning of 5th century (radiocarbon dates: 2 sigma 330–540 AD, 1 sigma 390–430 AD), period of general insecurity and chaos of the society present in that period among the town inhabitants. At the approximately same time, Principia (roman headquarters) at Tarsatica was also destroyed (VIŠNJIĆ 2009).

Roman baths were discovered during rescue archaeological excavations conducted by R. Matejčić in 1967/1968. Remains of underground heating system, as well as part of exedra and cloaca were brought to light. Already than two construction phases have been recognized (MATEJČIĆ 1968 and 1988).

Only southern and eastern border of the baths are found. Their exact dimensions are still unknown as well as the purpose of most rooms.

Old baths

Old baths are less preserved because they were leveled in the 3rd century. Because of the planned presentation of the site some of the younger structures were left *in situ*. They were partially placed on the old baths which couldn't be excavated in those places.

They were built 30 to 50 cm deeper than the new baths – during research they were mainly under water which tells us about different water regime in that period. Geological testing discovered that solid rock is situated 15 m deep (VULIĆ 1968). Since the site is placed on alluvial deposits, roman foundations of both phases are well built in *opus caementitium*. Walls were built in *opus incertum* (irregular small stones on the exterior face, filling of rubble and mortar) and only masonry floors were found (*opus signinum*) (MATEJČIĆ 1968: 29; ADAM 1994: 127–128, 232; SUIĆ 2003: 178–180; KOEPF and BINDING 2005: 323–325). No heating system was found.



Fig. 3 – Old baths: rooms A–F (Copyright: Croatian Conservation Institute).

Six rooms have been identified but their exact purpose remains unknown (Fig. 3). Rooms A and B are situated in the western part of the baths. *Hypocaust* of the 2nd phase of baths was placed over their eastern wall but was not removed during our excavations. That wall was only partially excavated but we can trace its course below the hypocaust (Fig. 4). Room C is situated east of mentioned rooms. In the south it ends with semicircular apsis (Fig. 5). Semicircular space is often connected with roman baths and usually a pool was placed in it (FABER 1992: 151–152; MACDONALD BOYLE 1980: 19). The northern part of the room was not found during our excavations. In room D parts of a plaster floor were found. In the NW and SE corners square structures were found (70 x 70 cm). Their exact purpose is unknown: perhaps they were used as a stand for some architectural decoration. During renovation in the 3rd century northern and eastern walls were levelled and another wall was built across the room. In modern times SE part of room was destroyed with the construction of the cesspool with its outpouring in the ancient *cloaca* (Fig. 6).

Room E is placed to the east, mostly below nowadays buildings. Southern wall was used in the second phase when another wall was built over it. Room F is placed south by the church. Northern wall was found below church foundation and it seems like there was a passage placed there. In the 3rd century it was closed and filled with *opus caementitium*. These facts tell us that baths spread further to the north.

During 1960s excavations a vaulted channel was found at the southern end of the excavated area (MATEJČIĆ 1968). Its eastern part was found during new research but traces of vaulted ceiling were not found. On the southern wall two construction phases can be seen. Judging by the position of the walls from the 3rd century, the channel lost its function when the baths were renovated.



Fig. 4 – Wall of the 1st phase of roman baths under the heating system of 2nd phase (Copyright: Croatian Conservation Institute).



Fig. 5 – Part of an apsis in the room C (Copyright: Croatian Conservation Institute).



Fig. 6 – Southeastern part of the room D destroyed with the construction of a cesspool (Copyright: Croatian Conservation Institute).

New baths

During the second half of the 3rd century baths were rebuilt: new baths were built larger and improved with underfloor heating system. They were minimally 38 m wide (E-W) and minimally 43 m long (N-S). Southern perimeter was found during 1960s and eastern in the new excavations while the exact northern and eastern border still remains unknown.

10 rooms have been identified (Fig. 7) as well as purpose of some of them: *caldarium*, *tepidarium*, *frigidarium*. Three rooms had underfloor heating system: rooms 1 and 2 are identified as *caldaria* (hot rooms) and room 3 as *tepidarium* (moderately heated room). Room 1 is the biggest one with its size 13 x 6.5 m. Room 2 is the smallest (6.5 x 3.5) and warmest one. It had mosaic floor and a small basin (*alveus*) in the northeastern corner (Fig. 8), closest to the heat source. In the walls that separated rooms 1 and 2 with room 3, openings were found – through them hot air passed into the hypocaust of room 3 which wasn't directly connected to the heat source.



Fig. 7 – New baths: rooms 1–10 (Copyright: Croatian Conservation Institute).

Hypocaust remains are rather well preserved. Lower floor was made out of reddish plaster and the upper *suspensura* was approximately 20 cm thick and fragments of it were found *in situ*. Columns or *pilae* are made out of 12 or 13 circular bricks and sometimes lay on square *plinta*. Their height amounts up to 90 cm. Walls in heated rooms were covered with hollow bricks (*tubuli*): through them hot air could circulate and heat the walls (KRETZSCHMER 1953: 38–39; DEGBOMONT 1984; YEGÜL 1992: 357). They were found during 1960s excavations. In the new excavations *tubulus* was visible only in the NE corner of *alveus*. Lower parts of walls, below floor level, were built of bricks (*opus testaceum*) because they are more resistant to great heat coming from the *praefurnium*. In their upper part walls were built of bricks and stones (*opus mixtum*). Inner part of walls was packed with rubble and concrete (ADAM 1994: 139–150). Walls were covered with plaster traces of which are still visible.



Fig. 8 – *Hypocaust* and *alveus* in room 2 (Copyright: Croatian Conservation Institute).

Rooms 4 and 5 were used for firing – in the northern wall of room 2, two openings were found through which hot air could pass from room 5 into the hypocaust. In room 5 layers of ashes and slightly baked clay were found. Room 4 is devastated and we can only assume it was connected with heating because of a large area that had to be heated for which room 5 probably wasn't big enough.

To the east of the heated rooms a *frigidarium* is placed. So far, it's the biggest room of roman baths in Rijeka: 16.5 m long and 8 m wide. Eastern and western walls had very well constructed foundations so they can transfer heavier weight to the ground (Fig. 9). This room had mosaic floor: few fragments with black and white *tesserae* were found. In the northern part of the room a pool (Fig. 10) was placed (dimensions: 7 x 3.5 m). It was about 65 cm deep. Floor was made out of 77 *tegulae* placed with their upper part downwards. On the inner side of the pool, walls were covered with hydraulic plaster. On the northern wall of the pool, church was built in later periods. One could enter the pool from the south, by descending three steps placed on the eastern and western end of southern wall. All around the pool ran a bank which could be used for leaning or sitting whilst in water. By the eastern wall of the *frigidarium*, near the pool, traces of a fountain were found. Not much of it was excavated because it is placed beneath nowadays buildings. It consists of an arch construction in the eastern wall in front of which is a square siphon where water would flow. On the other side of the wall, small portion of a channel was found, probably where surplus water was gathering.



Fig. 9 – Southern part of the eastern wall of the *frigidarium* (Copyright: Croatian Conservation Institute).



Fig. 10 – *Frigidarium*: pool during research and modern age grave architecture (Copyright: Croatian Conservation Institute).

Remains of other rooms are scarce but we can assume the existence of at least 4 rooms.

To the east of the *frigidarium* there's at least one room. Most of it is situated below nowadays buildings. In the northern part traces of floor made in *opus spicatum* were found. Southern part of the room ends with some kind of a niche whose walls were built without foundations. Perhaps a porch or an entrance was placed here.

In the area around the so called Leaning tower, in front of the church of St. Marys Assumption, horizon of roman baths is scarcely excavated because of the early Christian basilica with well preserved mosaics that were found there and left *in situ*. By the position of the walls beneath the mosaics we can assume there were 3 rooms placed there. Since they were not excavated, their purpose and size for now remains unknown. In all of the rooms traces of red plaster floors were found. It is possible that these rooms do not belong to the roman baths.

Difficulties of urban archaeology

Because of its position in the city centre, there were some difficulties which were encountered during archaeological research.

Excavation was slowed down because of the existing infrastructure (large number of all sorts of cables, gas and water pipes, sewer, Fig. 11). Because of that excavation around them and documentation of finds (first of all architectural remains) was rather complicated. When sewer and pipes were placed during 20th century, some of the archaeological remains were devastated.



Fig. 11 – Infrastructure slowed down excavations and destroyed archaeological remains (Copyright: Croatian Conservation Institute).

An additional difficulty was the fact that this part of Old Town's pedestrian zone is exceptionally crowded. Therefore a permanent pedestrian passage through the site had to be provided. Smaller sections had to be excavated so a part of the street or square could be left open for pedestrians (Fig. 12). Sometimes these sections were only 2–3 m wide and work had to be done in such a narrow place.



Fig. 12 – Narrow trenches made the excavations somewhat difficult (Copyright: Croatian Conservation Institute).

The area and the dynamics of research were considerably tailored to the needs of the construction works. Archaeological excavation was done before the replacing of infrastructure.

The excavation, sometimes over 2 m deep, ran along nowadays buildings. Some of them are built without foundations, and sometimes bottom of the excavation trench was deeper than foundations. Most problematic was so called Leaning tower which leans slightly towards church (its NW side is built on older wall, unlike their other sides). In order to preserve the statics of surrounding buildings, larger excavated areas could not be left open for a long period of time. Every few researched and documented quadrants had to be backfilled in order to proceed with the research.

Ground water caused some problems and complications: in some parts of the site, excavation was carried out with constant work of water pipes (Fig. 13). Since water on some places advanced constantly, documenting of some of the finds was rather difficult.



Fig. 13 – Ground water caused some problems during research (Copyright: Croatian Conservation Institute).

Since the site is located in an urban area, which was settled almost continuously from the 1st century, stratigraphy is rather complicated. Older structures are often leveled or used in younger historical periods and younger structures were built over older ones.

Roman walls built in 1st century were sometimes used in the 3rd century when baths were rebuilt. Because they had good foundations, new walls were sometimes built on them.

Roman walls could sometimes be traced under floors or other structures. For example, colonnade of early Christian basilica from 5th and 6th century was placed on older walls. This can be seen because the site is placed on alluvial deposits. That is why layers and structures without foundations sink as the time passes and walls with good foundations retain their height.

Long term plan for the site is its presentation. That is why most of the site was not excavated to the sterile ground. Early Christian mosaics were not removed (Fig. 14), and the situation beneath them could be traced only in small portions where they were devastated in earlier times.



Fig. 14 – Southern nave of early Christian basilica with mosaic floor (Copyright: Croatian Conservation Institute).

Medieval and modern age cemetery was situated on the place of roman baths and basilica. Grave architecture is in its big part placed inside the basin of roman *frigidarium* (Fig. 10) and some graves are placed directly on mosaics. Recent time infrastructure resides upon older layers and structures.

Presentation of the site

After archaeological research, all the structures were temporarily protected: they were covered with geotextile. Walls were additionally protected with styrofoam, and hypocaust columns with wooden coating. They were covered with sand on top of which substrate for asphalt and final layer of asphalt were placed. After the archaeological research the next step is to find the best possible way for the presentation of archaeological values. Most attractive finds are those of early Christian basilica with its beautiful mosaics as well as the remains of the second phase of roman baths. A suitable solution has to be found so all the features could endure outdoors conditions. Perhaps the most adequate part of the site for presentation is a triangle south of the church where remains of *frigidarium* and two *caldaria* were found. Today terrace of a coffee bar is placed there and in terms of communication it represents rather unused space.

Municipality of Rijeka, as well as Croatian Conservation Institute is interested in presenting this small but significant part of town history. All the efforts are made in providing sufficient financial assets. First step is publishing a monography about the whole site which is in progress.

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Urban Archaeology in a European Capital: the Brussels' experience

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Abstract: This paper presents the recently installed operational workflow concerning archaeology in Brussels, capital of Belgium. In 1991, 2 years after the creation of the Brussels Capital Region, the Heritage Direction of this Region started, in collaboration with the Royal Museums for Art and History, the elaboration of an Atlas of archaeological expectations. Since the introduction of the archaeological law in the Brussels Code for Urban Planning and Housing in 2008, specific conditions concerning the organisation of preventive archaeological research, based on the results of the Atlas, are integrated in the building permits in the case of the destruction of the standing or underground archaeological heritage. These interventions can only be executed by the Region itself or by acknowledged public institutions and private organisations.

Keywords: urban archaeology, preventive archaeology, building archaeology, archaeological management.

Introduction

Belgium is a federal state with three regions: the Dutch-speaking Flemish region or Flanders, the French-speaking Walloon region or Wallonie and the bilingual Brussels Capital Region. Since the federalization of the Belgian state in 1989, heritage and therefore archaeology is a regional matter, each region having its own legislation. Heritage is integrated into the "General Direction of Urban Planning and Housing".

In 1830, date of the independence of Belgium, the city of Brussels only has a surface of approx. 400 ha. It will know a rapid expansion in order to respond to its new administrative, political and economical functions as a capital. Under the reign of Leopold II (1865–1909) the city undergoes fundamental transformations with the installation of large boulevards, e.g. the *Avenue de Tervueren*, and huge monuments like the *Palais de Justice*. After the 2nd World War, the extension of the city reaches the actual 165 km² of the region enclosing the villages around the city, extension not only on a horizontal level but also in depth with the creation of numerous underground parking spaces. The 20th century is at the same time marked by large infrastructure works like the unique partly underground North-South railway junction, the metro and a huge number of traffic tunnels creating an impressive communication network, but at the same time ripping up the city during a very long period. And the European vocation of the city occasions various constructions for the new international institutions and organisms.

This rapid growth of the city, unfortunately also renown for its so-called *Brusselization* (the architectural term describing the uncontrolled development of a city) stands in huge contrast with the only very slowly growing interest for the archaeological heritage and the battle against its massive destruction.

The first archaeological actions in Brussels will be undertaken by the *Société royale d'Archéologie de Bruxelles* between 1890 and 1910. The *Société* organizes the archaeological surveillance of some of the city's larger construction projects, e.g. the Palace of Justice. The majority of their actions will however take place elsewhere on Belgian soil and rarely within the Brussels region. Meanwhile, in 1903, the first National

Archaeological Service is created, but its members will only accomplish a limited number of excavations on the city's territory. In 1963, during the economic boom of the city, the Service becomes a real state-subsidized scientific institution that unfortunately does not have enough staff to cope with the rising awareness for archaeology in the country and therefore puts its priorities elsewhere in the country. In 1989, during the federalization process of the country, the National Archaeological Service is dissolved and regionalized.

In 1991, the regional Brussels government together with Anne Cahen, curator at the Royal Museums for Art and History, decide to elaborate the Atlas of all known archaeological sites within the region. This will be the start of a new era, acknowledging finally the fact that Brussels also has its own history, just like any other city or village in the country.

The Archaeological Atlas

This regional atlas covers in a detailed way the 165 km² of the territory with its 19 communes and is developed within the cartography project of the Administration of Town Planning and Housing (www.BruGIS.irisnet.be). This public cartographic site contains all urbanisation information concerning the city: its protected monuments, sites and trees, the zones of economic expansion and urban planning, transport facilities, etc.

It consists of a compilation of ancient topographical maps, historical documents and various types of archives projected on the actual cadastre. Synoptic maps show, for each of the 19 communes of the Brussels' Region, the old roads and waterways, ancient buildings like farms, churches and manors dating till the 18th century, and the archaeological zones around these constructions (Fig. 1). A description of the archaeological objects found on and around these sites completes each commune.

As the detailed information for each feature is actually only available in a paper edition, the Archaeology Department is preparing a website giving detailed digital access to these features, linking them to their cartographic counterpart. This website will also give the possibility of subject-related and diachronic research.

The degree of precision of the digital maps enables to distinguish a level of archaeological potential for each cadastral parcel. The atlas has thus become the principal tool for evaluating the potential within the scope of a building project or a building to be renovated. To qualify this potential, a consultation and an interpretation of the assembled data by an archaeologist is however necessary.

This desk-based evaluation can be completed by a terrain evaluation like e.g. a location visit to identify fossilized traces of the original relief, or the execution of pedological and/or archaeological trenches in order to precise the absence/presence of remains, their nature, their state of conservation etc. These evaluations have been multiplied in recent years and are linked to the systematic development of preventive archaeology. Subsequently they enable to calibrate, foresee and plan the excavations.

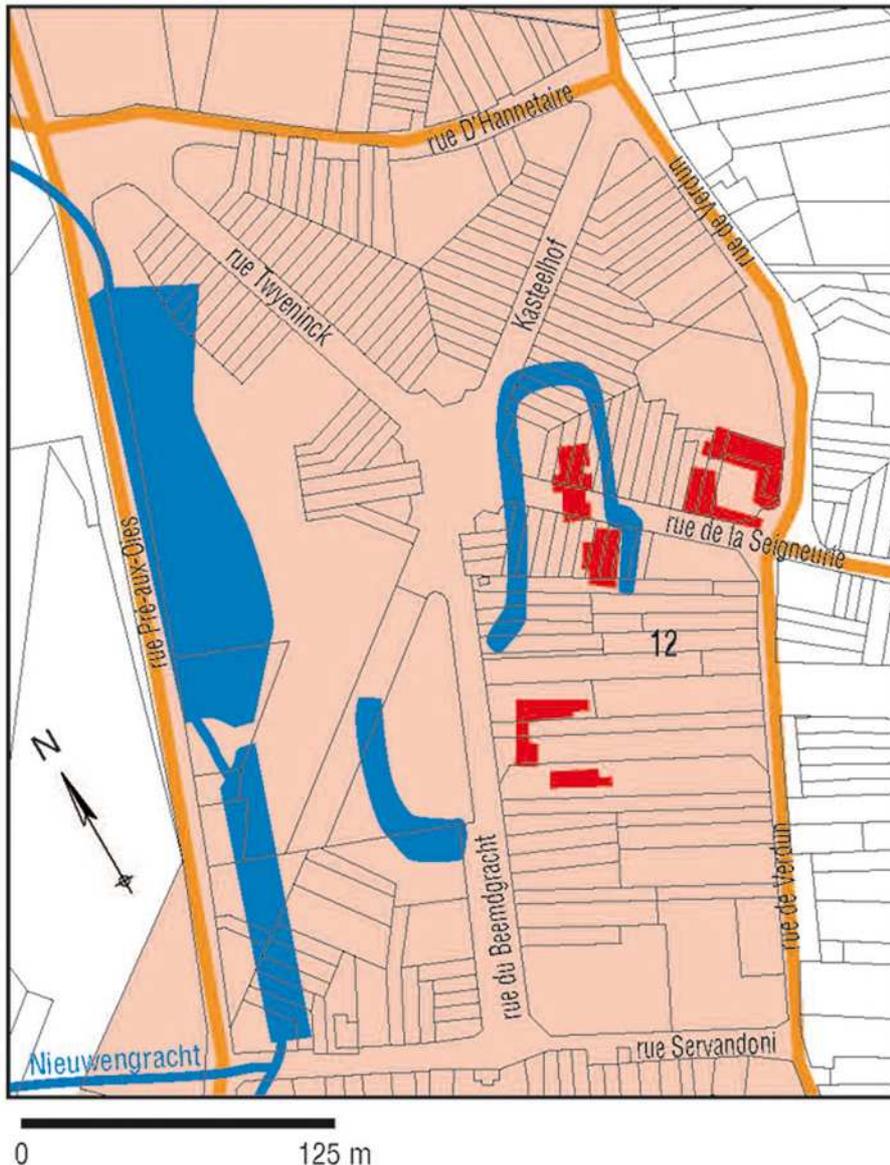


Fig. 1 – Example of the Atlas of the Archaeological Subsoil, commune of Haren. In blue: ancient waterways, in orange: ancient roads, in red: *Ter Elst*, the 16th century castle of Haren, in pink: the parcels with a high archaeological potential (© MRBC-DMS).

The organisation of the archaeological excavations

The general dynamics of the archaeological research in the Brussels Capital Region are based on the Malta convention, ratified by the regional Brussels parliament in 1992, and by the Belgian Government on October 8, 2010 (taking effect from April 9, 2011). The implementation is however a slow process resulting in a public action almost exclusively oriented towards preventive archaeological operations.

Between 1992 and 2008, excavations were negotiated with the landowners on a purely scientific base.

Having only two archaeologists for the whole territory, choices had to be made, e.g. the parcels on the layout of the 13th century city wall.

The actual legislation was adopted in 2004 in the Brussels Code for Town Planning and Housing (art. 243 - 250), completed in 2008 with two decrees organizing the archaeological excavations.

The legal definition of the archaeological goods is neither limited in a chronological way nor in space. Building archaeology is handled in the same way as subsoil archaeological excavations, the distinction being of minimal relevance in an urban context organized around a medieval urban nucleus originating between the 11th and the 14th century AD.

The archaeological clause in the building permit

The first case to be described by the law is the deliverance of a building permit, subordinated to an archaeological clause. Various types of clauses oblige thus the builder to accept the organisation of an archaeological monitoring of the authorized building works and/or the realisation of archaeological research before the building activities. The clauses are based on the archaeological expectations as described in the before mentioned Atlas. Therefore, each demand for a building permit within our region is since 2009 systematically examined and compared with the Archaeological Atlas.

The realization of the archaeological research, be it in the subsoil or in the existing buildings, is limited to the holder of a specific permit, i.e. *author of archaeological research*, accessible as well to legal as to natural persons. This permit is subject to conditions of competence (university diplomas in archaeology and history and at least 3 scientific publications) and terrain experience (5 years of experience during the last 10 years concerning at least 3 different archaeological operations for which the reports have to be presented). The permit is valid for 5 years.

The regional government can then give the authorized service providers the authorization for excavating a not threatened site or a mandate to execute preventive archaeological excavations. This mandate, organised via public procurement, specifies every detail of the intervention: research program, planning, facilities, excavation strategy and methods, and the registration documents and reports to produce.

The regional Administration bears all expenses for the preventive archaeological operations and the reporting via its own teams and intervention logistics or via the authorized service providers (Fig. 2). The financing is thus almost exclusively public (the Brussels Government) with, occasionally, the logistic help of owners and building promoters, e.g. heavy machinery, enabling thus the prescribed research to be executed in a faster pace.

The archaeologist disposes of a comprehensive manual, containing among others a field guide on the handling of archaeological objects during the excavation phase, a sampling manual, guidelines for drawing the objects and for constituting the archaeological report.

The finds are processed by the Laboratory for Archaeology in Brussels (the LAB), created in 2007 and housed within the administration's buildings. This laboratory counts a ceramics and a metals specialist, both being at the same time responsible for the management of the storage rooms. They are assisted by technicians, each trained for a specific part in the restoration process, e.g. the stabilization of glass. Incoming objects are washed, restored (Fig. 3), marked before being studied and described in the report by the archaeologist in charge (regional or by mandate) and finally stored. All laboratory actions on the archaeological objects and their location in the storage rooms are inventoried in a centralised Archaeological Database.



Fig. 2 – Archaeological excavations by the mandated service provider *Recherches et Prospections archéologiques en Wallonie asbl* on the terrain Quai aux Barques 5, Brussels (© MRBC-DMS, photo: Véronique Moulaert) :

This management system functions at the same time as a research tool. Every author of archaeological interventions within the Brussels Capital Region is therefore obliged to use this database to introduce all the information and documentation of his/her excavation. The information demanded concerns *int.al.* the stratigraphic units and their relations, the objects discovered with a detailed description of the material, decoration, form, etc. and is based on a unique number system.



Fig. 3 – A 15th century greyware jug, discovered during excavations in the basement of café Greenwich, rue des Chartreux, Brussels (© MRBC-DMS).

Fortuitous discoveries

The archaeological legislation also provides for the fortuitous discoveries. They must be signalled to the Heritage Direction of the region, being in charge of archaeology, within 3 working days. They can be accompanied by an automatic halting of the building activities during 21 working days in order to enable the intervention of an archaeological team (an Administration team or an authorized team mandated by the Administration). In the case of an exceptional discovery, the regional government can prolong this time period and, if necessary, suspend or cancel the building permit. But the number of fortuitous discoveries is almost non-existent: many building operators do not / cannot recognize archaeological remains nor their importance. Unfortunately, only the discovery of human remains will establish the necessary connection between archaeologists and the building operators. We therefore work closely together with the local police and the internationally renowned Disaster Victim Identification Team, often the first ones to be called on the spot.

Excavations of Public Interest

The archaeological law finally also provides for excavations *of public interest*. The Brussels Government indicates the archaeological site and the conditions of the excavation (geographical area, time period of the excavation, etc.) and provides the owner with compensation in case of damage. No excavations of this type have been carried out in the Brussels Capital Region till today.

Building Archaeology

Emerging from his trench, the urban archaeologist does not see the sky: he sees buildings. The archaeological interventions in Brussels are therefore twofold: the so-called “classic” sub-soil archaeology and the building archaeology or *Bauforschung*. Both are combined in order to obtain a complete picture of the history of a place.



Fig. 4 – Building archaeology by the authorized service provider Royal Museums for Art and History, at the Quai au Bois de Construction, Brussels (© MRBC-DMS, photo: Patrice Gautier).

The starting point should therefore be “today”, no longer only looking at the mere historical chronology of a city but also at its physical development: how did we arrive at the present day situation? How can we explain the actual map of the city, the layout of the streets and the buildings? Are the actual buildings build on top of older ones or did they integrate, fossilize the older ones inside their new walls? How was the internal circulation? How did people live in the house and use and transform the space?

While subsoil archaeology has slowly made its way through Brussels and today is mostly accepted by the different partners during the various building phases on a plot, building archaeology remains a difficult item. The existence of numerous older, fossilized building phases, hidden underneath layers of modern plaster, is difficult to apprehend for many owners and project architects, haunted by the idea that archaeology equals the obligation to preserve the newly discovered remains.

While it is a fairly young discipline, the *excavation* techniques remain the same: we have trenches through the various plaster and wallpaper layers where each layer is also considered to be a stratigraphic unit, just as in subsoil archaeology. Each building element, be it windows, doors, timber frames, floor tiles, beams, framework, fire places, window frames, and much smaller objects like hinges, decorative elements, the mortars used, etc. – each element is described in a thorough way in order to obtain a complete picture of the evolution and the various building and transformation phases of the construction. The combination with subsoil archaeology becomes here imperative.

It is therefore extremely important that interdisciplinary teams should be put in place right from the start of the project. This team should not only include architects and engineers, but also, and at the same level, archaeologists, building archaeologists and art historians. Only by working together and establishing clear procedures, avoiding at the same time the various difficulties presumed by the building companies, one will obtain a project with a high heritage value. But it is our role as archaeologist to explain this approach to the private and public town planners, and convince them of the added value of archaeology and especially building archaeology.

What about *in situ* preservation?

Once the archaeological remains excavated, which criteria will nourish the decision to safeguard, restore and eventually open them to the public? If the archaeologist puts the traces of early medieval agriculture on the same level as the remains of the duke's palace, the latter has the merit of being probably easier to present to the public than the little bits of “black earth”. Nevertheless, archaeological goods lack, more than any other heritage form, information and necessitate often heavy restoration options in order to preserve them. In most cases, they also need a didactic angle, sometimes only a hypothesis. However, the decision to conserve is mostly less one of the archaeologist than of the proprietor, cultural organisation or political deciders.

And the future?

In conclusion, the management of the archaeological heritage should not aim at the excavation at whatever cost, but rather the preservation of this heritage with excavations only executed in the case of absolute necessity. But history is eroding: per definition, the number of archaeological sites will not augment – it is finite. Any destruction is definite and irreversible. Only the number of *discovered* sites will augment. The fundamental problem is, however, that archaeology often still isn't integral part of the initial urbanization planning. The sensitization of the non-archaeological actors in the administrations or architect offices charged with the appraisal of the building documentation should therefore be the archaeologist's priority.

We can therefore only join the concern of Michel de Waha, professor at the Université libre de Bruxelles, expressing already in 1994 the wish that urban archaeology should be an “archaeology of the city” and an integral part of its environment, and not a more or less accidental archaeology “in the city”.



Fig. 5 – The archaeological museum of the Coudenberg, ancient palace of the Dukes of Burgundy (www.coudenberg.com) (© MRBC-DMS).

Urban archaeology of Koper/Capodistria

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Abstract: Koper/Capodistria is one of the typical Mediterranean towns along the northern Adriatic coast. It is located in the densely settled area. Its history is known only from the rich archival sources. Building activities in the 1980ies and during the last decade have intensified the research in the town's historical core. More than 30 archaeological excavations have been performed and have revealed great amount of archaeological material which has not been adequately studied and published. The lack of the scientific research of the material remains presents a great obstacle to the thorough interpretation and understanding of the establishment and development of the town and conservation and presentation of its heritage.

Keywords: Koper, urban archaeology, interpretation, presentation.

Introduction

The town of Koper /Capodistria is a typical coastal town and municipality situated on the eastern Adriatic coast. It was established on the island that was large enough for the establishment of the permanent settlement and at the same time due to its isolation from the coast it enabled the safe and protected environment for its development.

Its establishment is dated to the antiquity but still with no sure archaeological evidence. It has reached its economical and cultural peak in the periods of middle ages and Renaissance when it was ruled and strongly influenced by the Venetian Republic. The town has become the cultural, religious and administrative regional centre also known for its navy, fishery and salt plants. At present it is the largest commercial port in Slovenia. It is also one of the main road entry points into Slovenia from Italy which lies to the north of the municipality. The cultural heritage of Koper contains characteristics of two main geographical areas that have influenced its genesis and further development – mediterranean influences and elements of continental – central european influences. Beside afore mentioned characteristics the specific geographical position has enabled Koper to develop as the multicultural centre where different ethnical and cultural groups have shaped its development by introduction of their own elements illustrating their social, economical and cultural characteristics.

Already mentioned influences that have formed multicultural base for its genesis and development could be traced through the study of urban development and structure. On the other hand they could be recognized on the level of population, their habits and other aspects of everyday life that are reflected in archaeological remains.

Archaeological research of Koper/Capodistria

Until the middle of 20th century history of the town and the interpretation of its genesis and development has been leaning on the urban traits, still standing architecture and epigraphical monuments discovered within

the town. Vivacious building activities in the 80's have been a reason for numerous archaeological excavations. Excavations have taken place in more than 30 locations throughout the town. These activities have yielded a vast quantity of data spanning from the very first phase of life of the town to its medieval and post medieval development as well as of the surrounding territory. Although these have unearthed a substantial amount of material many of these excavations have not been researched and published yet. Many of them have not even reached the publication of the preliminary report. On certain occasions authors have shown the attempt of presentation of the urban archaeology of Koper but the results have not exceeded the descriptive level of the general traits of history of research, presentation of most important or larger excavations or focus on one certain location within the town (CUNJA 1992, 1998, 2006; GUŠTIN 2001) thus not enabling the reader to get a clear and complete picture of the level of information considering basic questions of the town's genesis, development and history on the level of everyday life.

The second wave of building activities in the town started in the 1990ies and was intensified in the last decade due to the new development strategy oriented towards the economical growth and has shown that the quickly changing image of town is erasing the existing witnesses of town's history. More than 45 archaeological excavations have been performed and have revealed great amount of archaeological material which has not been adequately studied and published and lacking the thorough interpretation and understanding of the establishment and development of the town. Figure 1 shows the locations of the excavations carried out in the town's historical core that have been published at least in the form of the preliminary report.

The changes of the town have shown the need for their protection, but at the same time for its interpretation with the goal of satisfying the needs of the new structures of society, their environment and economical development. This problem has been noticed in many of the coastal towns on the Adriatic that are undergoing substantial changes depending solely of the economical needs of the contemporary society. The level of preservation of the town's cultural heritage ranges from the information preserved in the shape of the still unstudied archaeological material to whole buildings preserved up to two or three stories high. Previous work conducted in Koper has shown the need of a proper scientific evaluation of both the standing and underground/archaeological cultural heritage in order to maximize the amount of information available on an heritage which is increasingly at risk faced the fast development of tourism and infrastructures that the town is undergoing in recent years and that will probably be increased even more in the near future. This approach was characterized by the recognition of the broad historical and archaeological potential that can be inferred by the study of buried deposits, by the way of living and by the analysis of the economical systems. However, the importance of the finds and the historical – archaeological issues that have been investigated is such to deserve a wide dissemination that could address both the scholarly public and the general audience.

At the same time the evaluation of the archaeological, architectural and historical records on the town would enable the researchers to offer the interpretation and the reconstruction of town's genesis and development as well as many other aspects of its history. On one hand it would enable the study of the town as the whole, since its beginnings to the present and it would make the good base for the future research. At the same time it would form the base for the development of other aspects of the town. Once done, the results would

offer the theoretical and methodological base for the similar work in the numerous towns that are facing similar changes and problems incurred by those.

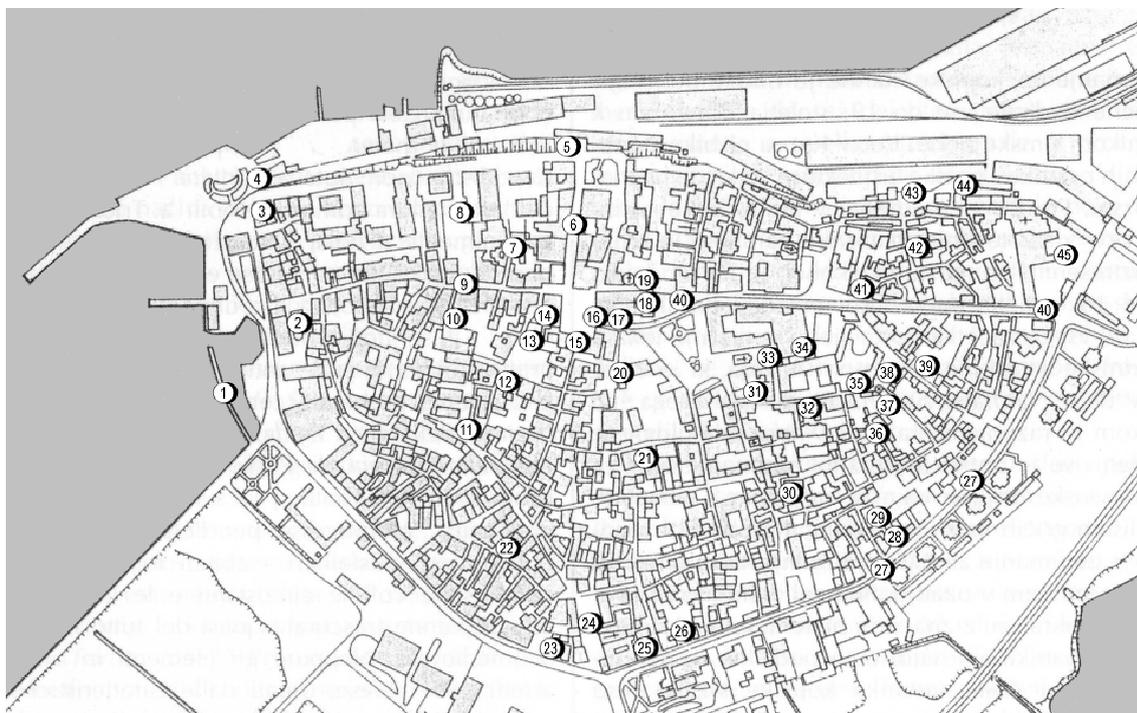


Fig. 1 – Plan of Koper/Capodistria with locations of the published excavations within town's historical core (2010): 1 – Porporella (2005), 2 – Carpaccio square (1999), 3 – Ukmar square 5 (2007), 4 – Ukmar square (2006), 5 – Belveder (2000), 6 – Verdi street (2006), 7 – Youth street 4 (1998), 8 – Museum square (2008, 2009), 9 – Kidrič street (1993), 10 – Museum garden (1997), 11 – Garibaldi street (1990), 12 – Garibaldi street, 1 (2001), 13 – Faculty of Humanities (2005, 2006), 14 – Armeria-Foresteria (1990, 2005–2006), 15 – Praetor's Palace (1993), 16 – Tito square (1980), 17 – Cathedral-outside (1986, 2006), 18 – Cathedral-inside (1991, 2006), 19 – Baptistery of St. John the Baptist (1995, 2000), 20 – Diocesan ordinary's office (1989), 21 – Street OF (1990), 22 – Street Velika vrata (1992), 23 – Port street (1985), 24 – Prešem square (1993), 25 – Soča street (1992), 26 – Kolarska street (1989), 27 – Vojko bank (2008), 28 – Tovarniška street 8–10 (1993), 29 – Tovarniška street, 4-Božič street 2 (2005), 30 – 22-Garden street 2, 4, 8 (2005, 2006), 31 – Krelj street 1 (2009), 32 – Krelj street 6 (1993, 2010), 33 – Martinc square (2003), 34 – Church of St. Francis (1996), 35 – Church of St. Claire (1989), 36 – Gruden street 3 (2008), 37 – Kumar street 4 (2004), 38 – Giordano Bruno square (1994), 39 – Cappuchin garden (1986–87), 40 – Cankar street (2007), 41 – Cankar street (1993), 42 – Bazovica street 34–36 (1997), 43 – Fisherman's square (2007), 44 – Fisherman's square 9 (2010), 45 – Convent of St. Anne (2007).

Future of the archaeological research of Koper/Capodistria

Lately the University of Primorska has started research project with the main goal of the evaluation and publication of the material culture. It will deal with study of the processes that have influenced formation and history of the particular town of Koper. The main goal of the research is to approach to the research of the town as a whole and to build tools and methodologies for the recording, preservation and management of the cultural heritage of Koper that could be later applied to the other towns with similar contemporary problems. In the more simple way the future research aims to make a step ahead from *the archaeology in the town* and towards *the archaeology of the town*.

Aims for the future research can be divided into three specific thematic groups, defined by their impact on different levels of the *town's memory*.

The attempt of the first group of research questions is focused on the *(re)search for erased memory*. The main questions to be answered are concerning town's establishment, development phases and chronology based on the study of architectural and archaeological remains. These would enable the researchers to form

the model of genesis and development of the Adriatic coastal towns. The research intends to produce and analyse the typology of the settlement and study the characteristics of the material culture, in comparison with the archaeological research already undertaken in the town. This way a preliminary reconstruction of chronological settlement phases and monuments will be made in order to preserve the knowledge of the cultural heritage of the town and create a tool for its management and for a preventive action in its preservation. On the other hand it will satisfy the need for the research of the town as a whole, enable the collection of the information needed to define and map risk areas and thus form the basis for the development of an uniform research strategy in urban areas.

The aim of the second thematic group is *reestablishment of lost memory* by dealing with inhabitants' identity and sense of belonging. Since the period following WW II brought a major shift in the structure of the population in the urban core has launched the changes in the social and ethnic structure and the disappearance of the majority of the once-autochthonous population which conveyed loss of the memory (all the intangible heritage disappeared) and the lack of knowledge, understanding and identification with the town's history and its heritage by the contemporary inhabitants. This problem is influencing their relation and maltreatment of heritage at risk.

Third thematic group is focused on the *rescue of contemporary memory* – dealing with the problems arising from the new economies. Urban heritage is mostly treated as mere real-estate. Instead of being renovated, buildings are replaced with new ones generating more direct income. The protection efforts of the authorities are outweighed by the negative results of their other activities and present a threat to the existing cultural heritage of the town.

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SESSIONS

Special Items and Methods

Digital Architecture meets Egyptology An Experiment in Interdisciplinary Education

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Abstract: Digital presentation methods for the transfer of knowledge are being applied more frequently in archaeology, however, predominately in the area of virtual reconstruction, principally as photorealistic renderings. In research this form of representation is controversial. Interdisciplinary cooperation between architects, computer scientists and archaeologists is indispensable for the development of new visualisation methods. The actual challenge lies in communication as well as in the differing work and mindsets of the partners. In the long term sensitisation and mutual understanding through the development of visualisation methods in cooperative educational courses. The following paper describes an experiment of the interdisciplinary collaboration/lecture between the Institute of Architectural Sciences/Digital Architecture and Planning/Vienna University of Technology and the Institute for Egyptology/University of Vienna. The subject of the lecture was taken from Egyptology. The students performed research and discussions in multidisciplinary groups to generate visual concepts from the collected data. The goal of these concepts was to show the ancient architecture as non-photorealistic 3D models and to use the virtual space to visualise additional scientific information. The results of selected student works will be demonstrated to inspire towards a more interdisciplinary tuition as well as stress the importance of the implementation of 'Digital Archaeology' in university education of students of Archaeology.

Keywords: Education, Collaboration, Digital Archaeology, Egyptology.

Interdisciplinary Education

Although interdisciplinary education is often desired in extending university curricula, it is very rarely realized and integrated into the formal education program. This is an unfortunate fact and many students will not experience different approaches to gain knowledge and insight in the cooperation with people from other disciplines. Sometimes the obstacles are at the level of bureaucratic constraints, very often also in the necessity to apply additional efforts at the side of the teachers as well as of the side of the students.

Organizational Structure

At our intended collaboration, we tried to follow a pragmatic approach that should avoid any necessary changes at the curriculum of the involved Master Programs (Egyptology, Architecture, Building Science). For the planned semester two lectures seemed flexible enough to allow an adaptation of the existing structure at the organizational level as well as the generation of common topics that could fit into all curricula.

So a Seminar in Egyptology (SE 2h, 6ECTS points) could be linked to the course about Information Architecture (VU 2h, 2.5/3.0 ECTS points). Beside the different type of lecture also the number of students differed greatly (7 students of Egyptology and 42 students of Architecture/Building Science).

Therefore 14 groups of 3 students per group were formed from students of Architecture and Building Science, where 2 groups had one partner from Egyptology. As the curriculum of Building Science is taught in English language, all students had to give the joint presentations in English language as well.

The following lists should provide an overview of the tasks the students from the different disciplines had to perform.

The disciplines are abbreviated with the first letter (Architecture: A, Building Science: B, Egyptology: E)

General division of tasks for the group members:

Research and Consulting	(E)
Visualization of investigated Information	(A,B)

Schedule and Main Responsibility for each Sub-Task:

Research	(E)
Concept	(A,B)
Design Critic	(A,B)
Seminar Presentations	(E)
Final Presentation of Visualizations	(A,B,E, Jury)

Egyptological Topics

Under the main title of the lecture 'Architecture for the Dead' seven egyptological subtopics were chosen. Each group had the opportunity to investigate their own area. The aim of the individual investigations was to provide the group members with the required information about the architectural remains and the scientific results. In addition tangible and intangible information about the architecture had to be acquired such as reconstructions and archaeological interpretations, the origin and development of special building structures styles and decoration, as well as the metadata. The topics concerned funeral architecture both private as well as royal. Only the Temple of Mentuhotep II. is from the Middle Kingdom, while the other topics cover the Old Kingdom from the 3rd to the 6th Dynasty. All examples base on known and accesible publications.

1. The Pyramid and Temple Complex of King Djoser / Sakkara
2. The Pyramids of King Snofru
3. The Private Tombs (Mastabas) in the Reign of King Khufu (Western Cemetery)
4. The Large Multi-roomed Mastabas of Dynasty 5th and 6th (Ptahshepses)
5. The Rock-cut Tombs of the Old Kingdom
6. The Suntemples
7. The Temple of Mentuhotep II at Deir el Bahari

Introduction to Information Architecture

To guide the students in developing suitable visualizations about their researched topics, several introductory lectures into the areas of Information Visualization, Information Design and Information Architecture were given. Hereby a special focus is put into use of metaphors, creating meaningful abstract visual presentations and how to avoid semantic conflicts of information representations. As the main area of research is related to architecture, abstract representations of buildings were emphasized, so that the main focus was led to the metadata that is related to the built structure.

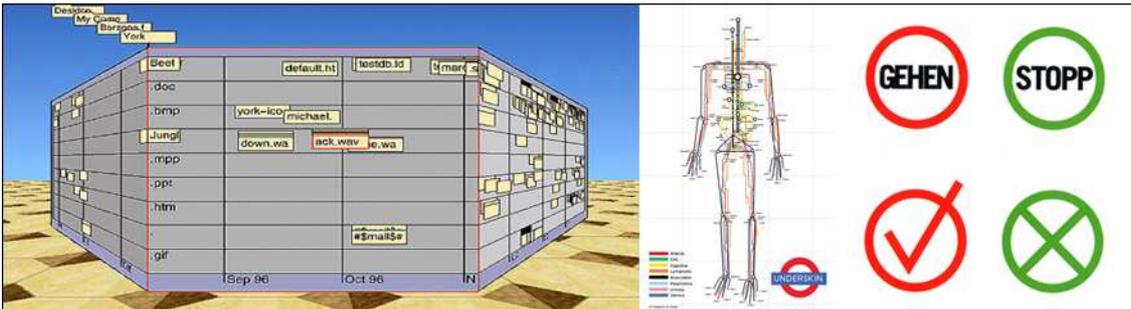


Fig. 1 – Perspective Wall (MACKINLAY 1991), Underskin (LOMAN 2010), Semantic of Colors and Symbols (LIDWELL 2004).

Research Results – Structuring the Data

The students of Egyptology researched their topics as mentioned above and presented their results to the students of Architecture and Building Science, who in return compiled the data into Excel tables. The goal of this task was to get a first overview of the entire data set, to define useful categories and to specify the metadata about the researched buildings.

Fig. 2 – The Temple Mentuhotep II. Excel Table Data by Teresa Blanco, Jessica Erci, Janne Kivelä, Jürgen Leitgeb, Olivier Rüt.

Visual Prototypes

Interactive visual concepts were then developed on the basis of the datasets that have been collected in the tables. The groups had complete liberty to choose their own metaphor and design, and to create visual prototypes – they were not required to implement their concepts. The architecture had to be shown in an abstract non-photorealistic way in order to enhance the data and the scientific information.

14 different and individual concepts were developed. An excerpt of the concepts will be introduced at the following pages.

The Private Tombs (Mastabas) in the Reign of King Khufu (Western Cemetery)

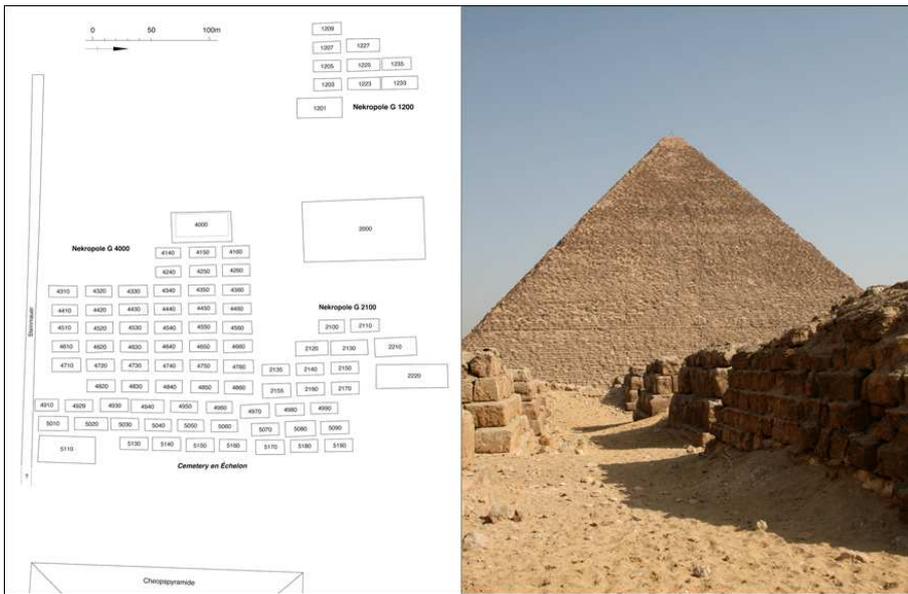


Fig. 3 – Overview Map of Western Cemetery and View of Mastabas (Peter Jánosi).

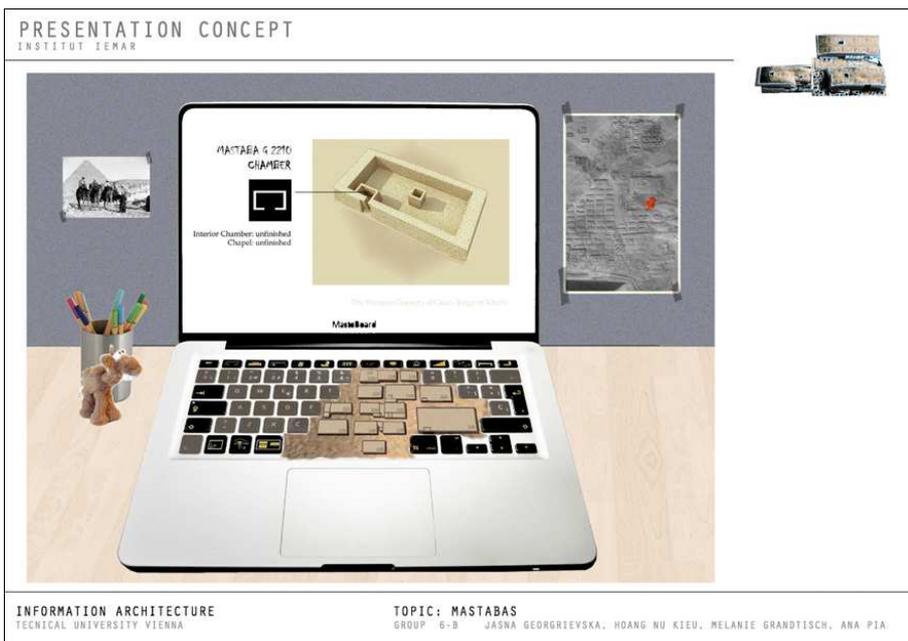


Fig. 4 – “Mastaboard” by Melanie Granditsch, Jasna Georgievska, Hoang Nu Kieu, Ana Pia.

The tombs of the cemetery were built in a symmetrical order. The group transferred this symmetry to a keyboard using the real desktop of a scientist as metaphor. The layout of the cemetery and the location of the tombs are indicated by the brown keys. The remaining keys are used for exploring the data of the tomb interactively and for navigation. Black keys with symbols encode specific information on the tomb.

The Rock-cut Tombs of the Old Kingdom

The exploration of the data on the rock-cut tombs of the Old Kingdom was the aim of this group. As the comprehensive information is stored in different kind of media such as images, plans, texts, drawings, videos, the group developed a “tomb excavator” using the concept of a library. Every tomb consists of stacks of information. Each stack contains different media which are color coded. These can be viewed at the reading table or put back on the shelf.

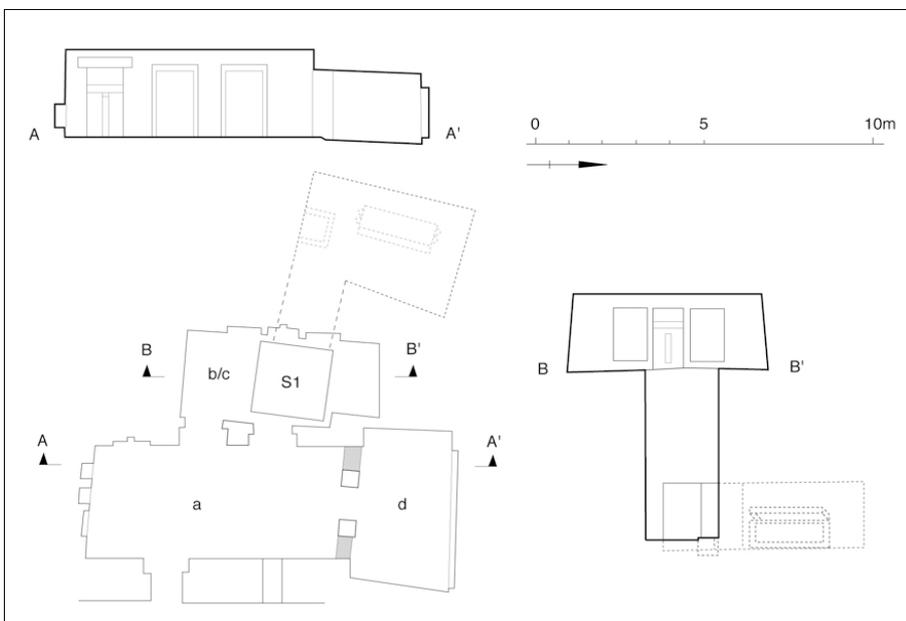


Fig. 5 – Map of the Rock-cut Tomb of Meresanch III G7530sub (Peter Jánosi).

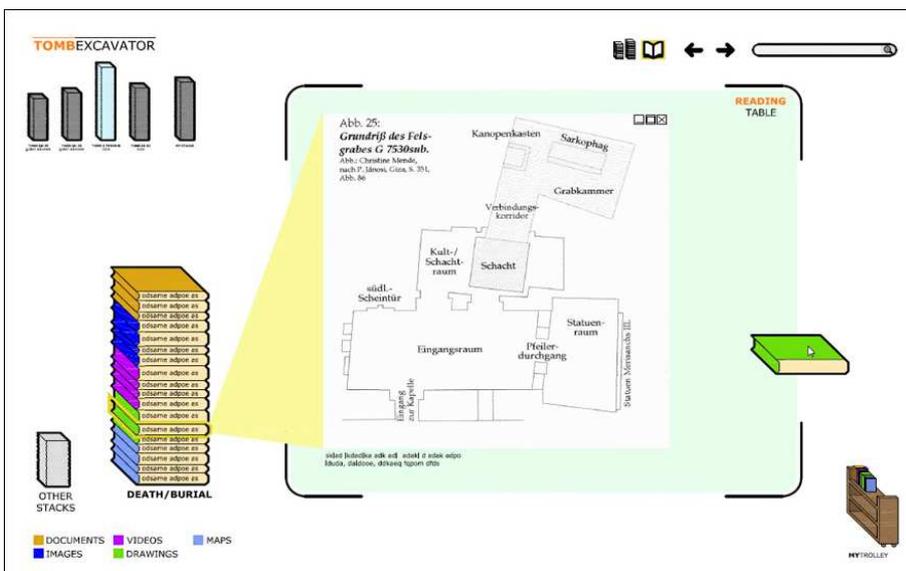


Fig. 6 – “Tomb Excavator” by Janett Busch, Or Aleksandrowicz, Diana Espinosa, Eirini Pisti.

The Large Multi-roomed Mastabas of Dynasty 5th and 6th (Example the Mastaba of Ptahshepses)

As open questions on the reconstruction of main parts of the tomb are still existing, this group investigated the tomb by applying an analytical method for built environments called “Space Syntax” (HILLIER 2001). The relationship of the chambers (here the connectivity) is encoded by a colour scheme. The “Space Syntax” can help to verify hypothetical reconstructions. A more in depth discussion will be presented in a separate paper (HIRZBAUER 2010).



Fig. 7 – Mastaba of Ptahshepses (Peter János).

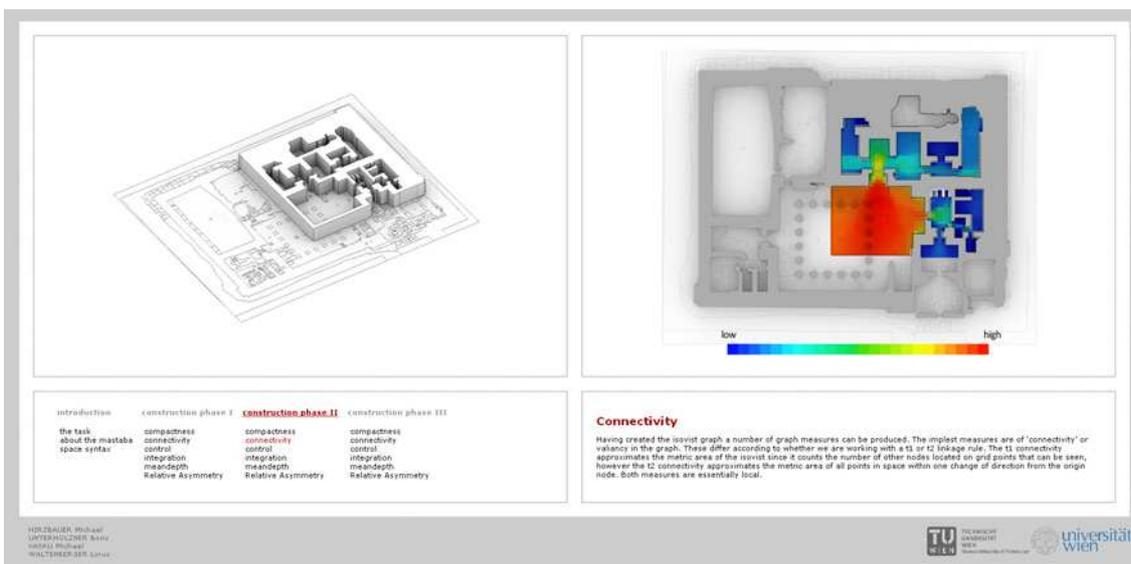


Fig. 8 – “Space Syntax” Analysis by Michael Hirzbauer, Linus Waltenberger, Michael Vasku, Boris Unterholzner.

The Pyramids of King Snofru

King Snofru (4th Dynasty, Old Kingdom) was the only reign in Egypt who build three pyramids for himself. The first two are considered attempts. They crashed or broke and had to be abandoned, while the third real pyramid is regarded as model for the Pyramids of Giza.

The web-based visualization is divided into three parts showing information on the construction as animated or static views and interactive tables. It allows a comparison between the three buildings.



Fig. 9 – Pyramids of King Snofru (Peter János).

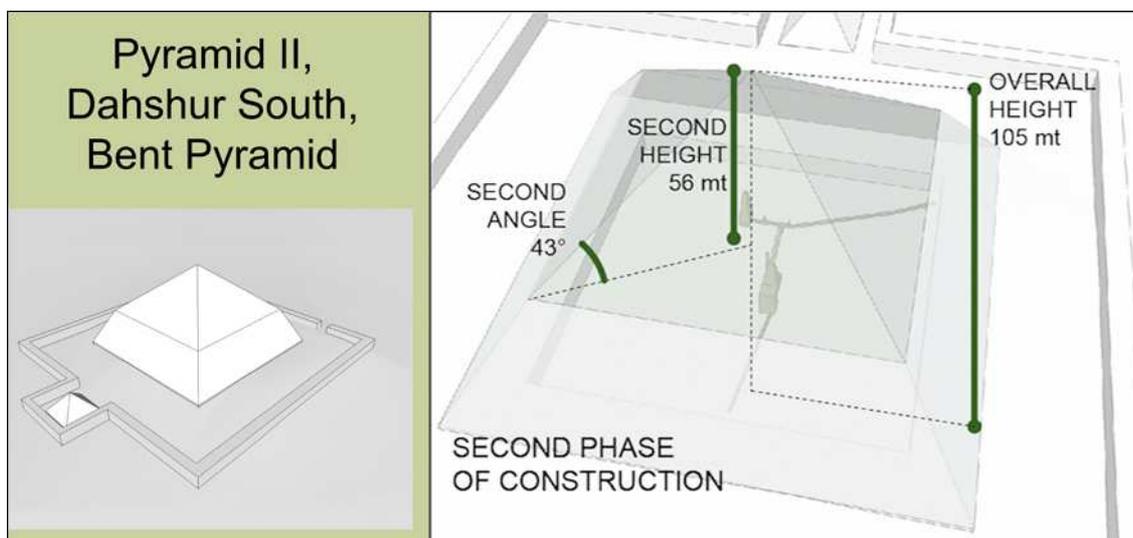


Fig. 10 – Visualisation by Kristina Hutter, Stefan Neidermair, Fabio Palvelli.

Conclusion

From our experiences of our collaborative lecture we can draw several conclusions as observed from feedback of the involved students and of course our own experiences. The overall impression was very positive despite of the increased effort in organization and workload. Despite that, some points might be still suitable for improvement. As the students of Egyptology were mainly involved at the research phase in the beginning, it would be useful, if the visualization results of the students of Architecture/Building Science could have been used at the seminar works in Egyptology. Some other improvements could have been made on the "social level" of the students as the interchange of visits and workload should be well balanced between both institutions. It turned out that Cultural Heritage topics might be of increasing interest also in the Architecture/Building Science Curriculum, and principles and methods of digital visualization should be made available for students of Egyptology. Finally as a general conclusion: both sides agreed to continue the interdisciplinary cooperation in education as well as in research.

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The Internet Encyclopaedia of the Brno History, the City on Display

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Abstract: The encyclopaedia provides information from various areas of the Brno history to internet users by means of mutually interconnected encyclopaedia entries.

Our article proposes a possibility how to deal with informational cultural heritage and a way how to make it accessible to public. This is realized by a professional community and because it is an encyclopaedia it is not focused only on archaeology but on all branches concerned with cultural heritage. Such interdisciplinary project supports an intensification of cooperation among individual branches and among different types of institutions.

The project is aimed not only at professional community but at subjects of public service too. Masaryk University and college (restoration, preservation department) students participate in the project through a developed student model.

Keywords: Popularization of City Cultural Heritage, Culturally Informative Portal, Database, Interdisciplinary Project.

The Internet Encyclopaedia of the Brno History is a cultural and informational website produced by a large team drawn from cultural and educational and research institutions around the City of Brno. Hyperlinked, encyclopaedically organised entries provide internet users with information about the history of Brno.

The project began in 2001, a response on the part of experts at the Brno City Museum to public interest in the subject. Their objective was to produce an interdisciplinary, electronic database from existing, at the time chiefly analogue, records covering a variety of subjects that might serve both those engaged in research into Brno's history and those merely seeking basic information. The team of scholars included archaeologists, historians, archive specialists and art historians, all of whom drew up a programme structure in Microsoft Access and subsequently tested the individual development phases of the programme. The idea of making the database accessible to the general public grew out of this first stage and reached fruition in May 2004, when the www.encyklopedie.brna.cz website was launched on the occasion of the 100th anniversary of the establishment of the Brno City Museum. This step was preceded, in late 2003, by the transfer of the programme environment to a supplier platform in order to maintain professional standards for technical aspects of the project. The year 2010 became another milestone: thanks to the subsidy from the "Education for Competitiveness" Operational Programme, the section devoted to archaeology started to take shape. A group of specialists from many of Brno's scientific, cultural and educational institutions, supervised by Masaryk University, are responsible for the further expansion of the database and the programme.

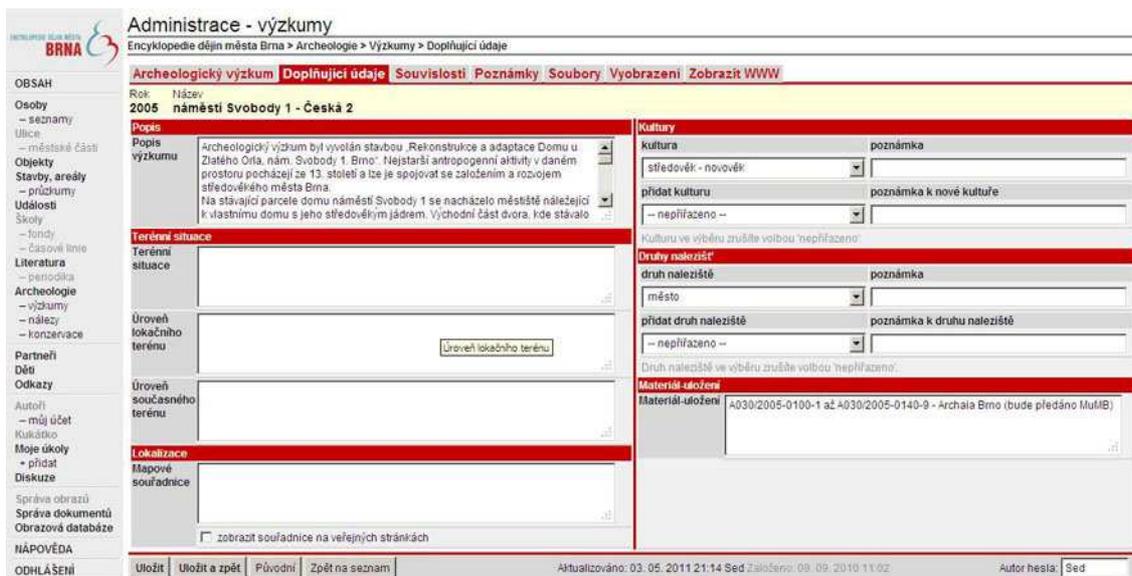


Fig. 1 – An example of a record in the administrative interface. Copyright: Internetová encyklopedie dějin Brna.

The encyclopaedia is being created in two different graphic environments, targeted at administration and at the user (Fig. 1, 2). Access to the administrative environment is passworded, while the user version is freely accessible but does not permit editing.

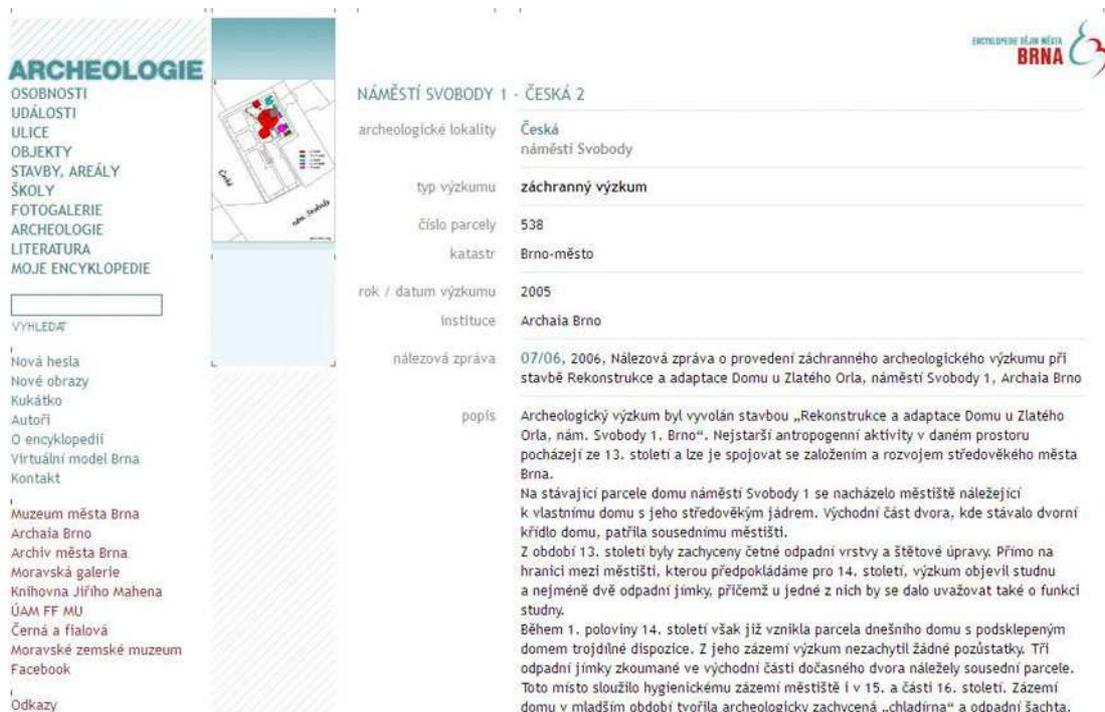


Fig. 2 – An example of a record in the web interface. Copyright: Internetová encyklopedie dějin Brna.

The internal structure of the encyclopaedia consists of thematic sections, the number of which is not limited, thus enabling their expansion within the structure of a uniform scheme. The individual sections (Personalities, Events, Streets, Objects, Buildings, Schools, Photographs, Archaeology, Literature) contain specific approaches to editing entries, structured into content fields among which active links may be made

across the sections. An event can thus be linked to a place (city quarter, street, building, school), people associated with it (personalities) and with relevant events (Fig. 3). Each entry can be provided with active links to external websites and text documents (a pdf version is recommended). Essential to these template approaches are the sources to be listed in the Literature section, possibly to be cross-reference-linked to other entries in different sections defined by the search terms or a given text citation. Each section has a fully worked-up search system, ranging from a full-text option to a multi criteria search. Entries can be also looked up on the basis of authorship and date of production or editing.



Fig. 3 – An example of a various sections interconnection to one query (in each section has been chosen one example). There are links to other particular related sections at each individual section. Copyright: Internetová encyklopedie dějin Brna.

The encyclopaedia is an evolving organism. New entries are being added and existing ones expanded and edited (language editing included). Individual entries (over 30 thousand of them as of February 2011) have been processed by a specialist, or several of them. The interdisciplinary approach is most evident in the Buildings section, where historians, archive specialists and art historians specialising on the history of architecture have collaborated. The editing is not slowed down by subsequent supervision on the part of the editorial board since each author is responsible for the specialist level of his or her data.

Pictures are processed separately. The authors submit illustrations, of the highest quality possible, to the administrator of the picture database who manages a picture archive (currently amounting to ca. 60 thousand items, 11 thousand of which have been included in the encyclopaedia) divided into sections identical with those of the encyclopaedia, and after appropriate graphic processing (Adobe Photoshop, Zoner) they are attached to individual entries.

The technical side of the project employs modern, tested internet and database technologies. It is created as an administrative interface and a public website. Both take the form of web pages that may be entered through ordinary internet browsers that support Javascript. In view of its safe and reliable record, the MySQL database server has been employed for the storage of data. The processing of data when reading the database, or before the entry into the database has been made, is performed in the PHP programming language. The encyclopaedia has its own server including the website and the database. The data placed on the server are protected in two ways: by double hard discs in the server and by regularly backing up the database and files saved onto a separate server.

Thanks to its universal structure, the encyclopaedia is a module that may be applied in any municipal environment, as illustrated by projects for the towns of Hodonín and Jihlava, with identical software but different graphics so that regional differences may be easily identified. The long-term goals of the project include creation of an interconnected network of town encyclopaedias, the authors of which may collaborate on development and enhancement.

The number of users interested has risen steadily since its launch in 2004. Any given search produces active links to related entries, enabling a visitor to track down the information they seek. Those whose interest in certain subjects runs deeper may make use of the “My encyclopaedia” section, where registered visitors can download entries from the encyclopaedia, organise them and attach their own notes. Communication with the public is solicited by an appeal for questions or comments at the end of each entry. General questions may be also sent from the Authors section. Public interest has already led to the encyclopaedia acquiring new information, as well as digital copies of valuable archive materials from individuals.

The encyclopaedia has been awarded several prizes, the first of them shortly after the project was launched; this came from the Czech committee of the ICOM in the third year of *Gloria musaealis* 2004, the national competition for museums organised annually by the Ministry of Culture of the Czech Republic together with the Association of Museums and Galleries of the Czech Republic. One of the reasons cited for the award was that, in the Czech Republic, the encyclopaedia stands out as a singular and pioneering achievement defying the “stone” limits of museums and reaching far beyond material collections, physical visitors, opening hours and geographical settings.

The technical side of the project is financed by several organisations. The basic annual subsidy is supplied by the Brno City Museum, supplemented by contributions from the Brno City Council, which has made the encyclopaedia part of its development programme, and by finance from further programmes and major Brno companies. The largest proportion of the total so far has been allocated to the archaeology section (2010–2012), from the “Education for Competitiveness” Operational Programme, in the Partnership and Networks section.

The objective of the project is to establish a communication platform that links research and scientific institutions by means of a joint programme module intended to create a database mapping archaeological

sites in the Brno administrative area and in the Jihlava region. The Brno encyclopaedia is thus developing in parallel with a counterpart in Jihlava. Apart from the Institute of Archaeology and Museology of Masaryk University, the main subsidy beneficiary, all major institutions specialising in archaeology in these regions take part in the project: the Archaeological Institute of the Academy of Science of the Czech Republic, ÚAPP Brno (an authorised institution for rescue excavations), the Brno and Jihlava branches of the Archaia Brno association (an authorised institution for rescue excavations), the Brno City Museum, the Highlands Museum in Jihlava, and the Vocational School of Restoration, Brno.

The archaeology of Brno and the Jihlava region is processed within a communication module, the programme and content of which are created in co-operation between all the participating institutions. Archaeological locations are characterised at three levels of identification: spatial, chronological and material. The basic unit of spatial identification in the city is the plot, supplied with a location name outside the city and with the names of streets and parts of the city within it. Chronological identification is facilitated by the accepted sequence of prehistoric cultures followed by medieval and early modern-age period divisions. Material identification covers both the sites disclosed by archaeological research and the material culture represented by any finds. Identities in terms of restoration and conservation form separate subgroups. Although these centre upon the aspects of material identification mentioned above, their first priority is the preservation and restoration of finds. The levels observed intersect with the remaining sections of the encyclopaedia and produce a communication system within the database.

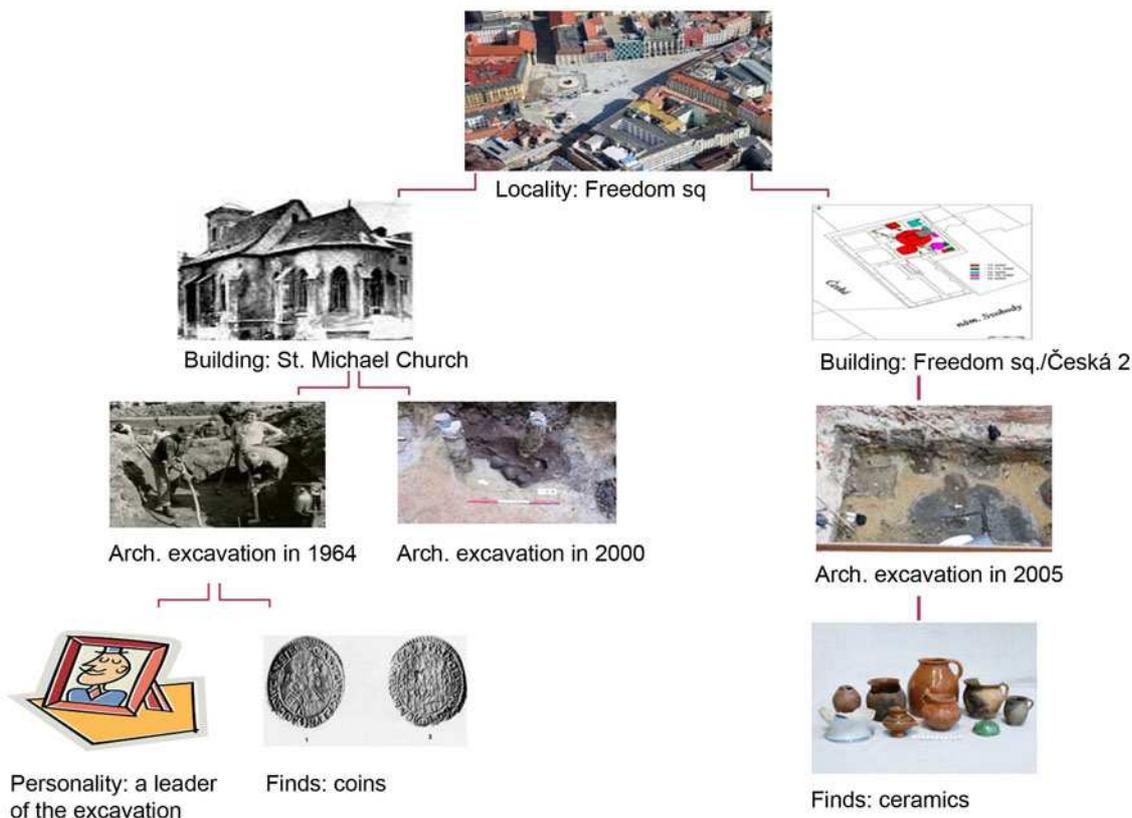


Fig. 4 – An example of the interconnection and ranking of records in the section Archaeology.

The archaeology module comprises the Archaeological Cadastre of Brno and the Jihlava Region, the objective of which is the mapping of archaeological sites in the regions (Fig. 4) and their connection with historical maps and plans, as well as with cadastre maps administered by the City of Brno. The module will also involve drawings preserved in the Moravian Municipal Archive and maps from the Brno City Archive. One of the outcomes of the encyclopaedia will be a simple browser enabling observation of the development of archaeological sites in space and time. The analytical assessment of the data will produce virtual models of Brno at different chronological periods. The model of Brno in 1645 (www.brno1645.cz) has been completed; it will be followed by a version with the town fortifications and a model of Brno in the high Middle Ages.

Apart from its obvious value to the specialist public, the project also targets public administrative institutions, which it should supply with essential information about the protection of archaeological sites. Archaeological data will be also inserted in the Geographical Information System for the City of Brno, a comprehensive approach to the collection, administration and processing of geographical data undertaken by the Brno City Council. Spatial identification of archaeological finds takes the form of verbal descriptions, drawings in paper maps and data localized in standard GIS formats. The data are then processed into individual vector layers - points, lines and polygons – with the aim of establishing an automatic system for the collecting, administration, processing and publication of spatially identified archaeological finds in Brno. In collaboration with the Brno department of the National Heritage Institute and the Megalit system of the Brno Archaeological Institute of the Academy of Science, this part of the database will be replenished with information on projected building work, the execution of which might affect archaeological sites. In view of the sensitive nature of some of the data, this outcome must be addressed at several levels. The maximum (editing) layer will involve the team of encyclopaedia authors, archaeologists and representatives of the participating institutions. Complete data, inaccessible to further editing, will be made available to the state administration, which can then use them in the assessment of construction projects. A filtered version with public information will be freely available to ordinary users of the encyclopaedia. This format is also designed for those who propose to build, to whom it will supply information that may be used in the preparation of construction.

The original idea of interdisciplinary and inter-institutional collaboration has been expanded this year to include an educational function as well. A student module for universities and vocational schools has been put into operation and introduced at the Faculty of Arts of Masaryk University and the Vocational School of Restoration, Brno. Its goal is to expand student capabilities in structuring and analysing information. Each student group uses a different part of the programme, but both draw information from the general database. The students at the restoration school concentrate on conservation and restoration of selected archaeological finds and expand the data acquired in the process in an independent section of the programme. Descriptions of conserved items needed for the definition of concrete conservation procedures are inserted in the database by archaeologists from the participating institutions, who are also responsible for their selection, representing series of finds from individual locations. Students of the Faculty of Arts may access the module from a broader point of view. They process encyclopaedia entries from the various sections that they select from the choice in the Masaryk University information system (Elf), where they may also find manuals for individual sections. All student records are supervised by teachers (Vocational School

of Restoration) and academics (Faculty of Arts). The completed parts of the entries are regularly checked and authorised. Teachers' instructions for students are displayed with the entries that are being processed, in the form of comments. After authorisation, the records are made accessible to the public in the user version.

The project introduces new forms of collaboration between scientific and research institutions and educational establishments, and its outcomes are used by science and research and educational institutions, as well as by the general public. The medium-term goals of the project involve data collecting, specification and interconnection of information, the expansion of sections with new subjects, a calendar of archaeological research in progress, the launching of a browser of historical maps and plans and the completion of virtual models of Brno.

The origins of the project were associated with the interest on the part of the public; let us hope that this interest will not fade and will ensure the viability of the entire encyclopaedia for the future.

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Which timbers were cleft from the same tree?

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Abstract: On the basis of the comparison of tree-ring series, we describe an approach to determine whether wood samples are from the same tree or not. It comprises two steps: (1) a numeric algorithm clusters the samples, and (2) by visual inspection of the long-term trends in the actual tree-ring measurements (which are filtered out before the numeric calculations) it is decided whether the grouping is correct. The clustering algorithm is tested with two data sets of modern trees; in these cases it is known which samples were cut from which trees. Next, the algorithm is applied to a set of samples from the Viking-time settlement of Hedeby, North Germany. Finally, we suggest the term ‘dendro-allocation’ for this kind of tree-ring research.

Keywords: Dendrochronology, Hedeby, Viking age, dendro-allocation.

Introduction

It can be very useful to know which wooden samples from an archaeological context come from the same tree or not. This may help decide whether complex structures within a settlement were built at the same time even if the underlying wooden samples are lacking bark or sapwood and their felling can therefore not be dated exactly to the year. The same applies for re-used timbers or solitary timbers in an excavation stratum. By allocating them to a tree individual, it can become clear to which construction they originally belonged. The proto-urban settlement of Hedeby in Schleswig-Holstein, North Germany, is one of the largest Viking-time trading places presently known. Of the settlement, extending over 25.5 ha within a semi-circular rampart, about 5 % have been excavated. Since the remains of Hedeby lie in a wetland area, many organic finds such as wood, bones and leather were very well preserved. Examples of wooden finds are houses and harbor constructions, track ways and fences, as well as ships.

The dendrochronological dating of the waterlogged wood enables the reconstruction of different developmental phases of the settlement with a high time-resolution. To know that two or more pieces of wood (probably) are from the same tree is additionally useful in this process of archaeological evaluation (ECKSTEIN and SCHIETZEL 1977). However, the more than 4.000 excavated and dated wood samples pose the problem of handling all or at least sub-groups of them simultaneously. That is why we are looking for a proper statistical method going even beyond our previously reported approach (MOM et al. 2010).

The data sets

For testing purposes, we employ two data sets from modern oak trees. If the method does not distinguish the correct number of trees in these data sets, it is deemed unfit to our purpose. The samples in the test data

sets 1 and 2 are different from the Hedeby wood insofar as the Viking-time oaks very likely were felled in nearby, dense, old-aged oak forests where the trees grew unmanaged and undisturbed for hundreds of years whereas the modern test samples came from less dense, planted forests of younger age. So caution is advised because our modern trees do not represent a real analogue of the medieval trees.

Data set 1

Data set 1 contains 52 samples from four trees (8, 13, 15 and 16 samples per tree, respectively), having grown near Schleswig, North Germany. One tree is 212-year old (1792–2004) while the others span periods from 1851–2007 (156 years), 1876–2007 (131 years) and 1888–2007 (119 years) (MOM et al. 2010).

Data set 2

Data set 2 contains 52 samples from 26 trees (two samples per tree). These samples are obtained from five sites in two forest areas between Schleswig and Ratzeburg in Northern Germany, at maximum 150 km apart from each other. This set is quite peculiar, since it does not reflect an average archaeological situation of timber supply from sites so far apart.

Archaeological data

The archaeological data set comprises 56 wooden samples from two fence-like structures of Hedeby ('Structure 22' and 'Structure 23') (SCHULTZE 2008).

The methodical approach

In a previous publication (MOM et al. 2010), we used a coefficient (Q) to measure the difference between samples ('distance'). The value of Q_{AB} indicates whether sample A and sample B are from the same tree or not. However, a practical problem surfaces when applying this method to more than two pieces.

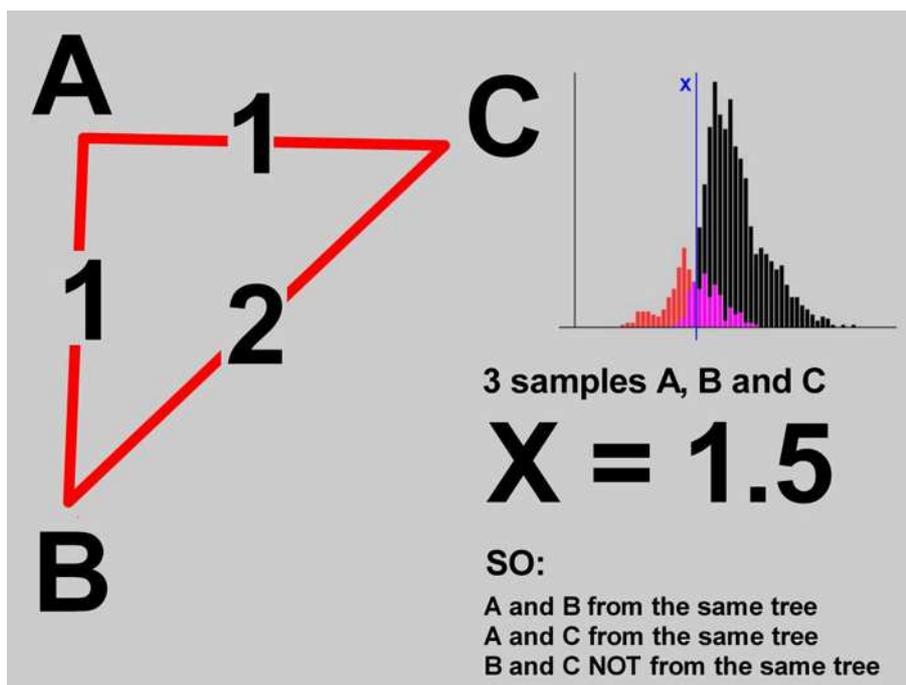


Fig. 1 – A problem using pairwise comparisons to allocate wooden samples to individual trees.

In the upper right corner of Figure 1 the distribution of Q for test data set 1 is shown. The problem is caused by the 'pink' area where sample pairs from the same tree (red) as well as sample pairs from different trees (black) have values in this range. Moreover, the minimum and maximum values of this mixed range are not constants, but depend on the composition of the data set. Even in the most favorable case only an estimate can be given.

So in practice we may end up with the following situation: comparing sample A with sample B and sample A with sample C may lead to the conclusion that (1) A and B, and A and C, are samples of the same tree because the values of Q_{AB} and Q_{AC} are small, whereas (2) the value of Q_{BC} is high what means that B and C are from different trees which, of course, is impossible. To avoid this problem, we returned to the classical statistical methods of Cluster Analysis (CA) and the non-metric Multi-Dimensional Scaling (MDS).

MDS is essentially a method to determine the similarity between items, expressed as *distances* in an n-dimensional system. The term 'non-metric' refers to the fact that the dimensions of the system are not 'lengths' in terms of, for example, millimeters (EVERITT and RABE-HESKETH 1997). MDS is based on a distance matrix. The algorithm applied attempts to place the data points in a two- or three-dimensional coordinate system such that the *ranked differences* are preserved. For example, if the original distance between points 4 and 7 is the ninth largest of all distances between any two points, points 4 and 7 will ideally be placed such that their Euclidean distance in the 2D-plane is still the ninth largest. Non-metric multi-dimensional scaling intentionally does not take absolute distances into account (HAMMER et al. 2001). As distance measure for the MDS analysis we applied, in all cases, the complement of Pearson's correlation coefficient using the formula:

$$d_{jk} = 1 - \frac{\sum (x_{ji} - x_j)(x_{ki} - x_k)}{\sqrt{\sum (x_{ji} - x_j)^2} \sqrt{\sum (x_{ki} - x_k)^2}} \quad (1)$$

The values of the correlation coefficient R run from [-1 .. +1]. The complement d_{jk} runs from $1 - R$, which is [0..+2]. A distance value of 1 corresponds to a correlation of 0 (zero).

Cluster Analysis produces a tree-like graph ('dendrogram') showing how items can be clustered. There are different algorithms available to do the clustering. Experimenting with our data sets has shown that Ward's method gives the best results: clusters are joined such that increase in within-group variance is minimized. We use the PAST (PA^laeontological STatistics) data analysis package to process our data. The PAST package contains a large number of common statistical plotting and modeling functions and a simple user-interface combined with an extensive manual (HAMMER et al. 2001) and therefore is quite adequate for our purpose.

Results

Data set 1

A. – First, we applied MDS to test data set 1, using the *absolute values* of the tree-rings. When ring data are missing they are not incorporated in the calculations, e.g. if we compare a sample of tree A (data from 1792 to 2004) with a sample of tree B (data from 1876 to 2007) the index i runs from 1876 to 2004. The results are shown in Figure 2A. Other distance measures like 'Euclidean' and 'Gower' (see HAMMER et al. 2001) do not improve the results.

According to the corresponding dendrogram of data set 1, generated by CA (Fig. 3A), the four trees are not exactly clustered as we would like it, although the result looks quite reasonable.

B. – The series of measured tree-ring widths contain much autocorrelation which may be a problem. Therefore, we transformed the absolute values into relative values using the formula

$$r_i = y_i / y_{i-1} \quad (2)$$

in which y_i and y_{i-1} are the tree-ring values of two consecutive years. However, by doing so the long-term grow patterns are also removed from the data. When discussing the results from the archaeological data set further down, we will see that this transformation may sometimes be a drawback because trends in tree-ring series may strongly contribute to the decision of whether tree-ring series come from the same tree or not. The MDS and CA results from the transformed data (Figs. 2B and 3B) look much better. The CA even separates the samples that were taken from different heights of the same tree (e.g. the clusters 101x vs. 102x, 301x vs. 302x, and 401x vs. 402x).

C. – A further alternative was using the *correlation coefficients* for the transformed tree-ring time series, instead of the time series (as described under B). For each sample pair, the correlation coefficient (see the formula 1) was taken as a measure for the dissimilarity between two samples, and the resulting distance matrix was used as input for the MDS and CA. This method gave by far the best results, speaking in terms of distinguishing the different trees (Figs. 2C and 3C). Note that the MDS separates the four trees very well. Also the CA does this, but the different sample heights in 'tree 4' (see samples 401x vs. 402x) are not such well distinguished as when using the tree-ring ratios.

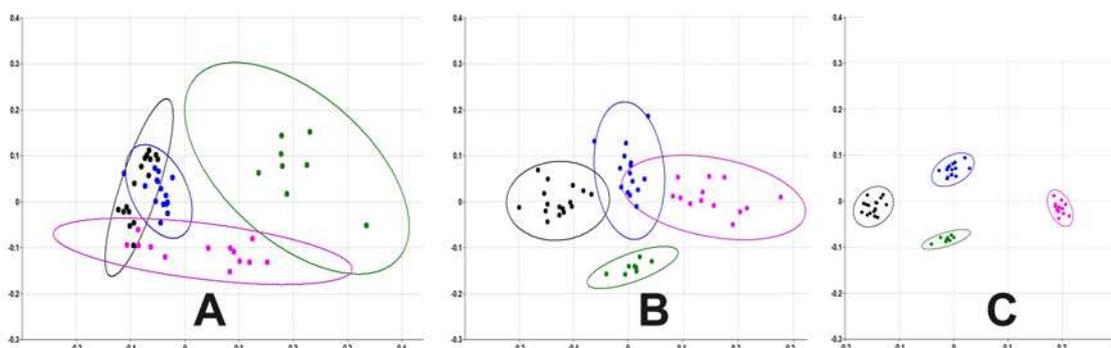


Fig. 2 – A: MDS using absolute values of tree-rings; B: using ratios of consecutive years; C: using the correlation coefficients.

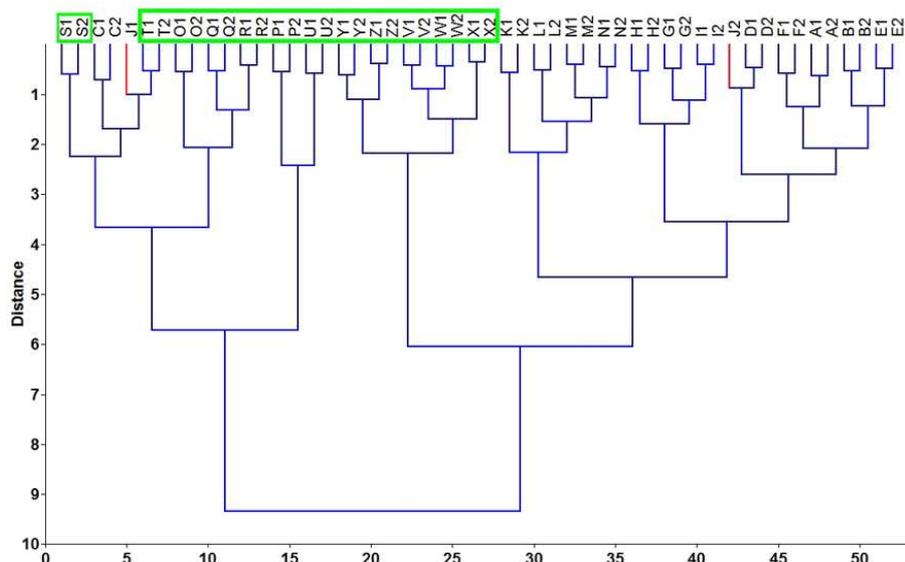


Fig. 4 – CA of 52 samples from 26 trees from the forest areas of Ratzeburg and Schleswig-Rendsburg. The forest area Schleswig-Rendsburg is marked in green. Note that the two samples of tree 'J' are the only ones not properly clustered.

Applying the method to wooden structures of Hedeby

In this paper, we focus on the fences herein termed 'structures 22 and 23'; they contain 23 and 34 dated pieces of wood, respectively. These two structures, in reality nested into each other, are separated according to archaeological criteria and also separately illustrated in Figure 5 with the archaeologically justified assumption that they were built at different times. Both fences consist of radially split planks, which were pointed at one end. Sapwood and bark remained in quite a few cases. The planks were driven into the ground one next to the other in order to form a palisade. The differing top and base heights indicate that the planks do belong to two successive fences (Fig. 5). Structure 22 must have been the older fence as is shown by its lower top heights. It was erected in 871, according to dendrochronological dating (Fig. 6). At some point in time around or after 881, structure 22 must have been in a poor state and was renewed (structure 23) (Fig. 5). The planks of structure 22 were either cut off at ground level or pulled out of the ground as is indicated by the various gaps in the older fence. The majority of the planks of the younger structure 23 were not driven into the ground as deep as the planks of the older structure 22. Moreover, they can be recognized by their higher tops. As is indicated by the dendrochronological dates, planks of the older structure 22, which were still sound, were re-used in structure 23. The re-use of timber for fences must have been common practice. Besides the planks of structure 22, timbers dating to the 850s or 860s were used again in structure 23. Likewise in structure 22, wood which was felled around 837 (+8/-0) was re-used (Fig. 6).

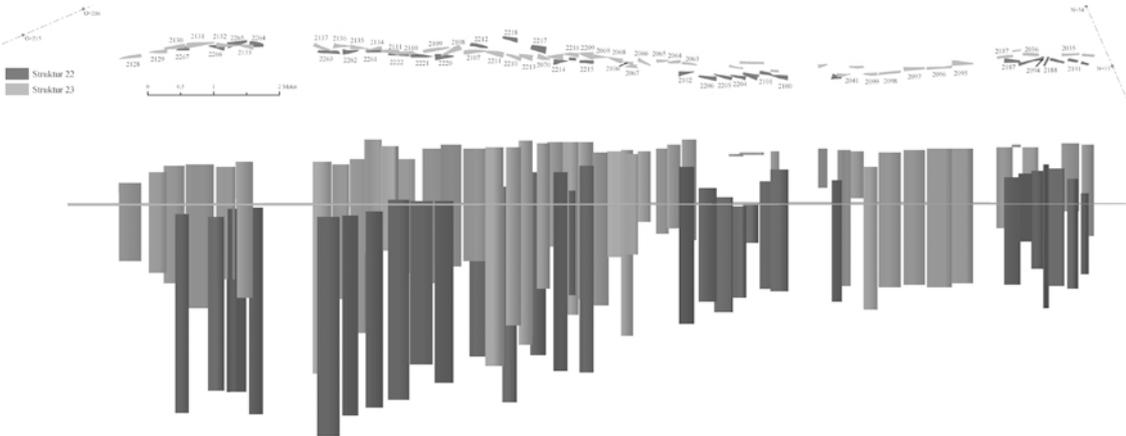


Fig. 5 – Structures 22 and 23, distinguished by archaeological criteria.

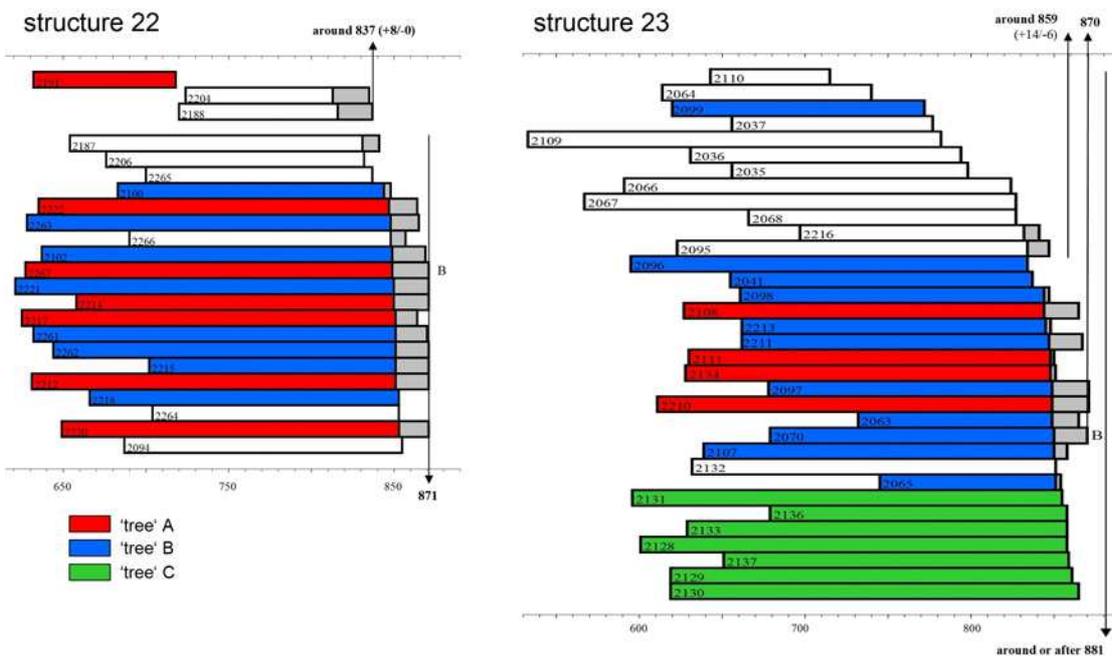


Fig. 6 – Bar diagrams for structures 22 and 23; the (probable) trees A-C are indicated by different colors.

Of the 57 samples 56 were analyzed and after removal of the autocorrelation, CA was applied on them. With this data set the problem arose in that several tree-ring series overlap only shortly or even not at all. Experimenting with different options made us decide using the value '1' in the distance matrix (which corresponds to a correlation coefficient of zero) for sample pairs without overlap. According to the CA, we tentatively discriminated five clusters ('trees') (Fig. 7). The question now is how to validate this grouping. We did it as follows: the clusters A-E are compared one by one with the respective original tree-ring patterns. Here, we are focusing on the original tree-ring patterns of cluster ('tree') A (Fig. 8). The most obvious distinctive tree-ring series is no. 2188 (marked in red) in two respects, the sapwood/heartwood transition deviates remarkably from all others and the age trend is also unique as compared to the other tree-ring series within this group (Fig. 8, bottom). We concluded that no. 2188 is not part of 'tree' A. Another distinctive feature is related to sample no. 2191; its tree-ring series is much shorter than all other tree-ring series within this group and its outermost tree-ring is dated by 150 years back in the

past. Nevertheless, it can be part of 'tree' A because it did not have any sapwood remains; it may have been cleft lengthwise from a board and in consequence would belong to the inner part of 'tree' A. But for the archaeological interpretation of the whole context it is even more important to realize that from the 11 remaining pieces of 'tree' A, seven were archaeologically attributed to 'structure 22' and four to 'structure 23' (Fig. 9).

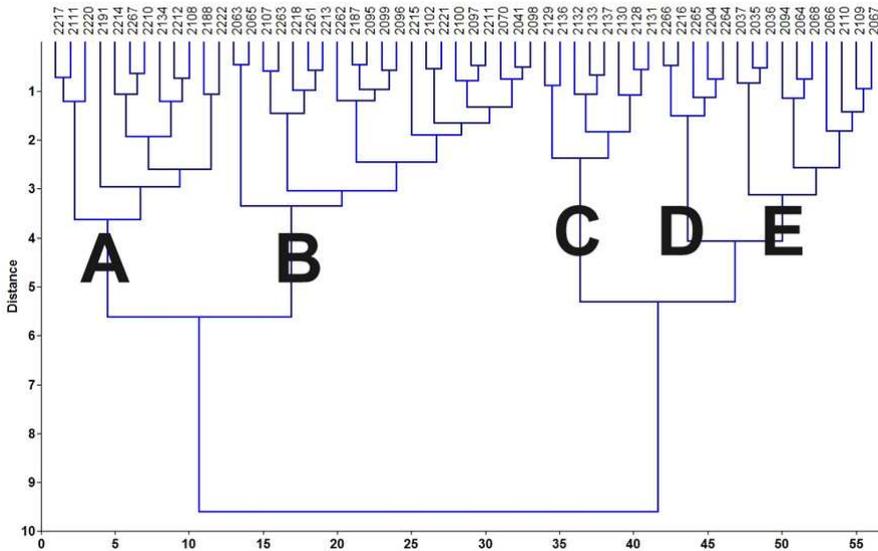


Fig. 7 – CA of the wood of structures 22 and 23, resulting in 5 tentative clusters ('trees' A-E).

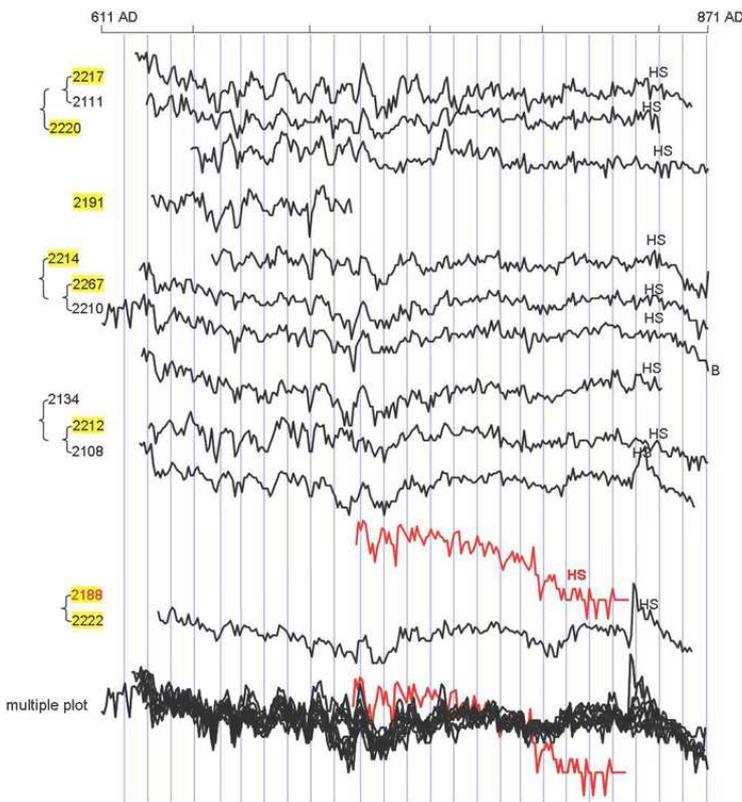


Fig. 8 – Original tree-ring patterns of cluster ('tree') 'A' – arranged according to the dendrogram (see Fig. 7) from left to right; at the bottom, all tree-ring series were plotted superimposed on each other ('multiple plot').

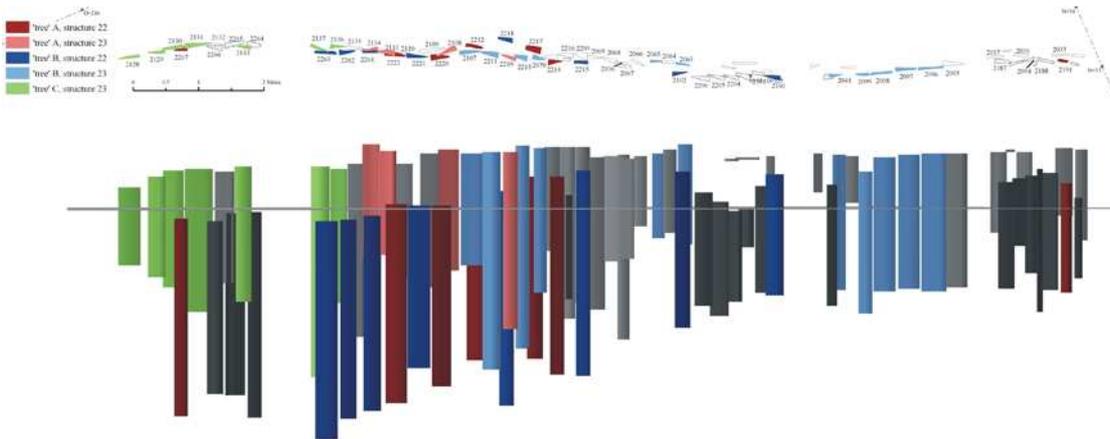


Fig. 9 – Structures 22 and 23, indicating the (probable) tree assignments.

This same screening procedure was also applied for the clusters ('trees') B-E (original tree-ring patterns not shown here). In Figure 9, different colors indicate the 'tree' assignments whereby only 'trees' with at least three samples are marked. In short: all samples of 'tree' B (except no. 2095 and no. 2187) and of 'tree' C (except no. 2132) can be considered to be cut from one tree, each. Conversely, the tree-ring series of the five samples of 'tree' D and the ten samples of 'tree' E appear to be rather inconsistent so that their statistical allocation can only partly be confirmed.

The suggested assignment of timbers to trees fits to the previously observed extensive re-use of older wood in fences. Timbers of both 'trees' A and B are found in both the older (structure 22) and the younger (structure 23) fence. Obviously the wood of these at least 261 ('tree' A) and 276 ('tree' B) year-old trees was of high quality and hardly decayed so that it could have been re-used. It can be speculated that the renovation of the fence started on its eastern end and first of all planks were driven into the ground which could be re-used (timbers of 'trees' A and B as well as timbers no. 2095 and no. 2216). On the western end, no older timbers seem to have been available and therefore a new tree had to be split up ('tree' C).

Conclusions and perspectives

We understand our study as exploratory and preliminary and are aware that cluster analysis is applied in tree-ring research for a long time. But to our knowledge, it has not been used for allocating wood samples with a high likelihood to the tree they were cut of. Our statistical approach to 'recognize' tree-ring series in a large data pool to belong to one and the same source tree has proven successful. Nevertheless, a visual inspection of the non-transformed, raw tree-ring patterns is required after the numeric clustering if in particular cases the resulting allocation is implausible. For this upcoming sub-field of dendro-archaeology we suggest the term 'dendro-allocation'. But we are aware of the need to intensify working with living trees in order to refine these methods and techniques and to enhance our experience with absolutely certain data sets. The interpretation of the proposed trees from an archaeological point of view shows, that such a careful and time-consuming analysis is still worthwhile. Insight into the amount of re-used timbers and into the building process – as in this case – are just two examples of a potentially broad spectrum of deduction.

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Perditurus

Project to preserve and research Nordic Medieval Town Culture

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Abstract: Perditurus-project to preserve and research Nordic Medieval Town Culture – casestudy Aboa vetus – insitu museum in Turku Finland. will combine different perspectives in town excavations like 3D documentation, monitoring the chemical characteristics, analysing of organic remains, ^{14}C dating and dendrochronological analysis. This approach will enable us to document the present state of the archaeological deposits very carefully and to simulate the history of the site and at least to some extent predict the future changes.

Keywords: 3d-documentation, virtual excavations, analysing of organic remains, ^{14}C dating with wiggle matching, insitu museum.

Introduction

The medieval archaeological deposits include valuable data about the early urbanization process. This data is threatened by changes in the chemical composition in the soil matrix, caused by natural decay but also accelerated by climate change and human impact. The aims in this project are to test and develop methods to monitor and measure these changes and through these investigations form a more complete picture of the urbanization process of the early medieval period in towns.

The most important source for studying the early urbanization process in the Nordic countries is the archaeological deposits or layers and data within. The written sources are scarce, especially in the eastern part of the area (Sweden and Finland). However, the data from the archaeological layers is not as biased and offers us a possibility to compare the everyday reality in Nordic countries from equal sources. (e.g. TAAVITSAINEN and UOTILA 2009) Radiocarbon (^{14}C) of especially 14th century layers has been problematic as the calibrated data is difficult to interpret. An approach exploited during this project, context dating using wiggle matching, which will help to overcome this problem and enable more accurate comparison of different sites.

Perditurus-project will combine different perspectives like monitoring the chemical characteristics, analysing of organic remains, 3D documentation, ^{14}C dating and dendrochronological analysis. This approach will enable us to document the present state of the archaeological deposits very carefully and to simulate the history of the site and at least to some extent predict the future changes. Project is running with deep co-operation with researchers for Norway, specially V. V. Martens and P. Sandvik. (DUNLOP 2008, MARTENS et al. 2007, MARTENS et al. 2008, PETERSEN and SANDVIK 2006, REED and MARTENS 2008, SANDVIK 2000 and SANDVIK 2006.)

The finnish researchgroup included specialists from different sectors. PhD Auli Tourunen is doing the osteological analyse (Arhaeology / University of Turku), MA Mia Lempiäinen. (Arhaeology / University of

Turku) is doing the macrofossilanalyse and Eila Varjo geological analyze (University of Turku). PhD Markku Oinonen. (Finnish Museum of Natural History / Dating laboratory.) in leading the datingsector with Phil.Lic. Pentti Zetterberg. (Laboratory of Dendrochronology /University of Joensuu. Ecological Research Institute.). Digital documentation for wiki-library is planned by PhD Isto Huvila. The fieldwork in ruins has done mainly by BA Janna Jokela and BA Marko Korhonen (Aboa Vetus & Ars Nova museums.) and MA Markus Kivistö (Muuritutkimus Ltd) (UOTILA 2009).

The Case-study excavations in Aboa Vetus -museum

The in-situ museum Aboa Vetus (Turku, Finland) is well documented since 1990` and the physical changes in the structures and layers since its founding have been carefully recorded. However, even if the mortar walls have been monitored carefully, changes in the soil have received less attention.



Fig. 1 – Excavations in year 2010. The distance between museum visitors and excavation group is less than one meter.

Different methods like monitoring the chemical characteristics, analysing of organic remains, 3D documentation, ¹⁴C dating and dendrochronological analysis are being combined in the excavations in Aboa Vetus-museum in this Perditurus-project (lasting years 2009–2011).

This approach will enable us to document the present state of the archaeological deposits very carefully, compare the results with analyses of organic remains in 1993–94 excavations, simulate the history of the site and, at least to some extent, predict the future changes. Only rarely monitored archaeological sites have been excavated in a modern scientific way. On the other hand, archaeologist will only rarely possess

monitoring information prior to the excavations. In this excavation it was possible to combine monitoring data with excavation data and accurately date the layers in question (UOTILA 2009).



Fig. 2 – In winter 2010–2011 the excavation area was close to future. Before conservation the area (profile in the middle) was scanned with Faro 3d scanner.

In addition, the whole process is documented in 3D (total station, photogrammetry and laserscanning) and thus, the site can be in theory virtually excavated later. This kind of careful documentation have to be tested first in small scientific excavations before it can be utilized in large scale urban excavations.

Methods

Documentation

The aim of 3D-documentation is to form a detailed 3Dmodel of every excavation layer under examination. This approach shall combine various methods to build up point clouds gathered by using total station measuring, photogrammetry and laserscanning. Archaeology is destructive science – after the layers are excavated and examined, they do not exist physically any more. However, the 3D model of the layers together with knowledge about organic and inorganic materials in specific layers will enable reinterpretation of the data through virtually re-excavating the site (LEHTONEN and UOTILA 2004, UOTILA and SARTES 2000, UOTILA and TULKKI 2004).

To combine 3D documentation and other types of archaeological data (notes, pictures, videos, sample data) a wiki-based database will be used. The database, already in existence, will be developed further during the project through open-source-practise (HUVILA 2006a & b, 2008a & b, 2009a & b, UOTILA et al. 2008a & b, UOTILA et al. 2009).

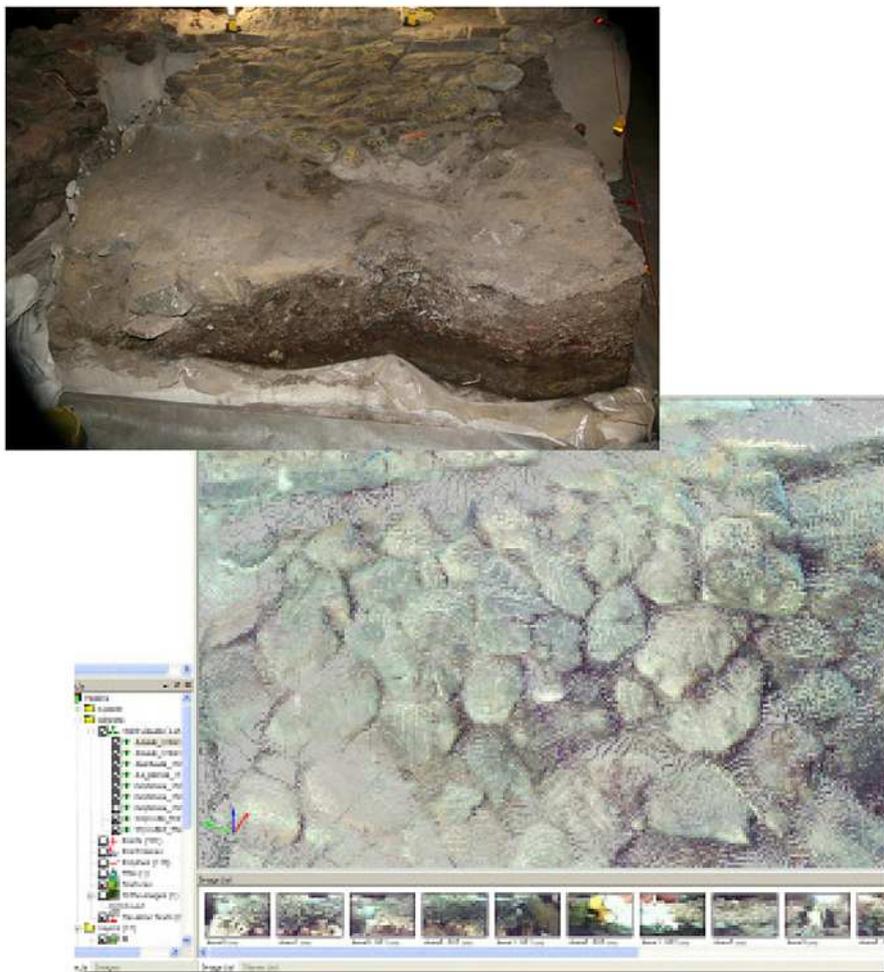


Fig. 3 – Photo from excavation area and scanned stone yard with Topcon IS Imaging Station (in winter 2009).

These methods shall be taught to the excavation team in various sites included in this project. This type of training has already been used in several building archaeology-courses held in Aboa Vetus-museum, Turku and it was presented in for example CAA-2010 conference in Spain in session on teaching digital archaeology in University level (UOTILA 2007, UOTILA 2009, UOTILA and HUVILA 2006).

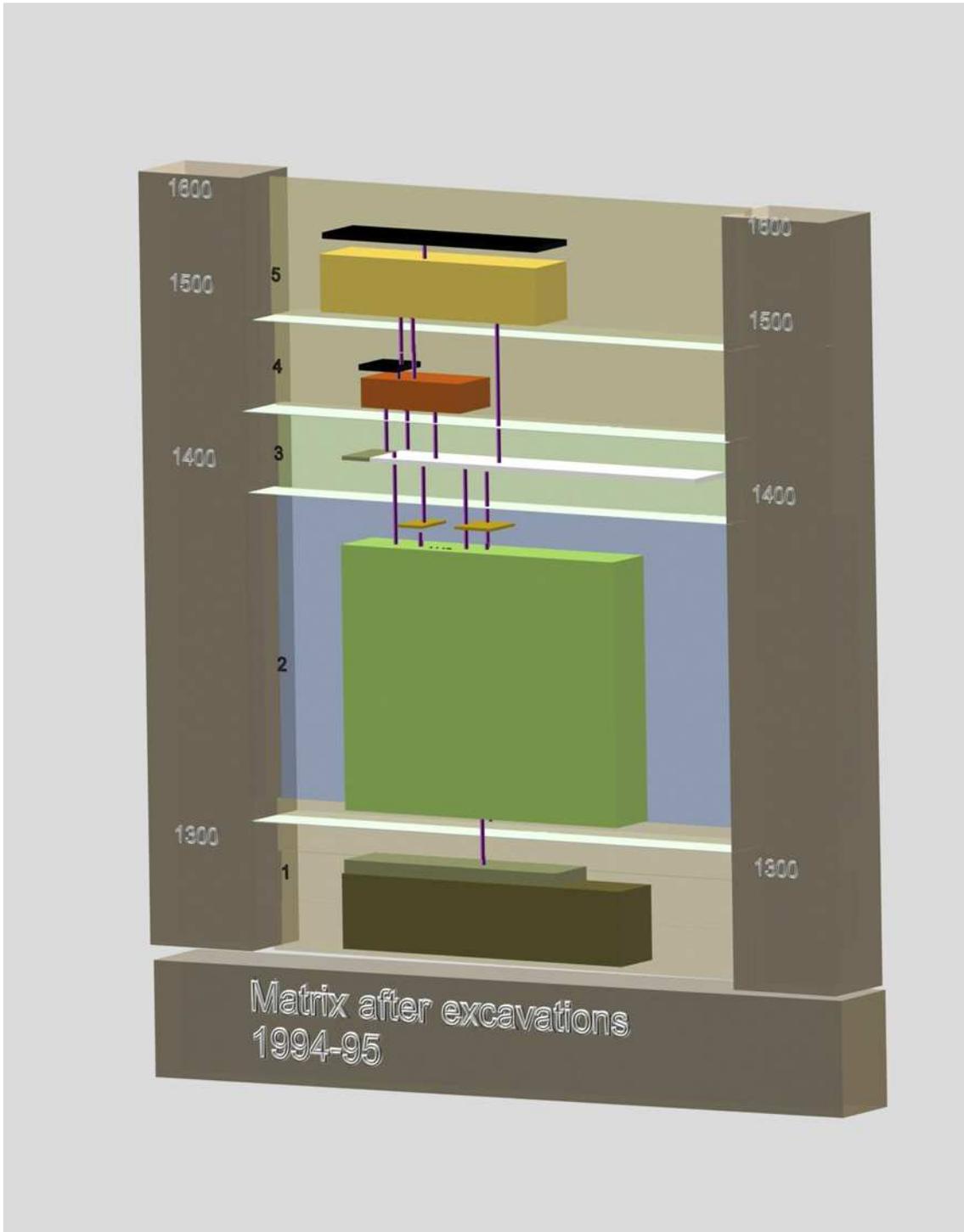


Fig. 4 – Matrix after excavations in 1994–95. In the area was find four medieval usingperiods and less than 10 layers.

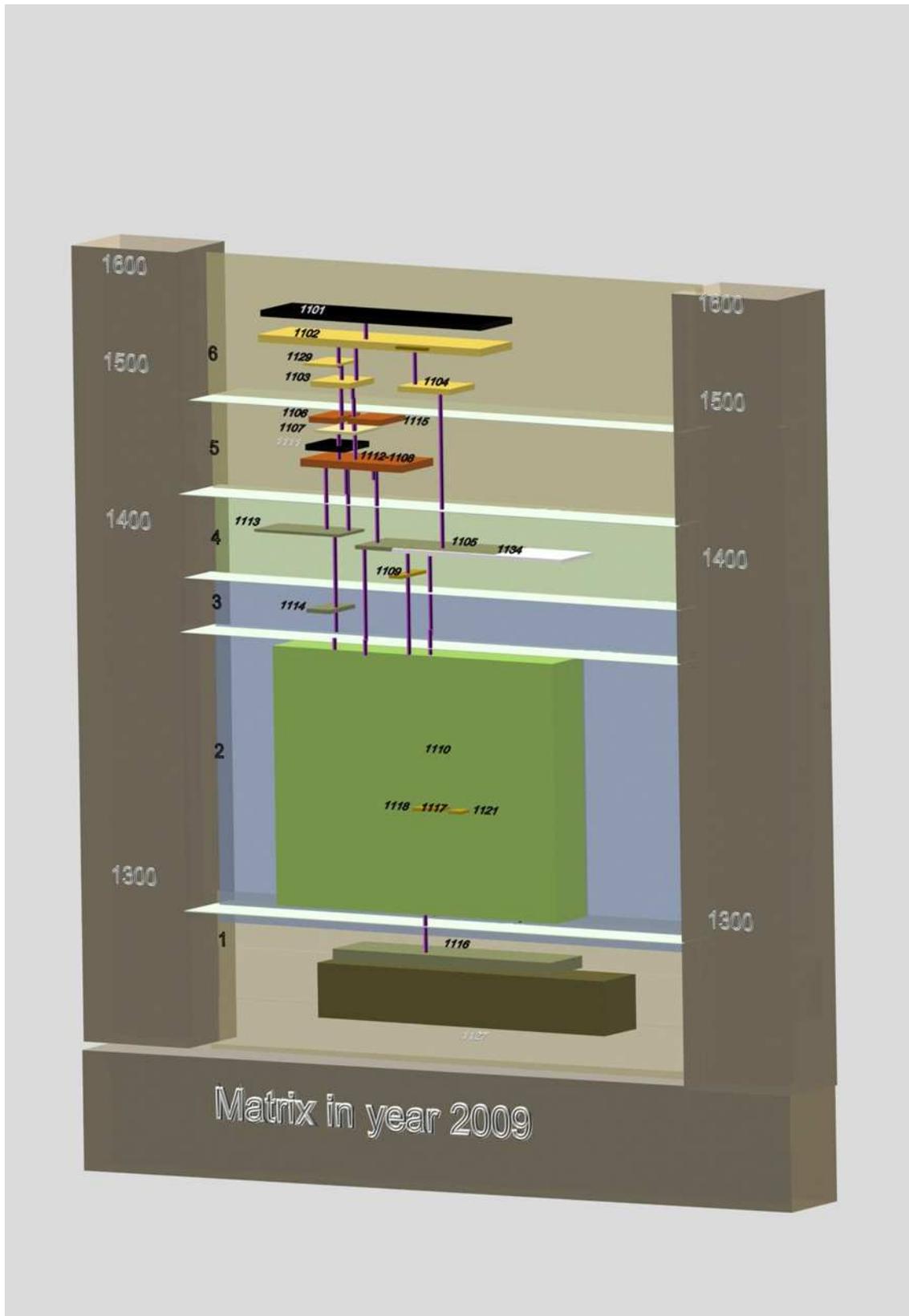


Fig. 5 – Matrix after year 2009. In the area was find five medieval using periods. In the upper (sand and clay-layers) the stratigraphy was quite clear. In the lower part wooden layers (layer 1110) were in bad condition and not easy to analyze. In 15 years (1994–2009) layers had lost main part of their stratigraphical information.

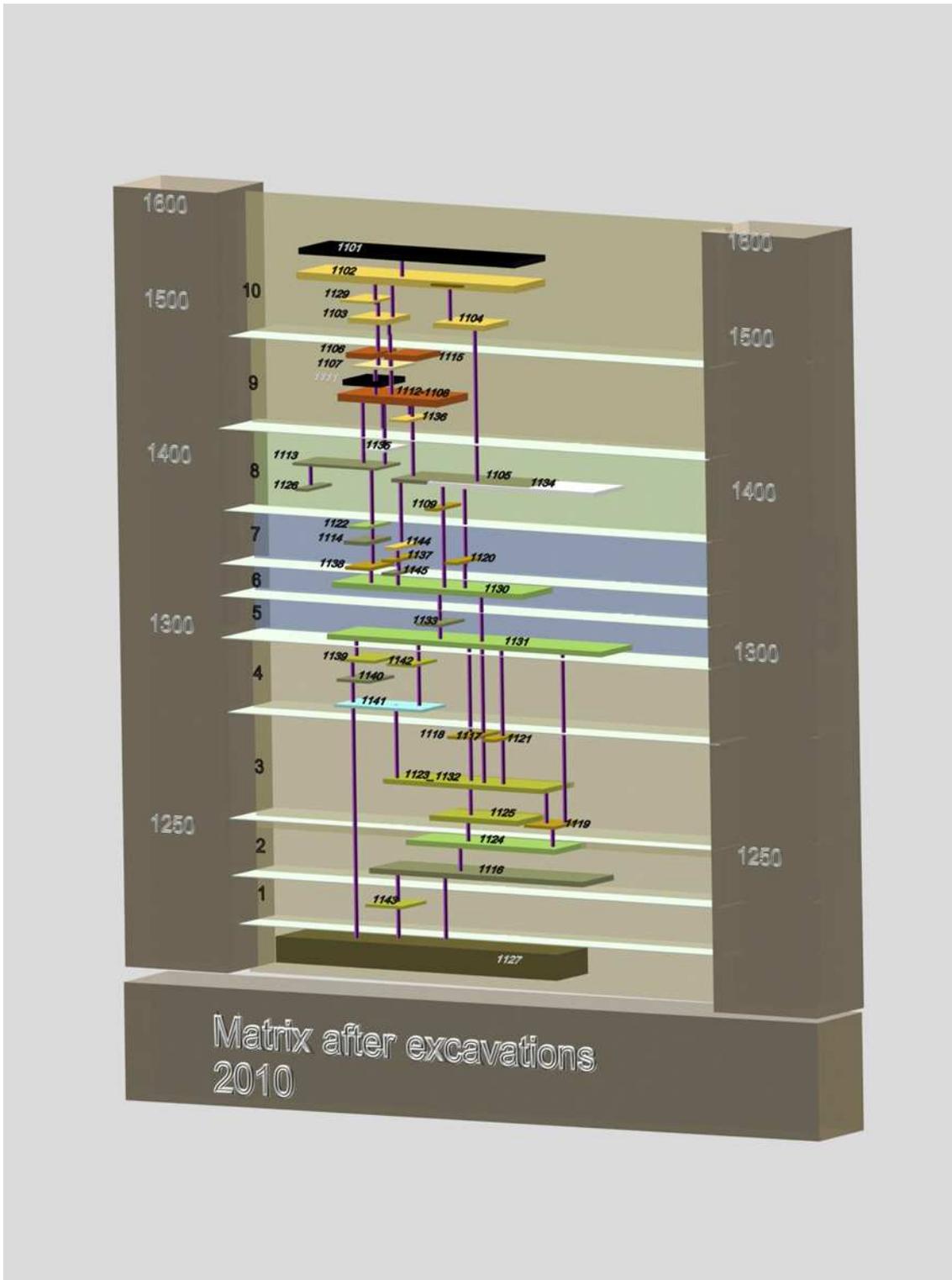


Fig. 6 – Matrix after excavations 2010. In the area was find 10 medieval using periods. In the upper (sand and clay-layers) the stratigraphy was same as in 2009. In the lower part wooden layers were in good condition and easy to analyze.

Measuring the preservation level in archaeological deposits

The organic materials like bone, insect and plant remains, wood, leather, and textiles recovered from the archaeological excavations are a valuable resource for studying subsistence strategies, environmental change and everyday life in the past. Animal bones discarded as food waste can tell us about the diet of the inhabitants and utilization of animals in an urban context. The small mammal bones and insect remains deriving from animals that lived on the site or nearby indicate the type of habitat and environment available. Plant remains recovered from the urban sites of local origin which tell us about the cultivation history and utilization of wild plants species. However, already during the Middle Ages more exotic plants like figs (*Ficus carica*) and grapes (*Vitis vinifera*) were imported to Nordic countries indicating international connections through the Hansa trading network.

Also leather and textile remains are important markers when investigating material culture, local production and import. Results have so far indicated that remains of plants, bones, and sediments together reveal knowledge about the ecosystems in all types of settlement, and are especially suitable in tracing the transition from a rural to an urban settlement which otherwise is very difficult to reveal. Therefore all types of physical remains and sediment samples from the past needs to be secured *in situ* or *ex situ* as physical archives for present and future research.

Organic material only survives in certain conditions in the soil and it is sensitive to environmental changes. Alterations in the moisture, acidity (pH) and oxygen level can lead to deterioration of the organic compounds. As the organic material is a valuable resource and tool when studying past societies, it is important to understand the changes in the environment that threaten its survival. By monitoring the geochemical characteristics of the site we can better understand the factors that can alter and bias our archaeological material. This can be done by for example inserting probes into the soil and measuring different key factors like moisture.

The preservation of the organic material can be used to compliment the data derived from monitoring the chemical characteristics of archaeological deposits. The physical condition of e.g. bones can be measured by using different factors like weight and surface abrasion (e.g. LYMAN 1994). The chemical changes can also be studied by for example measuring the proportion of organic compound in the bone matrix. Similar methods of recording the preservation of the plant remains do not yet exist and will be created during the project, but through loss-on-ignition, i. e. burning a sample, one can get information of the total content of organic matter in the layer (DUNLOP et al. 2008). By combining the preservation status of bone and plant remains with the results of the monitoring we can define the conditions where organic material will be preserved or destroyed. The suggested approach is unique in using both bone and plant remains as a tool in examining the preservation of the layers and in combining it with monitoring data. It will allow us to evaluate the usefulness of the existing recording systems, develop them further and create new criteria where appropriate (e.g. REED and MARTENS 2008).

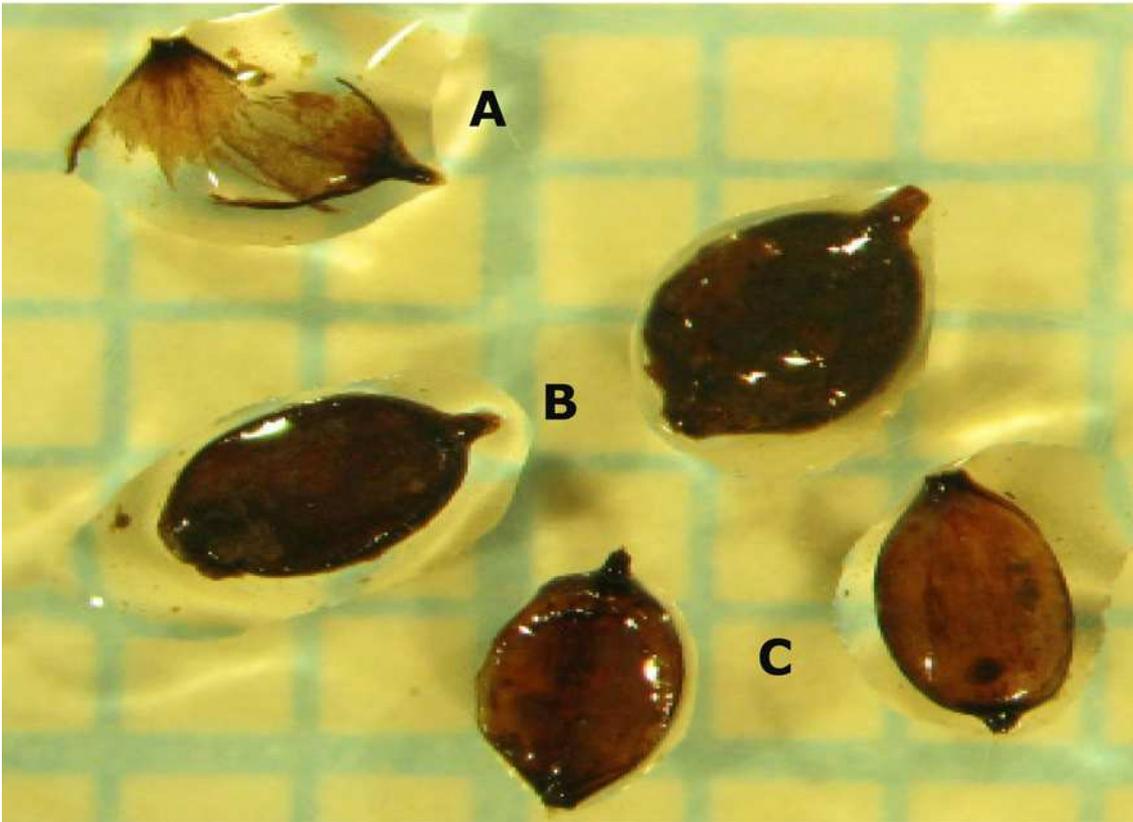


Fig. 7 – Different fragmentation and corrosion states of the Common Black Sedge (*Carex nigra*). seeds: a) POOR (broken seed/testa badly corroded), b) GOOD (seed and testa well preserved), c) MODERATE (seed well preserved, testa badly corroded). Text and photo MA Mia Lempiäinen.

Macrofossils

In this project, two main categories of deterioration were adopted for plant macrofossils: 1) fragmentation and 2) corrosion of the seed testa (seed coat). Fragmentation and corrosion were both estimated with a scale from 1–3 (1=good, 2=moderate, 3=poor). The calculation of preservation indices for macrofossils allowed comparisons to be made between samples and within a site. In one sample the preservation of seeds varied from good to poor.



Fig. 8 – Different preservation of bone in Aboa Vetus excavations. Bone on the left good preservation, bone on the right poor preservation – note the flaking of the surface. Photo and text PhD Auli Tourunen.

Bone material

The bone material was also used for evaluation of the deposition history and preservation of the archaeological layers. The bone preservation can be estimated for example by examining the surface structure of the bone. The lack of small bone and more fragile elements can also indicate destruction caused by taphonomic factors. In some of the examined samples, fish bones were observed but they could not be retrieved as they fell apart by the touch of tweezers. In other samples the fish bone preservation was noted to be better (TOURUNEN 2007, 2008a and 2008b).

Context datings on medieval town sites

Dating of the archaeological layers is crucial for understanding their wider context and enable comparisons with other sites. Provided that the studied site has preserved large remains of wood, dendrochronological analysis should be performed based on tree ring widths. If successful, this analysis provides one-year accuracy in dating. However, in some cases, there may not be enough material left or there is no dendrochronologically dated reference material available. Therefore, one may need to rely on radiocarbon dating (ARNOLD and LIBBY 1951).

Initially, the radiocarbon dating methodology assumes constant radiocarbon (^{14}C) content in the atmosphere over the ages (STUIVER and POLACH 1977). However, variation of the ^{14}C content does exist and requires calibration curve to be determined (REIMER et al. 2004). Procedure of converting the ^{14}C age to calendar years may result in wide calendar year probability distribution due to wiggles in the curve (see Figure 1). Thus the typical 25 year statistical uncertainty of the radiocarbon age may convert to even a half a century uncertainty in calendar years. On the other hand, the variation of the curve can be used to improve the dating accuracy by performing several ^{14}C dates on individual tree rings with known time separation and by fitting the obtained results on the curve. This is called wiggle matching (see, e.g. BRONK-RAMSEY 2001 and references therein).

To scrutinize the usability of the method, we have performed a wiggle matching analysis of dendrochronologically dated tree found from Aboa Vetus-museum in Turku.

The proposed work uses principles of dendrochronology and ^{14}C wiggle matching as a basis for context dating of the studied sites. This is complemented by individual ^{14}C dates in stratigraphical order and luminescence dating of bricks and fireplace rocks. By adopting such a context dating model, we aim to overcome the challenges set by the variations in the ^{14}C calibration curve which riddles especially 14th century dates. In addition, stable isotope analyses of organic material are used to characterize the site.

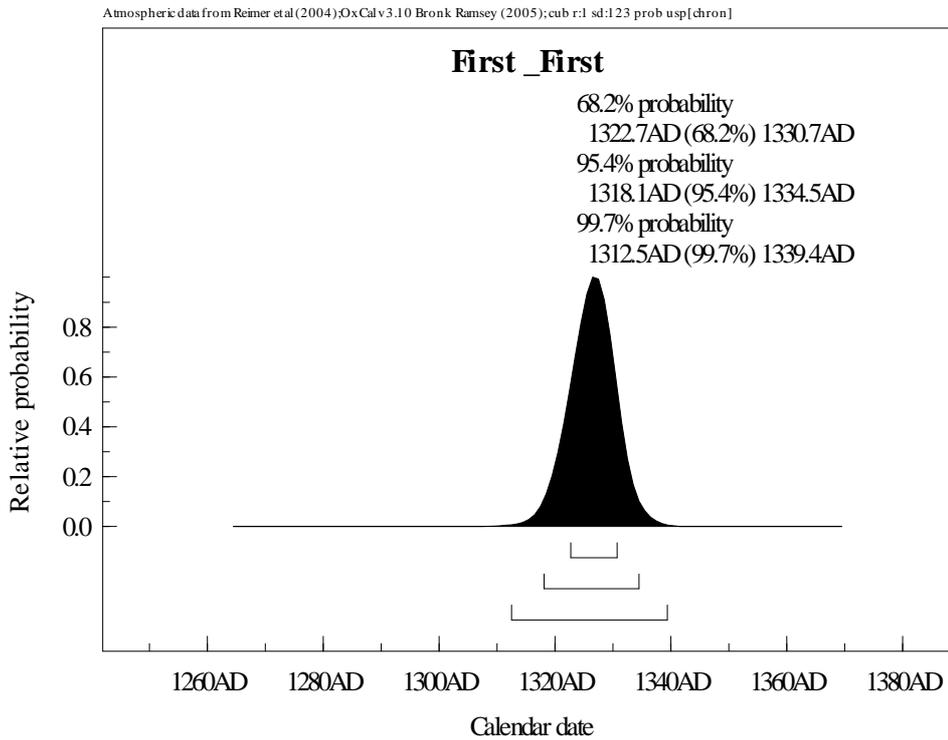
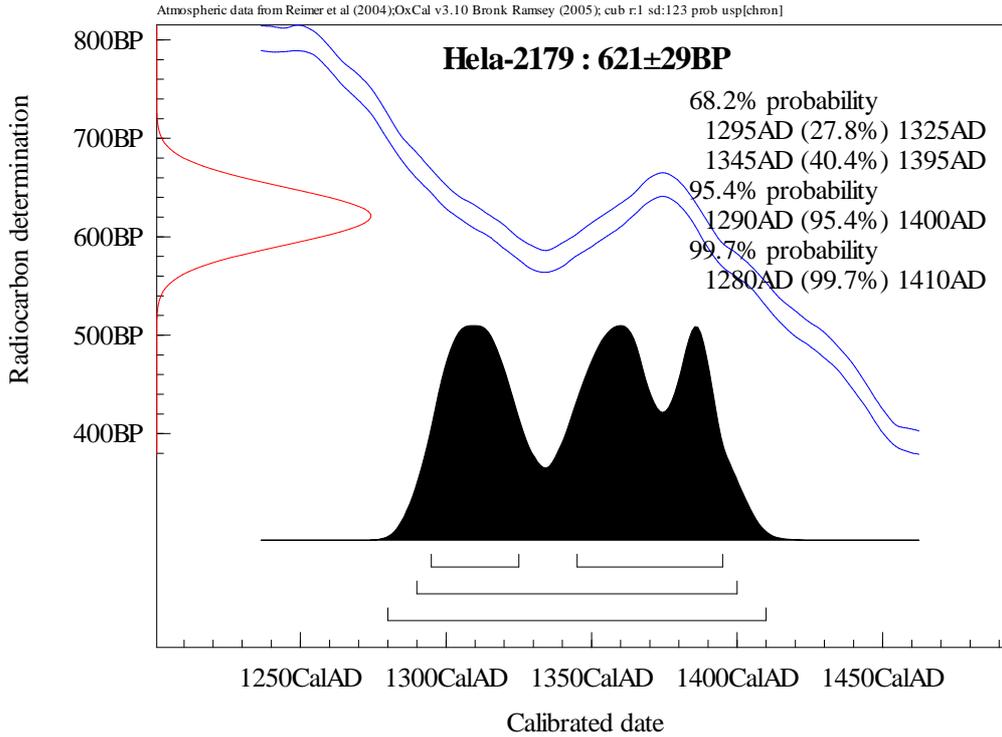


Fig. 9 – 9a and 9b shows the ¹⁴C result of an individual tree ring from the year 1318 AD (left) compared to the wiggle matching analysis by 6 tree rings. The procedure decreased the uncertainty of the dating by factor of 5 and we reproduced the year 1318 AD within less than 10 calendar year accuracy. Analyze and text Markku Oinonen.

To conclude

Only rarely monitored archaeological sites have been excavated in a modern scientific way. On the other hand, archaeologist will only rarely possess monitoring information prior to the excavations. In this project we can combine monitoring data with excavation data and accurately date the layers in question. In addition, the whole process can be documented in 3D and the site can be virtually excavated later. This kind of careful documentation will provide us with the tools to compare different sites and to better understand the first steps of the urbanisation processes in the Nordic countries.

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