mappa
metodologie applicate alla predittività
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Mappa

Methodology Applied to Archaeological Potential Predictivity

Francesca Anichini, Fabio Fabiani, Gabriele Gattiglia, Maria Letizia Gualandi

Università di Pisa

REGIONE TOSCANA

Volume I

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METHODOLOGIES APPLIED TO ARCHAEOLOGICAL POTENTIAL PREDICTIVITY

Francesca Anichini, Fabio Fabiani, Gabriele Gattiglia, Maria Letizia Gualandi

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Introduction

M. Letizia Gualandi
MAPPA Project Scientific Coordinator

The fruitful cooperation over the years between the university teaching staff of Univerità di Pisa (Pisa University), the officials of the Soprintendenza per i Beni Archeologici della Toscana (Superintendency for Archaeological Heritage of Tuscany), the officials of the Soprintendenza per i Beni Architettonici, Paesaggistici, Artistici ed Etnoantropologici per le Province di Pisa e Livorno (Superintendency for Architectural, Landscape and Ethno-anthropological Heritage for the Provinces of Pisa and Livorno), and the Comune di Pisa (Municipality of Pisa) has favoured a great deal of research on issues regarding archaeological heritage and the reconstruction of the environmental and landscape context in which Pisa has evolved throughout the centuries of its history. The desire to merge this remarkable know-how into an organic framework and, above all, to make it easily accessible, not only to the scientific community and professional categories involved, but to everyone, together with the wish to provide Pisa with a Map of archaeological potential (the research, protection and urban planning tool capable of converging the heritage protection needs of the remains of the past with the development requirements of the future) led to the development of the MAPPA project - Methodologies applied to archaeological potential predictivity, funded by Regione Toscana in 2010. The two-year project started on 1 July 2011 and will end on 30 June 2013.

The first year of research was dedicated to achieving the first objective, that is, to retrieving the results of archaeological investigations from the archives of Superintendencies and University and from the pages of scientific publications, and to making them easily accessible; these results have often never been published or have often been published incompletely and very slowly. For this reason, a webGIS ("MappaGIS" that may freely accessed at http://mappaproject.arch.unipi.it/?page_id=452) was created and will be followed by a MOD (Mappa Open Data archaeological archive), the first Italian archive of open archaeological data, in line with European directives regarding access to Public Administration data and recently implemented by the Italian government also (the beta version of the archive can be viewed at http://mappaproject.arch.unipi.it/?page_id=454).

Details are given in this first volume about the operational decisions that led to the creation of the webGIS: the software used, the system architecture, the organisation of information and its structuring into various information layers. But not only.

The creation of the webGIS also gave us the opportunity to focus on a series of considerations alongside the work carried out by the MAPPA Laboratory researchers. We took the decision to publish these considerations with a view to promoting debate within the scientific community and, more in general, within the professional categories involved (e.g. public administrators, university researchers, archaeology professionals). This allowed us to overcome the critical aspects that emerged, such as the need to update the archaeological excavation documentation and data archiving systems in order to adjust them to the new standards provided by IT development; most of all, the need for greater and more rapid spreading of information, without which research cannot truly progress. Indeed, it is by comparing and connecting new data in every possible and, at times, unexpected way that research can truly thrive.

Regional policies on research and innovation

Marco Masi *(DOI: 10.4458/8219-01)*
Regione Toscana - Area di Coordinamento Ricerca

Tuscany offers a large variety of local development models in which districts formed of small and medium manufacturing enterprises alternate with tourist areas and urban systems featuring strong tertiary sector development as well as universities and international research networking centres.

The presence of widespread scientific and technological expertise in universities and public research centres (attaining international excellence in many disciplinary and application fields), as well as the presence of enterprises operating in high-quality traditional sectors and high-technology emerging clusters, provides the Region with the challenge to take on a proactive role in promoting effective interaction between institutional groups and in improving existing specialisation techniques.

Within this context, the valorisation of archaeological, artistic and cultural heritage is a major priority: alongside the major archaeological sites and museums that have made Tuscany famous worldwide and a centre of attraction for multitudes of visitors, the region is also filled with 'minor' centres and museums, considered so only because of their smaller size and not for the historical, artistic and cultural value of their collections.

Use of this 'hidden' cultural heritage is a strategic objective for achieving full awareness of our cultural identity and for building the memory of our history, which cannot be founded solely upon the most extraordinary works but must spread throughout the entire region and fully embrace its special characteristics.

At the same time, the challenge to find new strategic solutions leading to the coexistence between archaeological heritage and contemporary urban environments has become increasingly pressing. The synergistic interaction between past, present and future is even more urgent in times of economic crisis; aware planning is necessary to optimise resources and support ideas that create new development and employment opportunities. Knowledge of our cities' buried history must be supported in order to plan new solutions that combine the development of the urban environment with sustainable cultural and economic choices.

Following the reform of Title V of the Constitution, both Regions and Local Bodies have been called to enhance a cultural heritage in respect of which they have no previous skills or specific professional expertise.

At the same time, the rapid development and diffusion of Information Technology has opened the door to new methods for using, enhancing and spreading cultural and archaeological heritage.

Furthermore, the creation of new digital innovation opportunities is one of the instruments to strengthen and manage new development models capable of creating new value for both supply and demand.

The MAPPA project provides a case study in which operating methods and new tools may be tested with the purpose of proposing a model (with specific operating procedures) which may be applied in other urban centres, both in Tuscany and nationwide.

The Region, also through these projects, intends to set up and further strengthen relations with research institutions and local government, with the aim to: enhance local areas, cultural heritage and educational and research facilities; implement actions to strengthen and develop infrastructures for the effective clustering of functions and services; and promote the creation of research networks as well as the development and strengthening of centres of expertise.

By sustaining the regional capacity to generate new knowledge and by connecting research to enterprises, it will be possible to stimulate the diffusion of new professional skills and technologies and, through these, support the modernisation of the regional productive system.

The enhancement of functions and skills, the systemisation of the results pursued, the creation of shared databases and the implementation of a regional network, providing a balance between research supply and demand, as well as between innovation and technological transfer, are key elements for the work agenda of the Regional Council, through the Regional Conference for Research and Innovation.

The AIR (Long-term Research and Innovation Guideline), one of the most significant fulfilments of Regional Law no. 20 of 2009 regarding "Research and innovation requirements", presents the innovations introduced by the law and proposes a framework for regional, national and EU programming, emphasising the close link to research and innovation issues.

Focus is placed on creating or improving conditions to strengthen enterprises through the creation or inclusion of enterprises in networks oriented towards international markets, and the development of high quality services and technology.

This means improving the quality of education, strengthening research, fostering innovation and knowledge transfer, using information and communication technologies effectively and endeavouring to turn innovative ideas into new products and services, so as to stimulate growth, create good quality employment and take on the challenges of society.

The development of mechanisms to effectively transfer research results into entrepreneurial opportunities is a growing challenge since leading to a more accurate and oriented exploitation of public resources, the creation of entrepreneurial communities, and the creation or stabilising of new employment opportunities throughout the region, thus attracting talents from all over the world and encouraging the transformation of Tuscany into a network of smart cities.

University and research can and must have a key role in accompanying Tuscany along a new development path, not only by forming human capital and producing new knowledge but also by providing regional enterprises with knowledge useful for innovation and implementing new application solutions with them, with a view to developing a truly free and democratic knowledge-based society.

The value of knowledge. the contribution of MiBAC to the MAPPA project

Anna Patera, Stefano Anastasio *(DOI: 10.4458/8219-02)*
MiBAC Direzione Regionale per i Beni Culturali e Paesaggistici della Toscana

The Republic promotes the development of culture and of scientific and technical research.
It protects the Nation's landscape and its historical and artistic heritage.

These contents, referred to in Article 9 of the Constitution, constitute the founding introduction to the principles illustrated in the first part of the Code of Cultural Heritage and of Landscape (Italian Legislative Decree no. 42/2004 and subsequent amendments and integrations). The protection and enhancement of cultural heritage play an important and mutually supporting role, contributing both to preserving the memory of the national community and its territory, and to promoting the development of culture (Article 1(2)). In the subsequent definition of these activities, significant reference is made to knowledge, regarded as an essential prerequisite for implementing cultural protection and as a propelling force for enhancing cultural heritage.

According to the Code, protection consists in exercising functions and in guiding activities aimed at identifying (on the basis of an appropriate knowledge-based activity) cultural heritage and at guaranteeing its protection and preservation for purposes of public use (Article 3(1)); enhancement is carried out, instead, by exercising functions and by guiding activities aimed at promoting cultural heritage knowledge and ensuring the best conditions for the public use of heritage (Article 6(1)).

Knowledge and other strictly related aspects (cataloguing, inventories, recording, study, research) are widely referred to in other parts of the Code, for example in Article 118. This article represents a novelty for sector legislation, since it has widened the procedural instruments previously in force, with the intent to stimulate synergies and good practices with public and private subjects that may, on various grounds and on the basis of specific agreements to be entered into with the Ministero per i Beni e le Attività Culturali - MiBAC (Ministry for Cultural Heritage and Activities), develop, promote and support research and studies regarding cultural heritage, and thus truly contribute to heritage protection and enhancement according to the well-known principle of subsidiarity.

Another important sector involving cooperation between MiBAC, the regions and Universities is the cataloguing of cultural heritage (Article 17). The field of application has notably increased thank to the development of new information technologies and includes territorial contexts.

The legislators of pre-unity Italy were aware of the importance of knowledge as a basis for protection. In the Pacca Edict, issued in 1820 under the Pontificate of Pius VII and considered to all effects the first organic law regarding protection, there is significant reference to the "exact description", regarded as an important information datum for the protection of ancient monuments, fine arts and antiques.

In the years that followed the Unity of Italy, despite the well-known difficulties that limited cultural heritage protection measures by the young national government, after various unsuccessful legislative attempts, a ministerial commission was set up in 1906 appointed to draw up a new text, which would then result in the first Italian organic protection law: Law no. 364 of 1909 regarding "antiques and fine arts".

These years saw the laying of the foundations of the administrative protection organisation achieved at the start of the XX century. Issue of Regulation no. 431/1904 confirmed the establishment of decentralized structures throughout the territory divided according to competences: monuments, excavations, museums, antiques, galleries and fine arts.

In over 100 years of territorial protection activity, the Superintendencies (peripheral bodies of the current MiBAC) have significantly contributed to developing – within the scope of the institutional duties assigned to them – knowledge of our cultural heritage, thus ensuring its preservation and promoting its enhancement.

The MAPPA project collects part of this precious knowledge.

An agreement signed on 29 July 2011 regulated the terms of cooperation between the Dipartimento di Scienze Archeologiche (Department of Archaeological Sciences) of Pisa University, the Comune di Pisa (Municipality of Pisa) and MiBAC, represented by its peripheral branches: the Direzione Regionale per i Beni Culturali e Paesaggistici della Toscana (Regional Directorate for Cultural and Landscape Heritage of Tuscany), which maintains contacts with the central ministerial structures, the Soprintendenza per i Beni Archeologici della Toscana (Superintendency for Archaeological Heritage of Tuscany) and the Soprintendenza per Beni Architettonici, Paesaggistici, Artistici, Storici ed Etnoantropologici per le province di Pisa e Livorno (Superintendency for Architectural, Landscape and Ethno-anthropological Heritage for the Provinces of Pisa and Livorno). The subscribers, together with the members of the Management Committee, are part of the Scientific Committee, established with the duty to consult, guide and monitor the progress of the project (information about the structure and competences of these Committees may be found on the project website: http://mappaproject.arch.unipi.it/).

The methodology adopted for the project activities is described in the following chapters: it is sufficient to remember, during this first phase, the information database upon which the general architecture of the project – aimed at developing a map of archaeological potential – has been developed.

The Superintendencies' contribution was of major importance since they allowed the researchers involved in the project to access their archives and databases regarding excavations, finds, monuments and historical buildings, thus enabling the consultation and reproduction of all descriptive, drawn and photographic documentation.

These databases, together with those listed in the bibliography, allowed the creation of a general archive, for exclusive internal use of the project, and the creation of a database, which may be viewed on WebGis, aimed at the development of the archaeological map of the city of Pisa.

The data of these archives will allow a detailed analysis of the history of the city's urban fabric, in order to devise the model of archaeological potential which will be addressed during the second project phase.

The records reserved for publication, which contain the minimum descriptive data relating to the single archaeological interventions catalogued, were processed according to indications provided by the Superintendencies in order to allow interoperability and information sharing with the MiBAC databases, especially SIGEC, the national system for the acquisition and integrated management of data pertaining to Italian cultural heritage, created by the Istituto Centrale per il Catalogo e la Documentazione - ICCD (Central Institute for Cataloguing and Documentation).

To make sure that the MAPPA project had the capacity to respond to the updating and implementation needs dictated by the continuous development of IT procedures and applications, minimum MODI specifications and requirements were taken into account. MODI is the Information Module created by ICCD and designed to allow acquisition of information regarding Italian cultural heritage according to procedures which, as indicated in the introduction to the experimental version 1.00 currently in use, are "...free from usual catalographic practices. This is basically a 'lighter' structure in regulatory terms than catalogue records, and is not associated with a national univocal code…, transversal to all types of cultural heritage (mobile, immobile, immaterial) and is in line with most updated ICCD regulations".

The catalographic records of MAPPA have taken minimum MODI requirements into due account, thus allowing future integration of the data in the "Information Module" once this has been adopted and become fully operational following the current experimentation phase.

In the perspective of data "interoperability" and sharing between the various systems, in order to promote maximum diffusion and effective use of the information collected, the MAPPA project has focused on the National Geoportal structure, i.e. the infrastructure for national territorial information, established by Italian Legislative Decree no. 32 of 27 January 2010, on the basis of EU Directive 2007/2/CE "INSPIRE".

In 2010, MiBAC signed an Agreement Protocol with the Ministry for the Environment and for Land and Sea Protection, which is the competent authority for management of the Geoportal, ensuring its participation in the project and its availability to produce mapping data that may be introduced in the Geoportal's meta-data: even in this case, therefore, the MAPPA project envisages further possible integration thanks to an instrument destined to become a point of reference for mapping data online resources.

During this first phase, an information level was set up within the database to be published online, regarding the protective measures falling within the research area. The visualisation record includes the ID field and link to the Map of Restraints, which was created by Regione Toscana in strict collaboration with MiBAC and is a useful knowledge-based instrument allowing the search for cultural and landscape protection measures at regional level (please see the contribution by R. Costantini in this volume).

The information data provided by the MAPPA project are also a starting point for territorial planning and for the application of the set of rules and practices which belong to the current expression "preventive archaeology". This type of intervention (which became Public Works Law in 2004 following introduction of Article 28(4) of the Code) makes it possible to intervene in advance for the protection of archaeological heritage which must be ascertained or brought to light in order to be fully known, unlike other types of cultural heritage whose evidence is ab origine.

These procedures improve safeguard actions by preventively intervening in risk areas in which protection authorities cannot fully apply the measures provided for by law since there are no ascertained archaeological emergencies.

The results of the MAPPA project research activities, consisting of a final IT and technological product, shall be fully available to MiBAC's peripheral structures which shall be able to use them for its own institutional tasks.

The MAPPA project: a new tool for gaining awareness of urban planning

Gabriele Berti *(DOI: 10.4458/8219-03)*

Comune di Pisa

The development of urban planning over the past two decades has overcome the pure and simple notion of "drawing a city", typical of XX century manuals, and "equipping it with standards", intended as public space (road systems, squares, parks, parking area and public services). The key focus has now moved to the environmental compatibility (broadly intended, not only in landscape-ecological terms) of transformation, foremost the preservation of non-reproducible sources.

The motivation at the basis of urban choices, therefore, depends not so much on the generally extensive planning concept of urban settlement but on the compatibility between such choices and the need to restrict the impact of certain components, such as territory (land consumption), quality of life (atmospheric and acoustic pollution, and social and economic consequences) and urban identity.

In the light of a phase of expansion which has affected cities throughout the XX century, more recent trends have proposed the "densification" of inhabited areas, thus overcoming the idea of independent neighbourhoods or agglomerates, each equipped with "standards".

Choices must be based on the acquisition of a knowledge base that is fully exhaustive and organised so as to favour a comparative reading of all elements comprising it, ranging from social to economic, cultural, ecological and landscape elements, and including also more traditional dimensional, demographic and infrastructural aspects.

A thorough and well-organised knowledge base which favours the comparative reading of all its constituent elements – ranging from social to economic, cultural, ecological and landscape elements, and including also more traditional dimensional, demographic and infrastructural aspects – is indispensable as a basis for taking decisions.

Whilst getting ready to draw up a new Strategic Plan together with the other municipalities belonging to the Pisa area, the Municipality of Pisa is highly committed to forming a knowledge base that goes beyond the administrative borders and embraces the entire area as a whole, in terms of internal inter-dependence and autonomy with the surrounding territory, as confirmed by the first studies on mobility and social-demographic studies.

In order to achieve in-depth knowledge of the local area, the MAPPA project, albeit its undeniable intrinsic cultural value, is a key element of the Knowledge Base upon which the new Strategic Plan will be founded, which until now has only been represented, in an uncritical, approximate and insufficient manner, by the implementation of a system of constraints.

The knowledge of our underground heritage will be of great importance when making urban choices, especially within processes aimed at managing urban concentration without new land use. The aim is both to preserve significant areas and valuable finds for future studies and to transform what is today seen as a "risk" into "potential", so that, if previously acknowledged, will not be regarded as an unexpected incident by construction workers (with all possible negative consequences) but will become an assessable item, also in economic terms, and may be included in the general costs and represent a possible added value for the intervention.

1. First phase of a work in progress

Maria Letizia Gualandi *(DOI: 10.4458/8219-04)*

1.1 The project

Like many other Italian cities, Pisa is a settlement that goes well back into history. Its subsurface conceals the remains of buildings, tombs and roads, as well as the fragments of tiles, vases, lamps and sculptures: briefly, the layered traces of the lives of the people who have inhabited the city over its almost three thousand years of history. Pollen, coal, animal remains, may also be found, as well as the traces of ancient marshes, cultivated lands, water courses and coastal dunes: i.e., the signs of the landscape, or rather the landscapes that have evolved over time and have influenced the city's economic and cultural development, and in turn have been influenced by them. The ground on which we walk, build and live today is an extraordinary palimpsest where uncountable traces that have been left by our predecessors evolve, merge and are concealed. Since these traces lie under ground, they need to come to terms with the vitally important needs of the city's life and development: safeguarding archaeological heritage does not mean fighting development but proposing sustainable management models within a framework of sustainability and respect for past and present needs.

In Pisa, two different rulings[1] define the boundaries of an area – corresponding to the area of the city inside the walls and to an external portion to the north and to the west – which has been declared of 'important archaeological interest' given that a high amount of archaeological discoveries relating to the Etruscan, Roman, Medieval and Post-Medieval city have been discovered over the past years. Since the finds were mainly fortuitous before the rulings, protection was governed by randomness rather than by targeted studies, with a view to analysing the development of the Pisa urban and peri-urban fabric throughout the centuries. There can be no denying that after the rulings were issued, the number of archaeological investigations (and finds) increased in the protected areas, whereas knowledge outside this area (i.e. in the areas to the east and to the south of the city walls) did not make any significant progress. The reason for this situation is that all public and private construction projects falling within the 'ruling' area must be submitted by the Municipality to the Soprintendenza per i Beni Archeologici (Superintendency for Archaeological Heritage of Tuscany) for approval. The Superintendency may order various types of interventions – ranging from diagnostic surveys (geophysical prospecting and cores) to archaeological excavations – or request the presence of an archaeologist at the building site. The archaeologist has the authority to stop the construction works and carry out archaeological excavations if any remains are found. All related costs – in terms of time and money – are borne by the contractor and their extent is difficult to envisage. This usually leads to delays, additional costs and closing of sites, leaving contractors with no other option but to keep archaeology as far away as possible from their sites. In the areas that are not included in the rulings, instead, the Superintendency only intervenes for public works: a 'voluntary' and occasional reporting system is used for private works, which naturally explains the lack of finds (or news about finds?). The paradox of this situation is that we know more about the well-known and protected areas, and less about the areas of which

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[1] Administrative provisions issued by the Soprintendenza per i Beni Archeologici della Toscana (Superintendency for Archaeological Heritage of Tuscany), in compliance with protection law 1089/1939, respectively on 10 April 1986 and 29 June 1993.

we have little or no information. To overcome this paradox and extend current legislation regarding public interventions to private interventions also, it would be sufficient to apply the "European convention for the protection of archaeological heritage' (La Valletta, 16 January 1992). The convention was signed by the Italian Government but has still not been ratified after twenty years, unlike all other European countries.

In a search for new solutions capable of effectively combining protection needs with urban planning and research requirements, a working group with different skills and aims was set up several years ago composed of the representatives of three institutions dealing with the buried heritage of Pisa: Soprintendenza per i Beni Archeologici (Superintendency for Archaeological Heritage), Comune di Pisa (Municipality of Pisa) and Pisa University. Their aim was to combine their efforts into a common project capable of projecting Pisa archaeology into the future and into what is called (by analogy to software development and, more specifically, to 'web 2.0'[2]) *Archaeology 2.0*[3]. This is how the idea to develop the map of archaeological potential of Pisa came about, especially the idea to use the Pisa area – i.e. a small-sized city but with a multi-layered past, as many other Italian cities – as a case study to implement a mathematical instrument capable of calculating its archaeological potential.

The map of archaeological potential is an instrument that turns buried remains into a source of wealth for the territory, not into a brake on development, which in turn can move from being an impending danger to ancient archaeological evidence to representing an extraordinary opportunity for knowledge. From a conceptual viewpoint, the map represents the evolution of traditional archaeological maps which are widely used because they provide synoptic frameworks of knowledge acquired from an urban or rural area, broken down by historical phases or according to specific topics. Archaeological maps, however, are of little aid to the study, protection and planning of areas about which we have no information. These areas (when speaking of cities) usually correspond to the peri-urban areas where there is a greater need to intervene for the construction of new neighbourhoods and infrastructures. The map of archaeological potential overcomes this limitation. It uses archaeological data as a basis, but integrates them with geological and geomorphological data, as well as with data from the analysis of vegetable and animal remains, maps and ancient registers, toponymy and the study of historical building components. This huge amount of documentary evidence provides a picture of the evolution of the urban and rural landscape over time and allows the archaeological finds to be situated in a much more detailed cognitive context. By 'projecting' information, through the use of statistical and mathematical processing, on areas for which there are no existing data today, the map of archaeological potential makes assumptions on the greater or lower chance of human presence in these areas and even on the type of presence (house, necropolis, production area, farming area…), with a degree of approximation that varies according to the quantity and quality of data available.

The map of archaeological potential is a predictive map that does not simply 'photograph' the existing situation (as in the case of archaeological maps), but uses it to hypothetically, but not arbitrarily, create new knowledge which gains greater detail after every new find. The benefits of using such an instrument for protection and planning activities are evident: urban and building decisions may be planned in a more informed manner, minimising the number of emergency archaeological investigations. The latter are detrimental to both the archaeological remains, which are often excavated hastily in the presence of diggers and cement castings, and the works to be performed, which are often delayed and need to

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[2] Web 2.0 is the development of the World Wide Web consisting in the set of applications that favour interaction between websites and single users, foremost social networks.

[3] KANSA, WHITCHER KANSA, WATRALL: 2011.

be modified. That 'prevention is better than cure' is also confirmed in this field by the approval of the regulations regarding the *preventive assessment of archaeological interest*[4], according to which Archaeological Interest Evaluations (VIArch) are crucial for directing the operational decisions taken for large public works involving construction or environmental transformation activities.

In agreement with the Direzione Regionale per i Beni Culturali e Paesaggistici della Toscana (Regional Directorate for Cultural and Landscape Heritage of Tuscany), Soprintendenza per i Beni Archeologici (Superintendency for Archaeological Heritage) and Comune di Pisa (Municipality of Pisa), a project took shape in the laboratories of Pisa University (ANICHINI *et alii* 2011) called *MAPPA. Methodologies Applied to the Predictivity of Archaeological Potential: the map of the Pisa urban area,* which was funded by Regione Toscana[5] in 2010. The two-year activities started on 1 July 2011 and will end on 30 June 2013.

1.2 The archaeological information layer

As already mentioned, the starting point for the creation of the map of archaeological potential is an updated and well-organised data archive. During the first project year, therefore, the research group focused on:

- Creating the digital archive (see § 4.1),
- Collecting documentation related to the archaeological interventions carried out in Pisa up to this day, regardless of their importance, ranging from deep excavations to the smallest road trench (see § 2)
- Implementing and georeferencing the data (see § 4.2),
- Developing a webGIS: we believed that having a GIS at the start of the project for online management purposes was the best solution to ensure maximum communication and sharing of information (see § 5 and 6).

The decision not to use the traditional term 'archaeological map' for the project results was intentional, mainly because this definition implies the idea of a 'finished' and independent product that has come to an end (see § 3). Instead, the archive of archaeological information of the MAPPA Project may be updated at any time and is simply the first step of our work, not the finishing point. Further information layers will be added to it, which will contribute to creating the database needed to calculate the archaeological potential. For this reason, we prefer speaking of an 'archaeological information layer', which clearly explains the role of the archaeological data archive within the overall architecture of the MAPPA project. The pillar upon which the entire project is founded is the clear distinction, within different information layers that may be continuously updated, between 'objective' data (that is, data arising from the ground and called 'archaeographic' in archaeological language) and the assumptions made on the basis of these data, i.e., the 'archaeological' interpretation which includes the evaluation of archaeological potential. Archaeographic data, once collected, cannot be modified (an excavation cannot be repeated like a laboratory test, since it would destruct archaeological stratification) and can only increase in number after new investigations; data interpretation, instead, may vary as a result of new discoveries, experts' different skills and expertise, and review of information in studies with different objectives and level of detail. Archaeology is a discipline that always refers back to its data: the

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[4] Articles 95-96 of Italian Legislative Decree 163/2006, published in the Official Gazette no. 100 of 2 May 2006 - Ordinary Supplement no. 107.

[5] PAR FAS, action line 1.1.a.3, disciplinary scope *Science and technology for cultural heritage protection and valorisation*. Teachers belonging to the three proposing university departments - Archaeological Sciences (head partner), Earth Sciences and Mathematics are involved in the research (www.mappaproject.arch.unipi.it). They are assisted by PhD graduates with expertise in all project sectors (archaeology, geomorphology, geology, numerical analysis, computer studies) and by university students who have been appointed with data collection and entry tasks and for whom the project is an excellent opportunity for inter-disciplinary professional training.

epistemological model upon which research is based – the circumstantial paradigm – only allows more or less probable assumptions to be made. These assumptions may become stronger or weaker at each new discovery but can always be reconsidered, starting from the data upon which they were made. In other words, whereas data never grow old in archaeology because they are unique, unrepeatable and can never be rendered obsolete by other data, this is not so for the interpretative assumptions made from them (unless they become relevant again in the light of new finds). Consequently, the archaeographic data resulting from investigations, which may be called 'raw data', are the real and only 'source code' of archaeology and, as such, must be easy to access and check whenever necessary, without any sort of interpretative filter.

Archaeological discoveries are fast-evolving far and wide, however, underground investigations (even simply for laying piping or cables) are growing at such a rapid rate in busy urban environments that paper maps quickly become obsolete and cannot be updated. For this reason, we decided not to include any mapping images in this volume but to refer to virtual and dynamic Web documentation.

1.3. Archaeological documentation

The archaeological documentation was collected and archived over many months of work. A number of critical issues arose which are explained in detail in the contributions of this volume, together with the solutions adopted to overcome them (see § 2). The purpose of this attentive examination was not to 'play it safe' in view of criticism and comments (unavoidable whenever operational decisions are taken) nor to trigger useless polemics, but rather to start a debate among archaeologists on the urgent need for the reform of procedures and the definition of qualitative standards, which must involve all parties involved in the archaeological sector: from the officials of the Ministry for Cultural Heritage to university teachers and representatives of professional categories – cooperatives, firms, service companies and freelancers – which have become an established reality in the archaeological field.

Archaeological data can be retrieved from excavation documentation, principally containing what has been defined as 'raw data', and from printed publications, from which 'interpreted data' may be mainly drawn. Logically, there should be correspondence between the two types of documentation; specifically, the excavation documentation ('raw data') preserved in the Superintendency's archives should contain an interpretative summary of the published documentation and, conversely, the original excavation documentation of the latter should be available in the archive. Unfortunately, this does not always happen. The results of many investigations (the majority, according to GATTIGLIA 2009: 51) are never published: they are often – although not always – rescue investigations with limited scope (narrow trenches for checking underground piping, cores for analysing building plots, small excavations for the laying of manholes…), which sometimes provide fragmentary and apparently inexplicable data, but upon which light is shed when compared with other data. In contrast, many publications contain often brilliant but extremely brief interpretations and summaries based on the 'raw data' of investigations of which there is no existing documentation in the archives, and so cannot be re-examined. The reason for this is that the person carrying out the investigation often delivers the documentation to the Superintendency only when the results of his/her research have been published, with a view to protecting their authenticity. The problem is that there is a mistaken belief that the publication of articles and monographs makes 'raw data' obsolete, which often never reach the Superintendency's archives. This rather diffused habit of not delivering documentation is based on a misunderstood principle of 'intellectual property' (quite different from 'authorship'), which although understandable to a certain extent, is certainly not justifiable. Moreover, this practice leads to a third situation, certainly more harmful from the point of view of knowledge and protection of archaeological heritage: cases in which no type of documentation is available, neither 'raw data' nor a publication containing even a brief interpretation. These are usually wide-scope investigations (there is little interest in publishing data about a small trench) which years and sometimes decades after their conclusion, have still not been published. The executors stubbornly claim that the data are 'still being studied' and that they have the 'right' to keep the documentation to themselves; in actual fact, they are subtracting precious information *sine die* to the scientific and general communities, in the majority of cases produced thanks to the use of public funding. Furthermore, such a disproportionately long period of 'study' could lead to the risk of losing the documentation for many possible reasons and, in this case, the results of entire excavation campaigns would disappear forever.

This is an important issue and opens the path to a debate on the accessibility and spreading of information – or, better, on open data archive – which has affected a wide range of public sectors over recent years. Urgent action needs to be taken in archaeology, where the circulation of information and the transparency of data analysis processes have an immediate impact on the effectiveness of archaeological protection heritage activities (how can a VIArch possibly be drawn up without updated data?) and on a territorial planning model respectful of buried archaeological heritage. But there is more than this. Pulling out information from archives, research laboratories and private firms, bringing knowledge of the heritage below our feet to the community and sharing its importance with citizens is of strategic importance for raising collective awareness of the need to preserve the traces of the past for future generations: this is the best guarantee for their protection.

The MAPPA project effectively contributes to this debate by creating the first archaeological open data archive (MOD - MAPPA Open Data) and promoting dialogue between experts of different disciplinary fields – archaeologist, historians, philosophers, and communication experts[6]. A central issue is the need to safeguard the expectations of the archaeologists who 'produce' the raw data with their own (hard) fieldwork and legitimately expect the 'authorship' (not the 'property') of the data to be acknowledged to them. A deadline could be defined, for example, by which a sort of pre-emption right could be exercised, based on the publication of the data. This deadline, however, must be reasonable: research that is still 'due to be published' (and, as such, subtracted from the community) after twenty years from its conclusion is unacceptable. Although researchers have the right to an appropriate period of time for studying and publishing the results of their work, it is essential for 'all' the documentation to be handed over to the Supertintendency when the fieldwork is over. After checking the documentation, the Superintendency should make it immediately available through open data policies, thus assigning authorship to the person who has produced it. To do this, it could use the web, an extraordinary instrument for providing rapid and low-cost dissemination of information and ensuring copyright protection: it is sufficient to assign a DOI (Digital Object Identifier: http://www.doi.org/) to the data, which protects their intellectual authorship, as in the case of the ISBN (International Standard Book Number) for printed publications. Researchers would immediately see the results of their work 'published' in their name, without losing the right to study them more deeply and publish more comprehensive results in the future.

But let us return to archaeological documentation. When available, problems arise related to the methods used for archiving information owing to the lack of uniformity of the sources, such as, the way the data are recorded, the terminology used for describing the finds, the chronological parameters adopted, and even the criteria used for locating the excavations. The solutions adopted by the MAPPA project to tackle this

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[6] For example *Opening the Past. Archaeological Open Data*, Pisa, 9 June 2012: the abstracts are published on the project website: www.mappaproject.org.

situation and to be able to compare different information are explained in greater detail further on (see § 2 and 8). It is important here to point out a key issue. While the lack of uniformity when recording information is predictable and understandable in the case of past investigations, this is not so for recent investigations, revealing a problem that needs to be urgently addressed by the Ministry for Cultural Heritage: the definition of common standards for all archaeologists working in the sector. It may seem trivial to state that excavation interventions must be georeferenced and that the height of finds must be expressed with measurements calculated at sea level or at least from zero-points for which the absolute height is provided; experience shows that this is not so. For this reason, a codification of procedures is essential, also in consideration of the widespread practice by archaeologists to acquire and process data directly in digital format (e.g. photographs and drawings) or at least to collect and preserve them in digital archives. Data must be able to dialogue; to make this happen, it is crucial to be provided with shared standards and good practices for the IT procedures to be set up. The possibility to share and compare data and, in prospect, preserve data over time depends on these choices.

1.4 A window on archaeology

As previously mentioned, the MAPPA project architecture was designed as a series of information layers which can be overlapped in different ways to combine information, leading to results that are not entirely foreseeable and opening unexpected research prospects. A specific example of this possibility has already been achieved: the examination of collected data in the archaeological information layer from a completely new viewpoint (see§ 8). Starting from the date of execution of the almost seven hundred interventions recorded, it is possible to reconstruct the history of archaeology research in Pisa and outline the evolution of the excavation methods, interests and objectives that have characterised over five centuries (from XVI century to the first decade of XXI century) of investigations. The way the investigations have varied over time also provides insight on the development of the protection strategies. Whilst occasional recoveries basically represented the only type of intervention up to the Second World War and were still numerous up to 1990s, after these years, the number of rescue excavations increased, that is, interventions carried out during ongoing construction sites, often reported by representatives of archaeological Groups and revealing the community's involvement in the monitoring of works. Preventive excavations, alongside other less invasive (and expensive) investigations, such as cores and geophysical prospecting, were established during XXI century.

A final consideration should be made on the individuals involved in archaeological investigations, which have changed over the past decades. After a long period in which research was conducted by Superintendency officials and University teachers and researchers, who availed themselves of construction workers and occasionally students and voluntary workers (especially Archaeological Groups), during 1990s, 'professional' archaeology gradually gained force, initially represented by cooperatives of young graduates and then by companies, specialised firms and, most recently, freelancers. Despite difficulties due to the fact that the profession of archaeologist has never been defined[7], professionals have become a vital part of Italy and freelancing has become a major job opportunity for the greater part of archaeological graduates. While the spreading of archaeology outside both protection (Superintendency) and research (University) institutions is a sign of greater collective

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[7] Since the creation of a professional register is no longer feasible, Legislative Decree 163/2006 simply indicates that individuals in possession of a specialisation or PhD degree are the only professional figures authorised to perform archaeological interest evaluations (VIArch), in addition to Archaeology university departments and authorised firms.

awareness of the importance in understanding and protecting the remains of the past, at the same time it takes us back to the introduction: i.e. the need to re-define the methods, time and procedures of archaeological activities and to adapt them to the opportunities offered by the digital world, especially as regards the circulation and spreading of information. Studying the past goes far beyond mere intellectual curiosity; it significantly affects the present and future world, not only in terms of a more conscious use of the area we live in. As stated by Vere Gordon Childe, an extraordinary representative of XX century archaeology: "I am an archaeologist and devote my time to trying to gather information about the behaviour of men long since dead [...]. Still I like to think that archaeological knowledge [...] may be useful to society [...], useful in helping to think more clearly and so to behave more humanely" (CHILDE 1962).

2. Acquisition of archaeological documentation

Fabio Fabiani *(DOI: 10.4458/8219-05)*

The progress of archaeological research is based on the direct access to archaeographic data since it is upon these data that circumstantial assumptions can be made or the problematic issues that nourish research can arise by constantly posing new questions. Since the traces around which archaeological investigation revolves only allow interpretations to be proposed, the product of our research must always be reconsidered globally in the light of new acquisitions; to do this, however, we must always go back to the raw data. These are obviously not original observations: a long time has passed since the 1970s when the echoes of the international debate promoted by New Archaeology reverberated in Italy. They gave way (initially in a number of environments and then in a more widespread manner) to a "scientific" approach towards archaeology and focused attention on the key importance of archaeographic data. Yet it is neither useless nor futile to reflect upon these issues since it is not always easy (as we will see) to return to the objective nature of data as a starting point for a new analysis.

We will present the work carried out for acquiring the archaeological documentation, as well as the criteria and procedures followed and the workforce used. The critical issues encountered when consulting the archives will be described, as well as the gaps and dissimilar quality found in the documentation. By drawing upon our direct experience, problems related to the accessibility and use of archaeological documentation will finally be considered.

2.1 Collection of archaeographic data

The creation of a digital archive for the archaeological data of Pisa and the periuraban area, which may be consulted through a web-GIS mapping tool, was mainly based on archive documentation and bibliographies.

In Italy, the current status of archaeological practice, whether developed by research institutions or cultural heritage protection authorities and whether performed directly or through cooperation with external professionals, shows that archaeological results tend to be published in delay. In many cases, the research results have been published several years after the end of the investigation or in some cases the information has never been published. Printed or electronic publications fully reporting primary data are rare, as also publications reporting stratigraphic sequences other than in the form of an interpretative summary. Very few publications attach stratigraphic diagrams, quantification of finds and the description of the methodological criteria adopted in subsequent periodised synthesis operations. Unfortunately, this practice is often accompanied by the failure to file all or part of the documentation produced during the research with the competent Authority. These evident shortcomings are also accompanied at times by limitations regarding the consultation of existing documentation; another associated problem is the fact that documentation is non-standardised, thus further restricting its use. On the one hand, therefore, we find incomplete publications, in which the interpretative part is often not sufficiently supported by adequate documentation, whilst on the other, difficulties in consulting the archive data.

On the basis of these considerations, various archives were examined and material already published was analysed for the area of study: the joined examination of the two sources, although each not fully exhaustive, allowed us to obtain an accurate inventory as possible.

2.1.1 Acquisition criteria

The collection of documentation was based on the following criteria:

No type of chronological selection of the archaeological source

One of the specific traits of urban archaeology and of research performed in multilayered centres is the opportunity to investigate the diachrony of complex stratigraphic sequences. This makes it possible to observe the city as it evolves, varies its constituent elements, and changes or maintains the functional purpose of its various parts, ultimately recognising its traits of continuity or abrupt discontinuity. The city's existing shape, which is the result of these transformations, becomes fully understandable within its historical scope. Since investigation aims at restoring Digital Terrain Models (DTMs) and reconstructing the city throughout different periods, diachrony represents one of the founding elements, allowing evidence of all historical phases to be collected, including modern and contemporary ages.

No type of chronological selection of the archaeological intervention

Information about finds without chronological limitation was considered: the most ancient information, retrieved from bibliographies or more recent documents, dates back to XVI century (only one piece of information). Information dating back to XVII century and XVIII is still sporadic and begins to increase from XIX century.

No selection of the archaeographic data

The acquisition of all the archaeological, drawn, photographic and descriptive documentation allowed us to critically verify the interpreted data. The search for primary data, of whatever kind, became necessary in order to acquire all the elements needed to review the information. Since we had already found discrepancies in previous works, we believed it essential in many cases to carry out a cross-check between the synthetic information (provided for example in excavation report) and the raw data. This is especially required when the person recording the data did not comply with the rules generally accepted or defined by the Istituto Centrale per il Catalogo e la Documentazione (Central Institute for Cataloguing and Documentation).

Analysis of indirect sources

Since the documentation related to archaeological interventions (maps, reports, photographs, catalogues) is often inadequate, so-called "indirect" sources were consulted which, nonetheless, contain informative elements. Indeed, information about minor interventions may be read between the lines of documents, issuing of opinions and authorisations, and ordinary or practical communications for granting discovery awards, which would not be otherwise documented: for instance, surveys that have not provided any archaeological evidence yet give a significant "no data" result; inspections carried out directly by Superintendency officials who note down measurements and the executors and chronology of works; the reporting of occasional discoveries of which only the finder's declaration remains. This is an important body of more or less detailed information, sometimes providing further elements to already existing but incomplete data.

A large number of excavations cannot be located in mapping terms but simply contain general city indications (name of road, house number, etc.) which are difficult to relate to a geographical coordinate. The need for highly accurate georeferencing of all archaeological evidence led us to seek sources that are not normally used. The collection of technical documentation connected to works that required or led to archaeological investigations, such as project plans, technical reports, etc., allowed us, in many cases, to have a mapping reference (relating to the land registry or Regional Technical Map) of the areas examined, representing a starting point for the georeferencing activities.

2.1.2 The archives

In order to allow access to state-owned archives, an agreement was defined with the project partner institutions and supporters in order to provide the researchers with all the information needed for the successful outcome of the activities. The documentation is mainly preserved in the Archive of the Soprintendenza per i Beni Archeologici della Toscana - SBAT (Superintendency for Archaeological Heritage of Tuscany) in Florence (Historical, Current, Graphic, Photographic and Plans Archives) and in the archive of Pisa. Another important source for information is the Archive (General and Photograph Archives) of the Soprintendenza per i Beni Architettonici e per il Paesaggio, per il Patrimonio Storico, Artistico ed Etnoantropologico per le province di Pisa e Livorno (Superintendency for Architectural, Landscape and Ethno-anthropological Heritage for the Provinces of Pisa and Livorno): the archive contains the finds discovered during the recovery and restoration of public and private constructions, from the medieval age to most recent years. The information may be found in the reports drawn up by the architects and/or works directors, and sometimes in the photographic documentation of the inspections conducted for ordinary control and protection activities. The greater part of the documentation contained in the archives of the two Superintendencies had already been collected for degree and PhD theses (ANICHINI 2005, GATTIGLIA 2010) and within the project for contextualising the finds of the archaeological site of the ancient ships of San Rossore, which SBAT commissioned to the Department of Archaeological Sciences (2007). Since the project did not envisage the acquisition of all excavation documentation, but only an initial cataloguing, filing and geographical positioning of the interventions, it became necessary for us to review the data already collected, acquire any missing data and fully examine the documentation regarding the most recent interventions, conducted after the previous work. At the same time, the Historical Archive and the Archive of the Opera del Duomo of Pisa were consulted: although the majority of data have already been published, information about old finds preserved in these archives could disclose data that so far have been overlooked, as well as maps or sketches. The deposits of the Soprintendenza per i Beni Archeologici (Superintendency for Archaeological Heritage) represent another source of information. Although our intention is not to specifically examine the preserved materials, it should be pointed out that the inventory of the boxes of material stored in the San Vito, San Matteo and via Santa Maria warehouses, contains finds from excavations that have not been documented.

2.1.3 Acquisition procedures

Given the heterogeneity of the type of data, various acquisition procedures were defined based on the actual need to transfer the data entirely or not. This operation was planned with a view to optimising the time and resources used, also in the light of future project implementation phases: entry in the database, creation of the WebGIS mapping tool and the Open Data archive.

- All documents not directly connected with the recording of the archaeological data (especially stratigraphic recording), but used as a source of information for some of the definition fields (maps, opinions, etc.) were directly filed (if containing simple or limited amounts of information) during consultation or were photocopied in order to be newly read and filed at a later stage. In cases where the document represented the only source of information for a certain intervention, it was scanned and preserved in an OCR searchable format in order to be subsequently entered in the specific database form.
- The drawn documentation of stratigraphic interventions and other kinds of intervention (pencil-drawn plans or plans finished with Indian ink) were scanned in original scale with 300 dpi resolution, archived and divided by intervention, for subsequent digitisation and georeferencing. Most recent digital printouts, mainly in .dwg format, were copied electronically.
- Context records were photocopied, scanned or, if already available in digital format (.pdf), acquired as an electronic copy.
- Regarding photographic documentation, prints and slides were scanned whereas digital photographs were copied electronically. All the material was processed in accordance with the privacy rules provided for by law.

2.1.4 Time and workforce

Acquisition of the documentation (as already mentioned partly carried out for degree and PhD theses) started on 1 August 2011 and ended during October 2011, although the Superintendency or specifically-authorised Superintendency assistants provided material up to mid-February 2012. A full-time collaborator was employed during the first two months and was joined by further two in October. They were supported by one of the team managers and were involved in defining the access procedures with the bodies and institutions that run the archives and in periodically checking the intermediate steps of the project. From the end of October, the three collaborators reordered the data collected and placed tags on each document acquired, in order to make its retrieval in the archiving system easier during the following work phases. Upon acquisition of the documentation, the bibliographical search was also updated and the information was classified in an archive. A fourth collaborator was involved from December who was involved in processing the archival and bibliographical data and implementing them in the database together with the intervention records. This final work phase finished in March 2012.

2.2 Critical issues

Difficulties were encountered during collection of the archaeological documentation, partly attributable to erroneous evaluations on our part, and partly due to "structural" difficulties related to the organisation of the archives and the access to documentation. We believe that reporting critical issues stimulates common debate, allowing users to become more acquainted with the services offered by the public administrations.

2.2.1 Consulting the archives

A series of practical problems influenced the work schedule of this phase. The bureaucratic procedures for the definition and signature of the agreement with the partner institutions delayed the start of activities to August when offices are usually closed for the summer holidays. The archives, furthermore, since operating with reduced staff, can only be accessed on certain days and during certain hours. Even retrieving the documents in the archives was not an easy task.

In the archive of the Superintendency for the Archaeological Heritage of Tuscany, for example, which contains the greater part of documentation regarding archaeological investigations, documents prior to the introduction of electronic protocol systems, are sorted in different archives in topographical order: the Historical Archive contains written documents; the Photographic Archive contains photos, slides, contact prints and negatives; the Graphic Archive contains a number of surveys (without any set procedures); the Maps Archive contains various attachments. Since the introduction of electronic protocol systems (in Florence in 2007; in Pisa in 2009), a number of documents (digital supports and written excavation documentation) are filed with the Current Archive in folders ordered by date of arrival and after a certain period of time are sent to the Historical Archive. Other types of documents are sent to the various archives according to a protocol order.

2.2.2 Gaps in archival documentation

Upon access to the archives of the Superintendency for Archaeological Heritage, a considerable percentage of documentation related to investigations (especially those during the 1980s and 1990s) carried out by Principal Investigators and executors belonging to Universities and the Superintendency or by their assistants, could not be traced. Although for some of these investigations it is possible to gather information from publications (only from the interpretative summary), for others, very few traces are available in accessory documents.

Given this situation, the contribution (highly recommended by the Superintendency itself) made by the MAPPA project consisted in tracing the documentation of previous excavations that did not exist in the archives and in listing the gaps found, thus helping the Superintendency to recover the missing documentation. As a result, the majority of documentation was obtained, although much of it was often incomplete, apart from documentation relating to excavations in course of publication. Data regarding certain interventions are still lacking despite repeated requests by the Superintendency to the Principal Investigators, some of whom state that they have already handed the data over. The Superintendency, therefore, provided us with the material it received, with the exception of material that is currently being studied.

Documentation pertaining to excavations in progress may be regarded as a side issue, since it is not available until the research is finished and the Superintendency has checked and validated the documentation. Nonetheless, the archaeologists involved in excavations (in agreement with the Superintendency) provided us with what we defined as "minimum data". The "minimum data" consist of a map showing the location of the excavation and a record containing key information: general type of find, general chronology and depth of reference.

2.2.3 Material acronyms

To have a full picture of the investigations performed in Pisa, the acronyms of the deposited finds were checked. Yet in this case also, data reading was at times challenging, given the absence of a centralised control for the acronyms used. The list by boxes of the material preserved in the Pisa warehouses reveals a very uncertain situation. The majority of acronyms can undoubtedly be related to interventions that are known through other attested documentation, yet sometimes there is no correspondence in years between the two different sources, with differences of one or even two years. In some cases, we may assume that the excavation was performed in various stages covering several years, and that the documentation, on the one hand, and the acronyms, on the other, refer to different moments of the same intervention. Sometimes acronyms do not have any chronological indications even when the excavations were performed on the indicated site in different years. At times, the same acronym is attributed to different interventions. Often, it was impossible to understand the acronym and determine which intervention it referred to: in this case, reference needs to be made to the oral memory of the people who worked on the site in those years. Finally, in some cases, the acronyms refer to investigations or recovery that are not attested anywhere else, and remain, therefore, the only trace of these interventions.

2.2.4 The quality of documentation

A further problem to be added to the difficulty in retrieving documentation is its quality and lack of standardisation. This depends on the different level of analysis (ranging from simple preliminary reports to partial communications and notices, and, ultimately, to integral publications), but also on the different people who collected the data (voluntary persons or professional archaeologists), on when the intervention was conducted and on the type of intervention, ranging from occasional recovery to preventive investigations and/or research (for statistical surveys regarding the variation of the quality of documentation in relation to other parameters see § 8).

In general, the passage from emergency and/or occasional actions, which dominated until the early 1990s, to planned actions, such as archaeological assistance and preventive excavations, adopted almost systematically from the early 1990s, inevitably led to an increase in the quantity and quality of the data produced, as well as to greater attention to the diachronic nature of the finds, especially to the post-classical phases. Drawn documentation is available only for interventions after 2000 and very sporadically during previous years. However, even in recent investigations, differences, at times strong, are still found in the quality of the documentation produced or delivered, which does not always include complete written, drawn and photographic production (context records, matrices, plans, phase plans, photographs and tables of finds). Topographic references are still lacking for certain interventions, despite the accurate recording of stratigraphic data, which is often correct and attentive. In fact, references to natural stratifications are often missing, which are important for reconstructing the environmental context in which human life developed; at times the description of a natural layer is provided but no interpretation on its origin is given or, instead, only an interpretation is provided – for instance, marsh or flood – without a description or any objective documentation. Finally, there are also cases that feature original forms of documentation, regarding both record items and "personalised" stratigraphic sequences: although it is important to keep alive the debate on methodological aspects and to look for new and better solutions, the rules defined by the Central Institute for Cataloguing and Documentation are the only rules that guarantee data comparability and a shared language.

2.3 Archaeological documentation: access problems

Preserving archaeological documentation in the archives of the Superintendency is the only way of guaranteeing that archaeographic data are not dispersed. The holder of an excavation concession must comply with the obligation to deliver the list of finds to the Superintendency within 30 days from the end of the excavation activities. A final report must also be provided at the end of the concession, providing accurate details on the outcome of the excavation, together with a scientific and descriptive report containing drawn and photographic documentation signed by the Principal Investigator and his/her assistants. Documentation relating to excavations supervised by Superintendency officials must obviously be entered in the archive. It is not acceptable for the only copy of excavation documentation to be held privately by the persons who produced it since this means removing a public good from the community. Even if the documentation is being studied and about to be published by the person who performed the research, a copy must be available in the Superintendency's archive. These considerations may seem banal and obvious, but it is important to draw emphasis on them because, as seen, a large amount of information is missing from the documentation available in the archives we consulted. We do not know the situation of archaeological documentation in other areas of Tuscany or in the Superintendencies of other regions and it may be wrong to generalise when speaking of Pisa. Nevertheless, this is an issue that must not be undervalued and should be regarded with great attention: the tools provided to ensure complete data archiving are evidently not satisfactory enough, if a large urban centre such as Pisa reveals such major weaknesses. The fact that these weaknesses regard not only past investigations, when the sensitivity towards archaeographic data had not reached today's level of maturity, but also interventions carried out recently, confirms that the problem exists and that it must be handled with particular care. The storage of documentation by private persons, especially if the former is not known to the Superintendency, carries the risk that the documentation may become lost, even accidentally or nonintentionally: the problem here is protection. Attempting to untangle the reasons for this situation is of no particular benefit and the performance of assessments and adoption of strategies and methods to remedy the situation certainly falls within the Superintendency's specific tasks.

Whilst a considerable part of excavation documentation cannot be found, another part, probably just as significant, cannot be used for project purposes since the principal investigators or executors exercise a right to study on it. The raw data can be "released" and made accessible only upon publication of the results. Yet, as pointed out by Andrea Carandini: "If I excavate a monument, it is clearly up to me to publish it within a certain number of years, but the map of that monument doesn't belong to me, not even for the amount of years I need to publish it. The map represents fundamental data of public interest, it belongs to society. If I die the day after, someone next to me has the right to know what I have found; everything is related and not knowing data modifies and compromises what we are doing" (CARANDINI, CARAFA 2011: 55-56). By pointing out the public nature of documentation, Carandini touches an issue that is particularly close to our project: the need to consult raw data in order to study the archaeological potential of the urban and peri-urban area of Pisa. As already mentioned, however, the majority of these data cannot be used because the investigations are still being studied.

Carandini's reasoning clarifies the terms of the issue by making a distinction between publishing an investigation and using its archaeographic data. Regarding the first aspect, i.e. publication, it appears reasonable that the person carrying out the research should publish it, although within a certain number of years (on the questionableness of the reservation of publication rights, TRABUCCO 2009). This is certainly a right, but also a duty: scientific communication and dissemination is adequate remuneration to the community that sustains the costs and discomfort of the investigations. Already during the mid 1960s, in the XXX Declaration of the Parliamentary Commission chaired by Franceschini, the issue of the right/duty to publish archaeological finds was addressed. A five year deadline was set and sanctions were established in the case of non-compliance: disciplinary measures for the official in charge, revocation of the concession and forfeiture of exclusive rights. Recently and in a less innovative manner, the Code of Conduct of the EAA, approved during the yearly meeting held in Ravenna in 1997, spoke of priority publication rights for project managers for a "reasonable" period no longer than ten years. By underlining the moral obligation to publish research data in the shortest possible time, the proposal of ANA's Code of Conduct (Article 5: "Duty to publish research results") establishes a new deadline of maximum five years from completion of the excavation, after which the archaeologist agrees to make the material and data in his/her possession available to others (CEVOLI 2007). The ministerial circular no. 11245 of 1 December 2008 (confirmed in circular no. 04 of 2010) lays down that all excavation directors and holders of research and excavation concessions throughout the country must prepare summary records of the works carried out for the "Fasti-online" website and for the related Fold&er review, on a yearly basis. Among the tasks assigned to concession holders: delivery to the Superintendency of a final report containing complete results, which will be followed by publication in highly well-known scientific reviews in the shortest time possible.

But how can the time needed to publish data be quantified? A standard rule does not appear to be followed or applied in practice, to such an extent that some investigations have still not been published after decades. No scientific community could possibly consider this a deolontologically correct practice, especially considering that it is not possible to consult the data required for the advancement of archaeology until a right of publication rests upon them. As Carandini sustains, there is no connection between the right to publish an excavation (regarded as the illustration of a stratigraphic sequence, study of the finds and historical interpretation of that sequence) and the consultation and reuse of the raw data quoting who has produced them. Consultation of the archival data is expressly indicated, together with other investigations, also in the rules contained in the Code of contracts and services for the preventive verification of archaeological interest during the preliminary project[1]. There are many opinions on this matter, some of which are highly divergent: the most conservative position believes that unpublished data should not be accessed, on the basis of a regulatory framework including (in a rather complex and sometimes unclear manner) copyright legislation (Italian Law 633/941), legislation regarding access to archives and EC Directive 2003/98/EC regarding data and reuse of data; however, the need for the total liberalisation of information, encouraged by use of the Internet, is becoming increasingly apparent. As shown in Civit (Independent Commission for the Evaluation, Transparency and Integrity of the Public Administration) Decision no. 105/2010, "total access implies access by the entire community to all 'public information', according to the concept of «freedom of information» of open government of US origin". The principle, which

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[1] Article 95(1) of Italian Legislative Decree 163/2006.

inspires the recent Code of Digital Administration and the Vademecum for Open Data published by the Ministry for Public Administration and Innovation, appears to be capable of steering the management of cultural heritage data in this direction. The MAPPA project intends to actively take part in the debate for defining the level of free data and to sustain the need for total access to data as a tool for scientific and civil growth (GATTIGLIA 2009; ANICHINI *et al.* 2011). The intellectual ownership of data must obviously always be protected, by quoting the executor and the principal investigator of the work that produced the data. To this regard, it would be interesting to start a debate on the opportunity to recognise the dignity of publication to the production of archaeographic data and to establish the procedures for their presentation; but these are new challenges for new goals.

3. Urban Archaeological Information System. Considerations and critical aspects

Francesca Anichini, Gabriele Gattiglia *(DOI: 10.4458/8219-06)*

The use of GIS software[1] and databases has become common practice in international archaeology and even the simplest functions of these platforms are becoming routine (although slowly) for the majority of archaeologists even at national level. This archaeological approach to IT has become crucial to our discipline because the relations required by the rationalisation of archaeological data are so many and so complex that only an archaeologist is able to organise them reliably and knows the general principles underlying data collection, whether direct or indirect[2]. The key importance of an archaeological structure entails transition from a *Geographical Information System* to an *Archaeological Information System* (GATTIGLIA 2011). What may appear to be a simple lexical artifice actually highlights the main aspect of a complex product that uses GIS software to steer towards archaeological practice[3], i.e. towards the archiving, management, processing and analysis of historical and archaeological data connected to a geographical reference system, thus basing itself upon the "integration between graphical representations and numerical mapping on the one hand and database management techniques on the other" (SALZOTTI 2005: 297).

To be truly productive, the AIS platform must be part of a network which, in addition to having hardware and software components, must gather archaeological "data, persons, organisations and institutional agreements in order to collect, record, analyse and distribute information" (FAVRETTO 2000:165). We are faced, therefore, with both IT and institutional aspects.

Within the MAPPA project, the former was developed through an integrated system involving different and specific documentation tools: GIS software, relational database, multimedia archives, and any form of data registration and presentation. The latter is represented by a relational network that handles documentation in a shared manner according to open standards also designed to acquire and spread data to and from the outside[4]. The main institutions involved were: Dipartimenti di Scienze Archeologiche, di Scienze della Terra, di Matematica dell'Università di Pisa (the Departments of Archaeological Sciences, Earth Sciences and Mathematics of Pisa University); Regione Toscana, Soprintendenza per i Beni Archeologici della Toscana (Superintendency for Archaeological Heritage of Tuscany), Soprintendenza per i Beni Architettonici,

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[1] "*Contrary to popular mythology, contemporary professional archaeologists may spend more time using GIS than a trowel*" (WHEATLEY, GILLINGS 2002: 10).

[2] It is important to consider that archaeologists must learn to manage data collected by others; suffice it to say that the great majority of archaeological interventions in Italy are not strictly related to research, but to preventive and emergency practices, especially in urban areas, which are often the training ground for professional archaeology. For this reason, we do not share the opinion expressed by VALENTI, NARDINI 2004: 343 (and confirmed elsewhere), that only the person who has collected the data is able to reliably reconstruct the relations required by the rationalisation of archaeological data. This is highly restrictive and would not only prevent further analysis of data collected by other archaeologists, but above all the professional development of archaeological practice.

[3] The introduction of this term is necessary to shift research interests towards the creation of AIS software. The same can be said for the acronym SITAR, intended as archaeological SIT (i.e. italian acronym for GIS). The English acronym shall be used here because already used internationally and also because it places greater emphasis on the archaeological aspect.

[4] Often defined as a "democratisation" process of accumulated knowledge (VALENTI 2009: 18), too often ignored (GATTIGLIA 2009).

Paesaggistici, Storici, Artistici ed Etnoantropologici di Pisa e Livorno (the Superintendency for Architectural, Landscape, Historical, Artistic and Ethnoanthropological Heritage of Pisa and Livorno), Direzione Regionale per i Beni Culturali e Paesaggistici della Toscana (Regional Directorate for Cultural and Landscape Heritage of Tuscany), and Comune di Pisa (the Municipality of Pisa (see Table 3 of the Appendix).

As opposed to many archaeologists who privilege the analytical-interpretative phase because they consider it the most noble aspect of archaeology, focusing on the archaeographic data management process (acquisition, recording, registration, and archiving of information from field investigations or laboratory activities) is a logical consequence in order for interaction and accessibility to perform and elaborate new knowledge. Raw data, which are essential for the following analysis phase, are increasing in number and quality and are at risk of losing their information potential: accurate registration is therefore essential. Since we are convinced that analyses come and go but data remain, the registration of all available data (ranging from most recent to most ancient and from detailed to superficial data) received special attention; an archive was created that can be used for future studies since it is continuously implemented and made available to users.

Data management and analysis, regarded as the digital processing of collected and archived samples, which directly increase available knowledge by combining conceptual, mathematical and spatial-statistical information, are the most evident advantages of IT applications. The possibility to produce knowledge through the use of GIS software is the most qualifying aspect of IT archaeological applications and, at the same time, one of the less-explored areas of this recent methodological topic (D'ANDREA 2003:335, VALENTI 2009: 16). This statement is even truer when we relate it to the archaeological study of Italian urban environments[5]: the past ten years have seen the creation of experimental archaeological GISs designed with different expectations and methods[6].

Very briefly, the potential of an urban AIS consists mainly in the capacity to manage a large amount of data (suitable for describing the complex nature of urban archaeology) and analyse them to obtain new and more in-depth knowledge and to develop effective predictive instruments. Related problems mainly regard the geographical scale to be used and data heterogeneity. An urban AIS uses an "intermediate" scale, half-way between a sub-regional territorial scale and the so-called GIS excavation scale. Territorial data (i.e. geomorphological, hydrographical and toponomastic data, etc.) must be added to the large amount of urban data, such as complex and diachronic stratification, existing and no longer existing buildings, road systems, the assumptions of historians and archaeologists, etc. An urban AIS solution, paraphrasing D'ANDREA 2003, must feature a more complex critical and methodological path than that used for an archaeological excavation GIS. An urban AIS must combine inter-site analysis – characterised by Boolean overlay of theme maps and calculation of the statistical correlation between environmental and/or social information and the sites – with the typical resources of an excavation GIS as well as predictive mathematical analysis. The complexity and heterogeneity of the data required for an urban AIS tool makes it more difficult to choose a data model that is capable of translating the drawn

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[5] This chapter does not intend addressing the development process and problems of urban archaeology in Italy, for which reference may be made to BROGIOLO 2000, GELICHI 1999b, CITTER 2007

[6] A general consideration that draws together the threads of this experience and highlights both the potential aspects and problems is still missing. See, for example, the Tuscan cases of Florence (SCAMPOLI 2007), Grosseto (CITTER 2007), Pisa (ANICHINI 2004-2005, Gattiglia 2011) Siena (FRONZA, NARDINI 2009), the C.A.R.T. system of Emilia Romagna (GUERMANDI 2001, GUERMANDI 2011), as well as Bologna (PESCARIN, FORTE, GUIDAZZOLI, MAURI, BONFIGLI 2002), Faenza (GUERMANDI 2000, GUARNIERI 2001), Forlì (PRATI 2001), Modena (CARDARELLI, CATTANI, LABATE, PELLEGRINI 2001), Parma (BIGLIARDI 2007), Ravenna (http://www3.unibo.it/archeologia/arcmed/progRa.htm) and the SITAR project of Rome (SERLORENZI, edited by, 2011).

and alphanumerical documentation that describes the archaeological context, without loss of information. The use of an 'intermediate' scale involves complex choices to assign a correct graphical representation (i.e. the use of geometrical primitives for the vectorial reproduction of objects) to data capable of highlighting the spatial distribution of the urban 'objects' and their chronological succession. Finally, an urban AIS must be able to bring together multi-temporal and multi-scale archaeological data in one working tool, thus solving problems regarding, on the one hand, the digital conversion and geo-referencing of excavation data acquired at different times and with different scales, and, on the other, the integration and overlapping of information obtained with different techniques and, therefore, with different reliability and topographic accuracy. The implementation of an urban AIS is an extremely burdensome operation, in terms of both economic and intellectual resources, since the structure and formalisation of information go beyond traditional data registration and organisation practices.

The AIS platform is a GIS platform for archaeological purposes. Its main features are:

- architecture based on a data model;
- management of geometrical data described by lines, points and surfaces;
- ability to geo-reference all the data registered in the database;
- ability to characterise all registered data through attributions;
- thematic and spatial search potential;
- spatial and mathematical-statistical calculation potential.

Its principal functions are:

- information archiving and processing;
- support for analysing and taking decisions or planning interventions;
- production of information and data reading (ISABELLA, SALZOTTI, VALENTI 2001:33)

Regarding the acquisition of data within the AIS platform, the following criteria theorised by NARDINI 2004: 365 ss were referred to:

- global data entry;
- objective digital translation;
- creation of a functional data model;
- faithful and graphically reliable reproduction.

As already seen, the urban environment can only be reconstructed if all its components are used; it is wrong to make an interpretative selection of data because this would diminish the platform's functions both as an archive and data processing tool. Global and accurate data must be entered, from both a geographical and archaeological viewpoint, to allow accurate queries and processing, and so reduce the researcher's subjectivity. Unlike excavation GISs, in which no sort of interpretative process must be made when entering data (VALENTI, NARDINI 2004: 347), in this case, the entry of data linked to interpretations of the urban fabric provided by previous experts requires the need to make compromises: these data are an essential working tool when, owing to topographic reconstruction purposes, the correct representation of a hypothetical building or hypothetical segment of walls is no less important than reporting one that actually exists (NARDINI 2004: 366).

In order to construct an open model suitable for registering such a large amount and variety of data, a structure is needed that takes into account the intrinsic features of the data's logical coherence and geometrical identity, and that respects the special features of the items entered (VALENTI, NARDINI 2004: 348). When implementing the AIS MAPPA platform, we decided – in analogy with SITAR (CAMPANA 2011: 44) – not to use symbolic representations when entering the data, acknowledging the material consistency of each evidence represented through polygon graphs. The use of point representations was thus avoided[7]. This choice reduces the interpretative aspect of the archaeological process: only what can be reproduced as a polygon can be reported; distinctions can be made at the level of attributions, by assigning codes of reliability rather than by differentiating the primitives. Linear representation was employed to reproduce

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[7] Since every rule has its exceptions, point representation was used only in certain specific cases, such as the vectorialisation of place names.

elements with accurate spatial location and specific routes, such as water courses and road systems.

Whilst correct geometrical attribution easily solves problems related to the objective digital translation of data (finds, buildings, roads, etc.), the same cannot be said when entering data that have already been interpreted. They are translated geometrically and not as simple attributes; an objective digital translation is maintained by making the same topographic element appear in two different manners: in the first case, real data are reproduced, whilst in the second, interpreted data. When this information is typologically similar, but taken from sources with different reliability, this diversity is pointed out by assigning reliability codes, rather than using typological differentiation.

A further problem regarding the geometry/type relation arises from the fact that cities continue to build on the same space. This leads to repeated changes to a building's use and to its shape. A building used for religious services in the Medieval age, may have been employed for public use over later centuries and today be used as a house[8], or, although keeping the same definition and function over the centuries, may have slightly changed its perimeter or interior space[9]: in the former case, links were made to the relational database, in the latter, two geometrical entities were drawn with separate attributes.

3.1 Archaeological map or archaeological information layer? Not simply a semantic issue

The logical and conceptual structure of MAPPA is essentially based on the dichotomy between objective and interpreted data and between data and information: more simply, in archaeological terms, between archaeography and archaeology. Although these two aspects are complementary, they are given unequal value, since the former has precedence over the latter: the former can exist without the latter, whereas the latter needs the former to exist. Archaeological information is more credible, the more transparent and accessible archaeographic data are. Many information layers may be developed within this structure, each with its own specific features and meanings, freely created from the aggregation of spatial information produced for exploring a determined specificity.

With this view, an archaeological information layer is the dataset that allows us to analyse the archaeological data already known and that at the same time deals with the spatial recording of all these data, of utmost need given the enormous amount of data produced. In semantic terms, therefore, the layer includes the archaeological information (which contains the archaeographic data from which it is derived) to which we attribute a greater capacity to last in time (which continues nevertheless to decline). We attribute, therefore, the ability to generate knowledge – both intrinsic and combined with other levels – to the archaeological information layer, i.e., to support new assumptions and/or interpretative syntheses, which use at the same time primary information and information already filtered by one or more researchers.

The idea is a structure continuously on the move, a varying background that changes aspect each time a survey or research result is added and automatically sheds new light on the information already available.

Within this context, the concept of archaeological mapping appears to be inappropriate, since its static paper-based nature is not able to adequately represent either the ongoing production of archaeological data or their topographic consistency: rapid data flows require greater virtual spaces (which must be real given their weight on our lives) in which the data may be aggregated in various ways. There is an obvious need to immediately update the archaeographic data and make the static nature of archaeological maps an *ante*

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[8] For example, the church of San Pietro in Palude, subsequently dedicated to Sant'Omobono and currently used partly as a house and partly as a restaurant.

[9] For example, the church of San Rocco, formerly San Pietro in Cortevecchia.

quem instrument. The idea that archaeological maps combine the presentation of spatial data with interpreted data related to the historical/archaeological reconstruction of urban and/or territorial settlement variations is no longer sustainable. Individual archaeological finds are key but are not sufficient: further information layers need to be added, such as paleo-environmental information, written and mapping sources, previous studies, etc. The aim is to create a flexible architecture which does not propose interpreted reconstructions but allows users to make information interact and contribute to describing the "city" while historically evolving and to transforming the archaeological information layer into a professional or research tool.

[G. G.]

3.2 An idea, a concept, a structure. Logical architecture

The archaeological information layer includes features that are inherent to the nature of the data/information composing it:

- Objective and transparent data management, both from the point of view of geographical translation and attributions;
- Contemporary reading of heterogeneous data produced in different moments and with different procedures;
- Complete acquisition (both theme-oriented and chronological) of data/information including buried archaeology, building archaeology and archaeological reading of air photo-interpretation traces.

The greatest difficulties encountered were synthesising the archaeological data produced over time, and making them consistent. This especially regarded data related to buried archaeological deposits, since the collection of building archaeology data (which will integrate the level in a subsequent upload) and air photo-interpretation traces (see § 8), was specifically performed for the project.

Considering the various typological cases, three main problems may be noted:

- Heterogeneity of the source of information;
- Dissimilarity between the chronological parameters adopted;
- Heterogeneity of terminology in the definition of classes and type of finds.
- Heterogeneity in the definition of spatial location.

The heterogeneity of sources and of a language (that has moved from "picturesque" to scientific over five centuries of archaeological recording in Pisa), necessarily led to a work of lexical categorisation, leading to the creation of an ontology. In some cases, the work required a strenuous interpretation of the archaeological culture of certain periods[10], as well as the need to redefine outdated chronological categories according to modern parameters. In order to integrate all the data and avoid the drawbacks due to the strong inconsistency of the above elements, we decided to follow a line of approach that, although arbitrary, took into account the indications provided in the "*Linee guida per la redazione della Carta Archeologica della Toscana* (Guidelines for drawing up the Archaeological Map of Tuscany)" (FRANCOVICH, PELLICANÒ, PASQUINUCCI 2001: 182-198) and the solutions already tested and adopted in research work on Pisa[11] (ANICHINI, 2004-2005; GATTIGLIA 2010; GATTIGLIA 2011), thus developing an archiving structure structure based on our research needs.

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[10] The data collected by various researchers can be compared only by taking into account their intellectual history and individual background (TERRENATO 2006:19); data grow old and it would be better to make them available at once, without seeking perfection, when the scientific community is in greater methodological harmony with whoever has produced the data (GATTIGLIA 2009: 56).

[11] The database represents the development and further study of a previous project aimed at implementing the first step towards the development of a GIS for the city of Pisa, resulting in the degree thesis of Francesca Anichini, entitled "Tutela, Ricerca, Valorizzazione del patrimonio archeologico: progetto per il G.I.S. della città di Pisa" (Archaeological heritage protection, research and enhancement: a project of a G.I.S. of the city of Pisa) (ANICHINI 2004-2005; ANICHINI, PARIBENI 2005). A database was created during the project which contained diachronic archaeological data only and was already based on the minimum spatial unit of the archaeological

We decided to handle sources equally: source information was synthesised with the minimum unit attributable to the *archaeological intervention*[12], regarded as a single archaeological activity of any type according to a continuous spatial unit (e.g. a work resulting in different and non adjacent excavation trials is divided into an amount of interventions according to the number of trials). This definition includes all information regarding buried archaeology, whatever its provenance: information from occasional finds and stratigraphic excavations, thus overcoming the contrast between data quantity and quality. By using varying relational levels of complexity, it is possible to move from interpreted data to raw data. While *archaeological intervention* represents the minimum unit of reference (which at the same time corresponds to an identifiable geographical position[13]), Context – with relevant records and material quantification – is the item of evidence with greater detail that needs to be managed in the archiving system. The aim is to make the highest and lowest level of information communicate in the same environment and, therefore, interact in a dynamic process of comparative analysis.

An intervention is objective when it corresponds fully to its spatial characteristics and attributions (Who? How? Where? When?), which are not subject to interpretation. In this case also, it was necessary to overcome the limitations represented (in the sources) by the use of different indicators for the spatial (and mapping) positioning of interventions. Since it was not possible to arbitrarily intervene on the inaccuracy of a spatial reference, which would have required entry of a subjective parameter and a discrimination that could no longer be recovered at a later stage, we decided to connect an attribute with the polygon graph (see §4), so that the user could immediately perceive the level of accuracy obtained from the source.

Transparency, instead, consists in re-proposing data with the same collection methods and streamlining the Superintendency's archives and the implementation of new data. Objective data and interpreted information are presented in different parts of the structure, so that users may trace the investigation process and validate or less the interpretation provided on the basis of their own experience. The system's maximum potential is expressed in the relation with the open data archive; however, it also provides a simple function to users: a rather old-fashioned but practical list-directory function to receive information on data available in the Superintendency's paper archives.

The problem regarding the inconsistency between the chronological parameters adopted in the sources was addressed on the one hand, by using a chronological classification with the widest diachronic coverage as possible (from prehistory to contemporary ages, which also includes the present day) and, on the other hand, by using accurate chronological parameters. The latter were defined on the basis of *thesauri* managed both as external tables linked to fields of reference, and as absolute and validated number

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intervention. The database was developed according to an open structure, making it a "container" of smaller units. Archives suitable for containing the description of the urban fabric were not created; however, given the large amount and heterogeneity of the data, they were collected in a single archiving system for the first time. The questions that guided the implementation of the database were essentially: Where? When? How? What? Easy questions, but necessary for building the foundations of a search that opens the door to many different opportunities and various levels of investigation (ANICHINI 2004-2005: 85). Practically: the location of finds in Pisa; intervention dating, i.e. the date of execution; quality, that is, the type of intervention; and, finally, the type of find, focusing on two sets of information: chronology and detailed type of find. (ANICHINI 2004-2005: 87).

[12] The decision to choose the Intervention as the minimum unit will also be used for the open data archive. This choice allows data to be updated more easily after the initial entry phase. This is the same criterion used by SITAR and by the Archaeological Data Service of the University of York (http://archaeologydataservice.ac.uk/ last access 20 April 2012); for a different position, based on historical topography, see FRONZA, NARDINI 2009:68

[13] Not necessarily univocal; several interventions that have taken place over the years may refer to one location.

fields (corresponding to an *initial date* and *final date)*, in order to define a highly accurate chronological context.

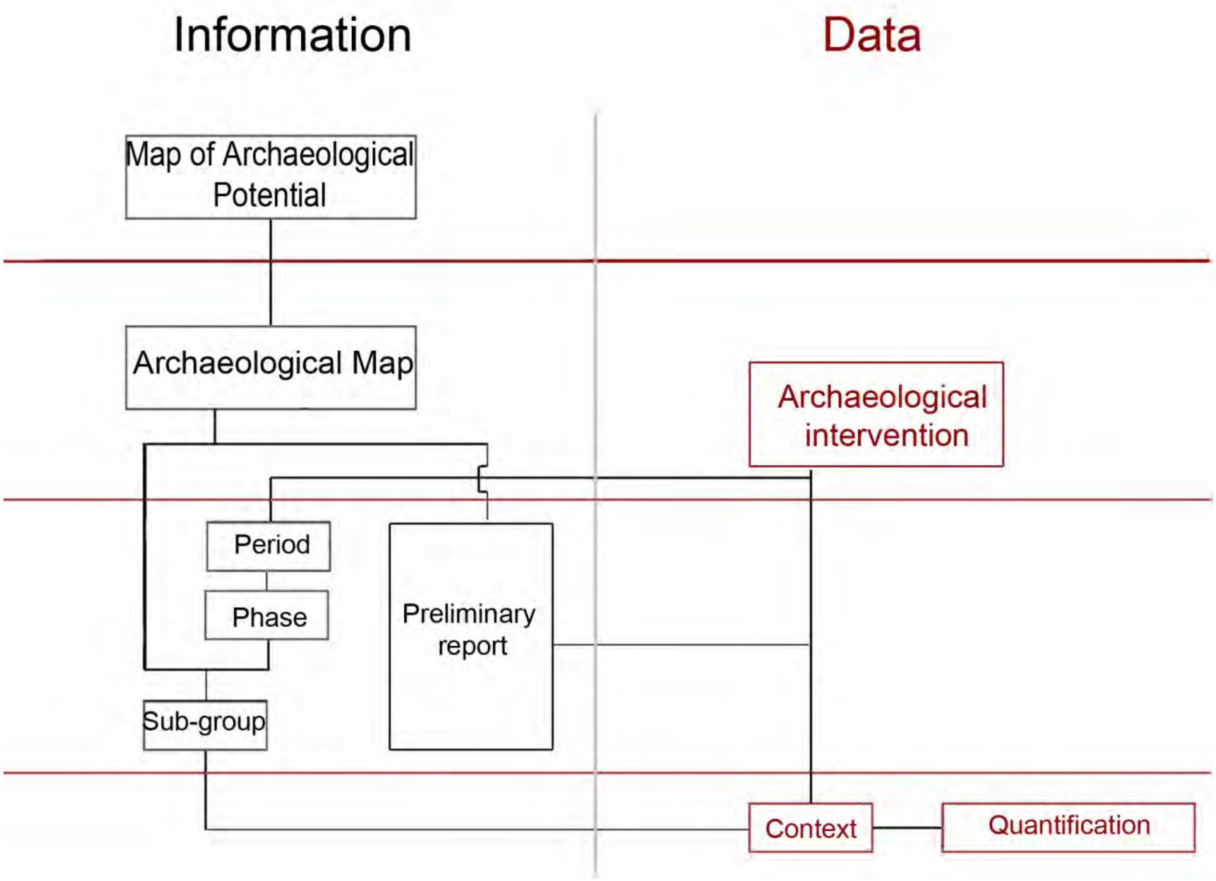
The heterogeneity of the terminology applied to the type of finds was also managed by defining *thesauri;* in this case, they were implemented and managed as external tables linked to the reference fields (see §4).

The problems described above were solved by creating an operating scheme based on four different logical levels that gradually manage information through an interpretative synthesis process. The process, starting from the material traces, transfers the data into typological and chronologically-divided macro categories. The diagram (Figure 3.1) that synthetically describes the levels and relations between the elements which contribute to defining the information potential of each intervention, starts from Level I which includes the primary data (Context and Material Context records, quantification records of mobile artefacts).

This level is available only for certain types of intervention and, among these, only those performed recently and for which documentation has been preserved. Primary data are faithfully reported in detailed records in order to reproduce the entire stratigraphic sequence (see §4).

Level II of the diagram contains data referring to the interpretative synthesis phases carried out by the authors of the work: description of Groups, Phases and Periods for the excavation data; reports or simple accounts of interventions for which we have no other kind of documentation.

Thanks to this second step, information drawn up very differently can be processed using the same



3.1 The diagram summarises the logical structure divided into 4 different and subsequent synthesis stages (bottom-up approach) and into data (non interpreted) and information (data interpretation).

method. Every document is recorded and catalogued using pre-defined and common criteria, thus representing a first link between heterogeneous sources. Level III contains Level I and Level II disassembled data. The following are taken into account: general details of intervention, information source, geographical reference, and reliability of data and additional information which allow their description and classification by single find. It is at this point that we encounter data produced and recorded with very different methods. The researcher must review and interpret the data and actively work on synthesising and classifying the data. The archaeological finds need to be classified in order to standardise them and allow their comparative analysis. While during the first two stages the researcher's work is to catalogue, computerise and partially review the documents, during the third stage the researcher directly converts them into standardised categories of archaeographic and archaeological data. This is a difficult step mainly because of the need to interpret poorly-detailed information which either describes very general material traces or provides an interpreted term without specifying its origin in the material traces. A critical review of the data unavoidably follows, which includes overall analysis of the intervention in terms of period of execution, type, executor's features, etc., which determine an overall level of reliability of the information acquired. The data standardisation process is structured along four levels of synthesis which allow the information to be analysed according to various levels of investigation in both spatial and conceptual terms (see § 4). Every trace is gradually related to four categories: the first defines the typological-qualitative component, the second defines the typological-functional component, while the third and fourth categories define the role of the specific datum within a broader system of spatial relations according to two different interpretations: local and urban.

At the same time, data that are not strictly archaeological data are processed using the same method. Level IV is part of a highly flexible and implementable architecture and represents the dialog box of all information levels. This level focuses on analysis: the classified data are compared and can be subject to processes for developing and creating new synthesis information.

The completeness of the data acquired is a fundamental principle of architecture, in spatial terms (collection of data available for the area under examination), in methodological terms (all types of interventions, including the study of buildings, specifically carried out for the project), as well as in diachronic terms. The need to work with a large amount of data, as complete as possible, led us to collect data from different types of sources: published archaeological data, archival archaeological data and unpublished archaeographic data. Where accessible, we attempted to privilege raw data since we are convinced that an appropriate archaeological synthesis can be performed only by tracing the primary source. This activity pointed out that heterogeneity is not always and only related to the "date" of the intervention (see § 8). Data completeness and the methods used for recording information are key factors when establishing an information reliability parameter. This parameter is necessary to adequately measure and weigh the information potential of a record during the subsequent comparative data processing phases, which the project must carry out to determine archaeological potential.

The synthesis process developed in the four levels described, transforms primary archaeological information into standardised categories which directly contribute to the calculation of the archaeological potential. This is a very delicate journey because it has a direct impact on the analyses and on the historical-archaeological and mathematical considerations that lead to the achievement of the final project product. Although we have designed an archiving system that attempts to reduce these problems as much as possible, we believe it essential to include a field that evaluates, with clear parameters, the overall reliability of data categorisation.

Since the source, intended as the archaeographic documentation of the intervention, was considered the crucial issue, we created a table for evaluating the documentation of every intervention, through a set of simple steps previously defined in order to encode operators' criteria and make them as objective as possible. The starting point was based on the assumption that the greater the amount of documentation, the greater the reliability of the information. Complete documentation allows more accurate checking and understanding of the raw data, as well as greater reliability of categorisation and more effective synthesis. (ANICHINI *et alii* 2012: 17).

Building archaeology was managed separately with respect to data archived as interventions. The basis of this decision was twofold. On the one hand, it is fair to recognise the specific nature of this discipline, whilst on the other hand, the number of interventions related to recorded buildings is extremely low[14]. For this reason, we believed it necessary to investigate the area under examination starting from zero. Previous interventions were taken into account and relevant information was placed in the same information level and logical structure to enable full interoperability between different data. The diachronic analysis of the buildings, structured in the first three levels of the system, allowed us to obtain a data set that may be fully integrated with other information level items[15].

Likewise, the results of air photo-interpretation trace reading – carried out both from a strictly archaeological (see § 9.1) and geomorphological (see § 9.2) viewpoint – were organised.

[F. A.]

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[14] The reason for this probably lies in its specific nature (as mentioned above), which is not always understood by archaeologists and heritage protection institutions, as well as in the fact that it is a recent discipline.

[15] The structure and results of this analysis will be described in a forthcoming contribution within the MapPapers.

4. The digital archiving structure

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The electronic archiving structure transforms the conceptual and logical framework, described in the previous chapter, into files, reports, tables and links, with the aim to manage and organise the wide range of data/information from different disciplinary fields. For this reason, the structure was designed and implemented directly by archaeologists, geologists and mathematicians. A granular archive was conceived, based on (tabular and non-tabular) datasets[1], managed through RDBMS, GEOdatabase or DAM[2] and organised in homogenous databases by type. High overall granularity allows continuous implementation of data and the production of a large amount of information; it also reproduces the researcher's rational process of logical-deductive analysis, thus extending beyond the project's goals and reusing the archived data for further purposes. The single datasets can thus be aggregated and disaggregated in many different information layers, making it possible to describe different aspects of reality each time. The archaeological information layer proposed by us includes datasets related to sub-surface archaeology, together with datasets regarding building archaeology and datasets related to aerial archaeology. Buried archaeology datasets, aggregated with geomorphological datasets, could form a geo-archaeological information layer, whereas buried archaeology datasets, together with building archaeology datasets and historical mapping datasets could generate a post-medieval information layer, and so forth. Archaeological information layers, therefore, do not have a pre-established and pre-ordered structure but an aggregation of data, chosen to describe the archaeological environment within the area examined.

The main datasets contained in the electronic archive may be summarised as follows:

- Subsurface archaeological dataset
- Building archaeology dataset
- Aerial archaeology dataset
- Geo-archaeological dataset
- Sedimentological/stratigraphic dataset
- Geomorphological dataset
- Hydrographical dataset
- Topographic dataset
- Historical mapping dataset
- Dataset from written sources

4.1 The MAPPA RDBMS

The relational database (RDBMS) has a structure that reproduces and interfaces with the general archive structure and with the vectorial data managed by the AIS platform (see. § 4.2), based upon a series of fundamental principles:

- Creating a container that allows the greatest possible amount of information with partially inconsistent features to be registered;
- Containing the greatest possible amount of information so that the consultation and analysis activities may take into account all the data collected and produced from the search;
- Being provided with an open architecture which can be easily integrated both in terms of data implementation and structure modification, if necessary;
- Allowing different use according to the user's computer literacy through implementation of a user-friendly interface (ANICHINI *et alii* 2012).

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[1] http://en.wikipedia.org/wiki/Dataset

[2] http://en.wikipedia.org/wiki/Digital_Asset_Management which contains all the documents acquired and archived: written documents, drawings and photographs.

The software chosen was the proprietary product: Microsoft Access. In order to understand the reasons for this choice, it should be remembered that this research project is the continuation and further evolution of a previous project (ANICHINI 2004-2005; ANICHINI, PARIBENI 2005; GATTIGLIA 2010), already developed in Windows environment with the same proprietary software, which was chosen for a series of reasons briefly summarised below[3]:

- compatibility with other software, especially ESRI ArcGIS;
- compatibility with software used by other institutions: Dipartimento di Scienze Archeologiche (Pisa University), Soprintendenza per i Beni Archeologici della Toscana and Comune di Pisa;
- greater knowledge of this software by the research team[4].

4.1.1 The archaeological database[5]

The archaeological datasets managed within the RDBMS regard subsurface archaeology, building archaeology and aerial archaeology. These datasets interface with both the vectorial data managed by the AIS platform and the directories specifically organised in the digital archive within the file server. They are structured so as to carry out the double role of archiving and analysing the data and of categorising them for the predictive calculation of archaeological potential (BINI D. *et alii* 2011; BINI D. *et alii* 2012).

The RDBMS architecture is based on a series of tables linked to each other. The tables contain the archived data and the *thesauri* or lists of values necessary for filling in certain fields in guided mode. The data tables have a user-friendly form, which allows easy entry of data and rapid navigation among the forms. The forms are grouped into two different user interfaces: the first, where the forms show all the fields of the data archiving tables, specifically addresses data entry operators (administrators); the second, where the forms mainly provide query results, specifically addresses users consulting the database.

The tables, called *thesauri*, have accessory features and are used by the RDBMS to standardise the language used. It is essential to normalise the language of a database, especially as regards the synthesis fields, in order to use the data. Non-standardised language can lead to inefficiencies that can also make the collected data completely unusable. The legibility and interpretation of a database highly depends on the formal clarity and completeness of these instruments. Basically, when designing a relational architecture, great effort must be taken to create an efficient database (FRONZA 2004: 415). *Thesauri* are divided into:

- closed *thesauri*, with values that cannot be modified by the searcher, referring to dictionaries with a very high level of language processing, such as that used to regulate chronological periods. In some cases, they also include the value *other* to help the operator in the event of missing items.
- open *thesauri*, which do not apply restrictive control to language and allow the operator to overcome any restrictions by automatically updating when entering data. These *thesauri* have been adopted for fields for which it is not currently possible to establish a univocal set of values. These dictionaries tend to gradually change into closed lists as the reliability of the sample increases (FRONZA 2004: 416). Open *thesauri* can also be used for data that, given their nature, cannot easily be used for closed lists: for example, fields containing the name of the Principal Investigator or the individuals performing the investigation.

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[3] The discriminating factor when evaluating the best software for creating a DBMS is the software's capability to manage archive complexity and its compatibility with the applications it must communicate with (GABUCCI 2005: 32)

[4] We decided that it was preferable to develop the project by using the software that the majority of research team members could easily use, with a view to optimising DBMS development and implementation with respect to the main research objective and the strict project schedule. Transfer of the RDBMS onto an open-source platform is part of the project's long-term secondary activities.

[5] For a thorough analysis see (ANICHINI *et alii* 2012).

Thesauri may be used on their own or organised hierarchically along levels to form an ontology, for instance, the categorisation of anthropic and natural traces (see § 4.4 and Table 1 Appendix).

4.1.1.1 Intervention record

A record was prepared drawn on the idea that the archaeological intervention is the minimum common denominator (see § 3.3), i.e. the minimum item of reference for the topographical management of buried archaeological data. The record highlights the basic features and information by identifying the main characteristics, type and chronological setting of the finds, as well as the source of information. The guiding principle of the intervention record was to provide the system user with information items that did not have a high degree of synthesis, allowing specific data and further details to be obtained and ensuring reference to specific documentation available (from lesser to greater detail).

The record contains:

- "Technical and topographic" data related to the intervention: topographic parameters, type and methods of execution, names of executors and Principal Investigators, and chronology.
- "Chronological" data referred to wide-ranging periods: Pre-history, Protohistoric age, Etruscan period, Roman period, Late Antiquity[6], Early Middle ages, Late Middle ages, Modern age, Contemporary age, non identified.
- Data regarding intervention-related documentation: in the event of stratigraphic interventions, indications are only given on the presence or absence of different types of documentation (written documentation, drawings, photographs) which are separately detailed in the Location Record (see § 4.1.1.2.).
- Data regarding the primary "source of information" used for filling in the form, i.e. the source that provides the greatest amount of information. Sources may be archival (*Firenze - SBAT (*Superintendency for the Archaeological Heritage of Tuscany*), Pisa - SBAPSAE (*Superintendency for Architectural, Landscape and Ethno-anthropological Heritage*), Pisa - University, Pisa Archivio di Stato - ASP (*Pisa State Archive*); Pisa Archivio Opera Primaziale*), and in this case the relevant protocol number, type of existing document and name of the official of reference is reported, or bibliographical; where complementary, both may be present.
- Drafting data which indicate both recording date and compiler(s).

4.1.1.2 Tables related to the Intervention Record

The table is linked to other 5 tables which specifically take into consideration several sets of information: georeferencing, description, location, bibliography and documentary references.

The **Georeferencing table** provides data on the reliability and degree of accuracy of vectorial georeferencing, as well as the basis and scale used.

The **Synthetic description** table briefly describes the type and chronology of the finds relating to each single intervention, processed by the researcher on the basis of available data (primary/raw or interpreted). Given its more interpretative nature, it is separated from the Intervention Record to which it is directly related.

The **Location** table links all existing documentation both inside and outside the database, and both in digital and analogical format, thus providing information about the physical location of the documentation and finds. It includes written, drawn and photographic records and information regarding mobile artefacts.

The **Bibliography** table provides details on the bibliography related to the intervention to allow more in-depth study.

The **Documentary Reference record** integrates the link to the main document used for the archiving and full digital version of the document used for data entry, allowing direct comparison between the synthetic data and the original source.

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[6] Intended as the "late Roman" period (see § 6.1).

4.1.1.3 Excavation documentation

The RDBMS also contains the excavation records in digital format. These tables faithfully reproduce the archaeological record which progressively describes the stratigraphic sequence of an excavation. The archive is divided into:

- Tables related to the chronological and interpretation stages of the excavation (Period, Phase, Group);
- Tables related to the stratigraphic data (Context/Masonry Context);
- Tables related to the artefacts.

The **Context Record** table contains nearly all the items of the Ministerial paper Context record with the exception of artefact-related data which are taken from a query between the "Context Record" table and the "Quantifications" table[7]. "Subtype" and "Synthetic interpretation" have been added; these entries are useful for searching in the archive with a standardised common field both as regards material source definition and interpretation. Both fields are linked to open *thesauri*, whereas the fields "distinction criteria", "method of formation", "consistency" and "status of preservation" are linked to closed *thesauri*[8] (ANICHINI *et alii* 2012: 9ss). The **Context Record** table is the item required for linking to the Context maps of every excavation in GIS environment.

The **Context Record** table is directly linked to the **Group, Phase, Period** and **Quantification** tables. They provide a brief description, synthetic definition and dating, and are related to each other and to the single contexts they are formed of. A synthesis field was not included because an effort of this kind was considered unproductive at this level of the interpretative process, where the definitions are strictly limited to the circumstance of the find and may have a very wide scope. The terms of comparison are of a chronological nature and can be analysed through numerical searching in the dating fields.

The **Quantification Record** table was conceived to quantify the ceramic materials found in the single Contexts. Type is the main field, in addition to function, production, shape, decoration, initial date and final date. The quantification record is linked to the **Context_Dating** record that allows automatic dating of the Context based upon the dates of the material classes available. This dating, however, is not binding and is proposed to the operator who can decide whether to accept or change the proposed dating.

4.1.1.4 Building archaeology

In order to file building archaeology[9] data, we described the data of the city in its current state. Every building was entered in a table called **UAU** (Urban Architectural Unit) **Record**, in which the following data are archived: name of the building, its current function, type of construction, initial and final chronology, first evidence and/or bibliography regarding the unit. The UAU Record is linked to the **CA** (Building Complex) **Record** and **CF** (Building) **Record**. The former includes fields related to the name of the building, function, construction type, initial and final chronology and description of the building, the latter describes the function, construction type, and initial and final chronology. Both are linked to the **Front Record** and **Building Phase Record.**

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[7] The fields corresponding to Masonry Context record entries can be directly filled in. Since a ministerial defined record is only partially available (http://www.iccd.beniculturali.it/index.php?it/251/beni-archeologici) for recording this type of evidence (stratigraphic reading of buildings), we are working alongside experts of this sector who belong to the project team in order to create fields and connected *thesauri*.

[8] For all Record fields for which specific changes have not been made (except for strictly IT-related issues), please refer to the indications provided by the ICCD on how to fill in Context records http://www.iccd.beniculturali.it/index.php?it/251/beni-archeologici.

[9] Building archaeology activities were specifically carried out for project purposes, consisting of the analytical filing of information regarding the area under examination. The filing system was designed together with Mara Febbraro and Fabiana Susini, who dealt with the study of buildings. The detailed analysis of this work, together with presentation of the data, will be taken into consideration in a forthcoming publication.

The former provides brief details and links to the drawn and photographic documents, whereas the latter describes each single construction phase in greater detail, through fields regarding construction materials, laying, building techniques, chronology, and description of brackets, putlog holes, supporting arches, portals and windows. It is also possible to connect to the **Context Record** table and reach each single Masonry Context.

4.1.1.5 Aerial archaeology

The description of each single trace identified from reading of the aerial photographs (see § 9.1) was archived in the **Trace record**[10] on the following fields:

- trace, free text field which provides a univocal ID code for each single trace;
- photo, free text field with ID code of photo(s) in which the trace appears;
- hypertextual link to the photo in the digital archive;
- institution, free text field
- availability, text field
- retrieval of inventory number, text field
- retrievel of negative number, text field
- flight, free text field
- date, date/hour, with flight date
- flight altitude, number field expressed in metres and reporting the altitude at which the aerial photographs were taken
- focal length, text field, connected to the **focal thesaurus,** which expresses the lens focal length in inches (*4 inches*, *6 inches*, *12 inches*, *24 inches*) and in millimetres (*101.6 mm*, *152.4 mm*, *304.8 mm*, *609.6 mm*)
- scale, text field
- definition, text field connected to the **trace definition thesaurus** composed of the following items: *Embankment, Environment, Area, Building, Hole, Ditch, Stone heap, Defence walls, Route, Excavation sample, Illegal excavations, Masonry structure, Trace*
- type of trace, text field connected to the ***trace type thesaurus*** composed of the following items: *Anomaly, Microrelief, Humidity, Vegetation*
- description, free text field providing a brief description of the anomaly found
- interpretation, free text field
- notes, free text field
- ground evidence, ComboBox text field: *yes, no*.

4.1.1.6 From data to information: interpretative synthesis

All data types must be converted into synthesised information, classified in an onthological system, which describes the urban and peri-urban areas in terms of anthropic and environmental traces. The different sources (archaeological, documentary, mapping, geological, geomorphological, etc.) from which the data are inferred must be able to dialogue with each other. The principle according to which an item of information from the system can gradually acquire more in-depth details is developed in the **Interpretative synthesis record** (based on three onthological levels), valid for all types of sources and, in the case of subsurface archaeology, in the **Level IV Record** table, which identifies the type and quality of the find[11]. Again, in the case of subsurface archaeology, the first (**Interpretative synthesis record**) is linked to the Intervention table, whilst the second directly to the first. Both create a common context through which data from different types of documentation may be compared using the logical scheme described in § 3.3. In practice, each find recorded in an intervention is described through four standardised definition levels, which provide chronological and typological-qualitative details on the information.

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[10] The record, which is described in thorough detail in this chapter, was created by Giorgio Pocobelli who was responsible for reading the aerial photographs of the MAPPA project.

[11] This could be compared to the synthesis level that leads to the identification of activities and/or group of activities when studying stratigraphic sequences. Working with a large amount of heterogeneous data led to the creation of this intermediate passage allowing the first step towards comparability between archaeological data, which is fully performed, however, at a higher synthesis level.

4.1.1.6.1 Interpretative synthesis record

This **Interpretative synthesis record** table contains **Level III, II and I** definitions (see § 4.4). Whilst the interpretation process in Level IV simply consists of finding a consistent term for all the typological-qualitative features of the find, in the following three levels, the process becomes a substantial part of the description of the data and of their relations with space. The typological-functional (Level III) features are gradually defined, through an onthological process, as well as the role assumed by a specific record in relation to space, at both local and urban level (Levels II and I).

Level I, II and III fields are ComboBox "text" fields. Each field links to its own "*thesaurus*" table whose choice options are influenced (apart from Level I) by the term entered in the field of the previous level[12].

The reference period is entered according to a chronological range (as in the Level IV record): Initial Date and Final Date. Both fields can be expressed either in text form, by choosing a sub-period ("text" field linked to the "chronology *thesaurus*" table that lists the various sub-periods), or in numbers (free "number" field).

4.1.1.6.2 Chronological management

Within this context, chronological data management is a key factor for allowing information interoperability. Information is heterogeneous in terms of its acquisition method and quality, yet dissimilar in terms of chronological definition. Indeed, it is not always possible to check the dates attributed in the light of new knowledge; they must be accepted, therefore, with a certain margin of doubt. Sometimes data collected recently also present a certain margin of uncertainty due to specific contexts or, more in general, the status of the research. We decided to use a simple system for managing this information, based on a chronological interval defined by two different number fields called "final chronology" and "initial chronology", in which the absolute date is included[13]. We decided to date centuries starting from year 1 and ending in subsequent year 100[14]. Data is recovered thanks to a query conducted on both numerical data in order to define an interval.

Number scanning is accompanied by a more general chronology expressed in text form which allows simplified searching: the macro-periods, already described in the intervention record, are divided into sub-periods, through a ComboBox "text" field called "Chronology" that is linked to the **Chronology thesaurus**[15] table and composed of the following entries: *Prehistory*, *Palaeolithic*, *Upper Palaeolithic*, *Middle Palaeolithic*, *Lower Palaeolithic*, *Mesolithic*, *Neolithic*, *Early Neolithic*, *Evolved Neolithic*, *Late Neolithic*, *Eneolithic*, *Early Eneolithic*, *Late Eneolithic*, *Bronze Age*, *Early Bronze Age*, *Middle Bronze Age*, *Late Bronze Age*, *Final Bronze Age*, *Iron Age*, *Iron Age I*, *Iron Age II*, *Etruscan Period*, *Etruscan Orientalizing Period*, *Etruscan Archaic Period*, *Etruscan Classical Period*, *Etruscan Hellenistic Period*, *Roman Period*, *Mid-Republican Roman Period*, *Late-Republican Roman Period*, *Imperial Roman Period*, *Early Imperial Roman Period*, *Mid Imperial Roman Period*, *Late Roman Period*, *Early Middle Ages*, *Early Middle Ages VII-VIII century*, *Early Middle Ages IX-X century*, *Late Middle Ages*, *Late Middle Ages XI-XIII century*, *Late Middle Ages*

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[12] Regarding the "Level II" field, only the entries included in the definition chosen for Level I can be chosen. Regarding the "Level III" field, the available terms are inside closed *thesauri* depending on the Level II item chosen. The principle is that every level is more detailed than the previous one, from Level I to III, or more synthetic, from Level III to Level I.

[13] According to some, the heterogeneity and uncertainty of chronological data is particularly evident in the accurate and precise archaeological information entered in the GIS; furthermore, the uncertainty resulting from an inaccurate chronology leads to the need to incorporate this level of indecision within the data architecture itself (HARRIS, LOCK 1995).

[14] For chronologies "before Christ", the numbers will be preceded by a minus (-) sign.

[15] This *thesaurus* was taken (and modified) from the Guidelines for Drawing up the Archaeological Map of Tuscany (FRANCOVICH, PELLICANÒ, PASQUINUCCI 2001: 195) and from ANICHINI 2004-2005.

XIV-XV century, Modern Age, Modern Age XVI century, Modern Age XVII century, Modern Age XVIII century, Contemporary Age, Contemporary Age XIX century, Contemporary Age XX century, Not determinable.

In cases where information does not allow more specific details, the *thesaurus* proposes a standard division where it is always possible to enter a more general item (which matches the macro-period definition, e.g.: Roman, Etruscan, Modern Age, etc.). Where possible, the sub-periods have chronological ranges expressed in centuries (e.g.: Modern Age XVII century); regarding other periods, the names used in different cultural sectors are reported (e.g.: Second Iron Age or Etruscan Hellenistic Period)[16], although the specific names are used for the area of study (e.g.: Hellenistic Etruscan Age instead of Second Iron Age). The number field avoids this problem and makes all data immediately comparable.

4.1.1.6.3 Evaluating the reliability of record categorisation[17]

The synthesis process developed in the four levels described, transforms primary archaeological information into standardised categories which directly contribute to the calculation of the archaeological potential. This is a very delicate process because it has a direct impact on the analyses and the historical-archaeological and mathematical considerations that allow achievement of the final project product. We have often underlined how the difficulties encountered, i.e. the inconsistency, shortage and absence of data recorded in the sources, unavoidably influenced this process. Although an archiving system has been designed that attempts to reduce these problems as much as possible, we believed it essential to include a field that evaluates, with clear parameters, the overall reliability of data categorisation. Since the source, intended as the archaeographic documentation of the intervention, was considered the key factor, we created a table for evaluating the documentation of each intervention. The starting point was based on the assumption that the greater the amount of documentation, the greater the reliability of the information. Complete documentation allows more accurate checking and understanding of the raw data, as well as greater reliability of its categorisation. Although our aim was not to achieve a qualitative assessment of the documentation (in the absence of acknowledged standards that accurately define documentation contents and above all the criteria needed for drawing up "quality" documentation), this kind of parameter necessarily had to be used alongside a quantitative parameter: the result of this work is a calculation table that assigns a score to each intervention, according to a set of simple and previously-defined steps, allowing codified and objective judgment parameters by operators.

The main fields are the type of intervention and type of documentation.

The different types of intervention were grouped into three macro-categories on the basis of type of documentation and information potential:

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[16] The Hellenistic Period is the period from the death of Alexander the Great (323 BC) to the battle of Actium (31 BC) where Octavian defeated Anthony and Cleopatra and gave way to a new political course. Pisa had already entered the Roman influence in III century BC, yet it received Roman citizenship only after the social war (89 BC) and after becoming a Roman municipality. From this date onwards, therefore, the correct term to be used for Pisa is the Late Republican Period, not the Hellenistic Period (nor the "Mid-Republican Roman Age"). We decided to extend this period up to 28 BC, since the following year Octavian received the title of Augustus and established the Principate. The Early Imperial Period coincides with the Julio-Claudian dynasty, up to 68 AD (death of Nero), while the Mid Imperial Period is the period from 69 to 192 AD (death of Commodus). Under this emperor's dynasty, the complex economic transformations that had steered the empire's production from the Italic peninsula to Gaul and Spain, and then to Africa, came to an end. The Late Roman Period or Late Antiquity started in 193 AD and ended with the arrival of the Lombards. The exact date in which Pisa was conquered by the Lombards is uncertain, so it was decided to arbitrarily set the end of this period as 600 AD.

[17] We would like to thank the following project team members for their contributions to this topic and for drafting the first report, upon which this paragraph is based: Antonio Campus, Lorenza La Rosa, Claudia Sciuto and Giulio Tarantino.

Written records			**Photographic documentation**			**Drawn documentation**		
Geognostic surveys	**Surface surveys**	**Excavations**	**Geognostic surveys**	**Surface surveys**	**Excavations**	**Geognostic surveys**	**Surface surveys**	**Excavations**
Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Description of Contexts identified	TU records	List and a few records	Photographs of cores	Photographs of land	A few photographs	Section drawing of cores	Mapping and delimiting of areas identified	A few maps
		All records			Photographs of each Context			All surveys

Table 4.1 Summary table regarding the document validation method used for determining categorisation reliability (graphic design C. Sciuto).

1) *Geognostic surveys*: cores
2) *Surface surveys:* surface investigations, geophysical surveys
3) *Excavations*: stratigraphic excavations (all types), surveillance, trenching, etc.

At the same time, different types of documentation were identified that need to be produced for every intervention according to standards (which are more or less acknowledged but in any case indicated by ICCD - Central Institute for Cataloguing and Documentation); information must be grouped into categories that allow the entry of documents acquired or drawn up using different methods:

1) *Written records*
2) *Photographic records*
3) *Drawn records*
4) *Reporting*
5) *Quantification of finds*
6) (Harris) 50*Matrix*

Each documentation category is interpolated with the three macro categories on the basis of the type of intervention; for each interpolation, three levels of accuracy and completeness of the documentation are defined. The three levels are the following:

- Level one: absence of documentation, value = 0
- Level two: intermediate, value = 1
- Level three: highest information level, value = 2

The sum of all the scores acquired for each category of documentation generates an overall value of reliability of the information in the archaeological record.

The parameters used for evaluating the type of intervention in every documentation category are described further on. Given the nature of the type of intervention they refer to, some interventions cannot attain the highest information level (Level III) in certain documentation categories. In these cases, it was established that the intermediate level corresponded to the greatest information potential that could be achieved and documented from that intervention.

Level III automatically includes Level II items.

Written records

Geognostic surveys:

Level I: the core documentation does not contain any type of Context recording.

Level II: description of Contexts identified in the core with description of most important features.

Surface surveys:

Level I: no evidence recorded.

Level II: Topographic Unit (TU) sheets compiled.

Excavations:

Level I: no Context records.

Level II: the complete list of Contexts is available, some Context records have been filled in, or the

Report			Analysis of finds			Matrix		
Geognostic surveys	**Surface surveys**	**Excavations**	**Geognostic surveys**	**Surface surveys**	**Excavations**	**Geognostic surveys**	**Surface surveys**	**Excavations**
Absent	Absent	Absent	Absent	Absent	Absent			Absent
General report	General report	Intervention report	Materials studied	Some information about the materials	Some information about the materials			
Complete report	Complete report	Sequence report		Photographs/ drawings of every context and quantification	Photographs/ drawings of every context and quantification			Present

majority of Context records have been filled in but not completely.

Level III: all or almost all the Context records have been filled in, at least the main fields (general data and stratigraphic matrix) according to ICCD (Central Institute for Cataloguing and Documentation) indications.

Photographic records

Geognostic surveys:

Level I: the core documentation does not contain any photographs.

Level II: general photos (intervention area, boxes) and photographs of the stratigraphic sequence identified in the core.

Surface surveys:

Level I: there are no photographs.

Level II: photographs of identified lands or of specific evidence, with name of TUs and appropriate references.

Excavations:

Level I: there are no photographs.

Level II: general photographs, sporadic photographs without Context documentation, illegible photographs (out of focus or bad lighting) or photographs without metrical or orientation references.

Level III: photographs of all Contexts and any specific items, or highly legible photographs (high definition) with correct metrical and orientation references.

Drawn records

Geognostic surveys:

Level I: the core documentation does not contain any type of drawn records.

Level II: drawn rendering of the stratigraphic section (LOG) with indication and characterisation of identified Contexts.

Surface surveys:

Level I: no drawn records.

Level II: mapping and delimitation of identified TUs.

Excavations:

Level I: no drawn records have been produced or only free sketches are available; the plans do not have any type of reference (benchmark) that can link them to the area of excavation or among one another.

Level II: only composite plans or phase plans are available, where the limits of the single Contexts are not identifiable; heights are not reported or are reported inadequately.

Level III: all Context plans are available with correct heights (absolute heights or relative heights with 0 point known) and benchmarks of reference.

Reporting

Geognostic surveys:

Level I: there are no reports.

Level II: a general report is available that simply summarises the interpretation of the evidence, without any reference or description of raw data.

Level III: complete report with description of the stratigraphic sequence and single Contexts.

Surface surveys:

Level I: there are no reports.

Level II: a general report is available that simply summarises the interpretation of the evidence, without any reference or description of raw data.

Level III: complete report with description of primary data.

Excavations:

Level I: there are no reports.

Level II: non periodised report, without description of the material source or with illegible excavation diaries or reports (syntax errors).

Level III: complete phasing report accurately referring to the raw data.

Quantification of finds

Geognostic surveys:

Level I: the material has not been studied.

Level II: any material found in the core has been catalogued.

Surface surveys:

Level I: the material has not been studied.

Level II: only little information is available about the material found, with partial documentation (only a few photographs, drawings or quantification tables).

Level III: washed/initialled material, photographs of all material per Context, drawings and quantification tables.

Excavations:

Level I: no drawings, photographs and quantification tables.

Level II: only little information is available about the material found, with partial documentation (only a few photographs, drawings or quantification tables).

Level III: washed/initialled material, photographs of all material per Context, drawings and quantification tables.

Matrix

Excavations:

Level I: not performed or illegible.

Level II: existing and performed according to agreements shared by the scientific community[18].

4.1.1.6.3.1 Depth

The height of certain finds is essential for developing period DTMs. As already mentioned, however, depth-related data reported in documentation are mostly relative, referring to generic ground levels or equally generic relative 0 points, and are only very seldom absolute. It was therefore necessary to check existing altimetric data and make them absolute, i.e. relate them to sea level. The data obtained, however, were influenced by the extent of the generic nature of the reference chosen and, therefore, were not equally reliable. Consequently, we decided to support depth-related data by checking their reliability along a triple-scale of values: *exact*, *good calculated reliability* and *poor calculated reliability*. The procedure for making height data absolute was conducted in GIS environment by comparing the relative heights to the 3D land model (see § *2.3.4.1.1*) and subtracting the respective value indicated in the documentation. The degree of reliability of the calculated height– *good reliability* or *poor reliability* – was attributed depending on how accurate the location of the relative 0 point was. The *exact* value was attributed for data that already had an absolute reference point since directly chosen during the excavation phase.

4.1.1.7 User interface

From the opening screen, a specific part of the database is available to non-administrator users

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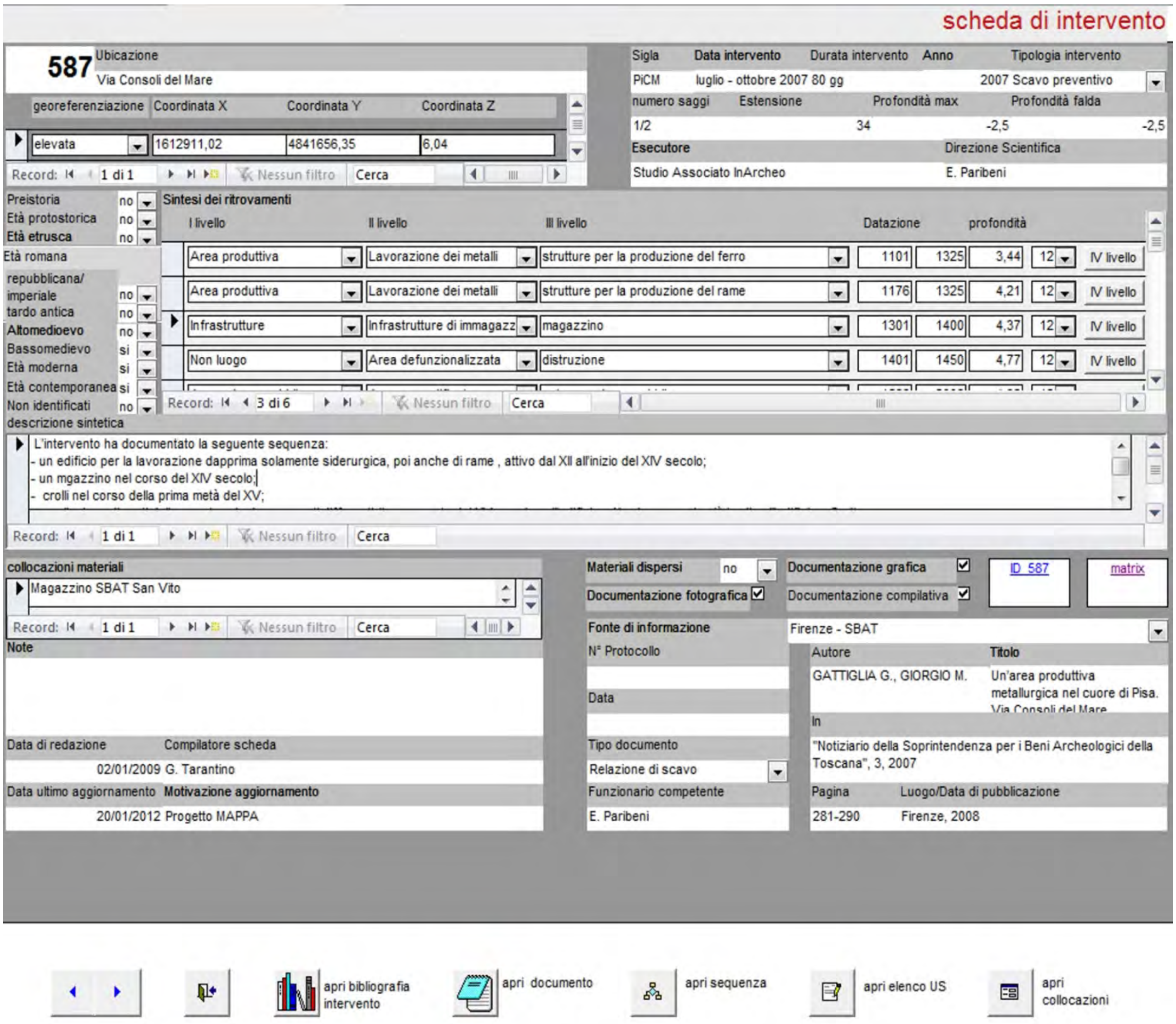
[18] It is necessary to consider this specification because matrices have been found that, although performed very recently, did not comply with the Harris diagram rules, but with non-specified rules that do not refer to any known bibliographic reference; furthermore, they do not have any sort of key to help understand symbols that are, at the moment, incomprehensible.

who can consult and search the database but cannot change or enter data. To make the archaeological data easier to read, each form contains data from several tables, since queries between different tables have been developed as well as sub-forms. The **Intervention record** user form (figure 4.1), besides providing **Intervention record** table fields, also contains the georeferencing coordinates (from the **Georeferencing record** table), the synthetic description (from the **Synthetic description** table) and the records related to the intervention according to the four levels of categorisation. The user immediately has an overall view of every single intervention and can carry out many search activities (chronological and typological) since all visible fields can be examined. The "sequence" button connects to the phasing query form which describes the overall phasing of an excavation thanks to intervention-related data from the categorisation level tables, the period table and the phase table. From these tables it is possible to reach the single phase or period records which include respective phases and groups, and finally the **Context record**, which is presented as a shorter version compared to the complete record and also contains the quantification data of the finds (Quantification Record table).



587 Ubicazione
Via Consoli del Mare

georeferenziazione	Coordinata X	Coordinata Y	Coordinata Z
elevata	1612911,02	4841656,35	6,04

Sigla	Data intervento	Durata intervento	Anno	Tipologia intervento
PiCM	luglio - ottobre 2007	80 gg	2007	Scavo preventivo

numero saggi	Estensione	Profondità max	Profondità falda
1/2	34	-2,5	-2,5

Esecutore	Direzione Scientifica
Studio Associato InArcheo	E. Paribeni

Preistoria	no
Età protostorica	no
Età etrusca	no
Età romana	
repubblicana/imperiale	no
tardo antica	no
Altomedioevo	no
Bassomedievo	si
Età moderna	si
Età contemporanea	si
Non identificati	no

Sintesi dei ritrovamenti

I livello	II livello	III livello	Datazione		profondità		
Area produttiva	Lavorazione dei metalli	strutture per la produzione del ferro	1101	1325	3,44	12	IV livello
Area produttiva	Lavorazione dei metalli	strutture per la produzione del rame	1176	1325	4,21	12	IV livello
Infrastrutture	Infrastrutture di immagazz	magazzino	1301	1400	4,37	12	IV livello
Non luogo	Area defunzionalizzata	distruzione	1401	1450	4,77	12	IV livello

descrizione sintetica

L'intervento ha documentato la seguente sequenza:
- un edificio per la lavorazione dapprima solamente siderurgica, poi anche di rame , attivo dal XII all'inizio del XIV secolo;
- un mgazzino nel corso del XIV secolo;
- crolli nel corso della prima metà del XV;

collocazioni materiali
Magazzino SBAT San Vito

Note

Data di redazione	Compilatore scheda
02/01/2009	G. Tarantino

Data ultimo aggiornamento	Motivazione aggiornamento
20/01/2012	Progetto MAPPA

Materiali dispersi: no
Documentazione grafica ☑
Documentazione fotografica ☑
Documentazione compilativa ☑

Fonte di informazione: Firenze - SBAT
N° Protocollo
Data
Tipo documento: Relazione di scavo
Funzionario competente: E. Paribeni

Autore	Titolo
GATTIGLIA G., GIORGIO M.	Un'area produttiva metallurgica nel cuore di Pisa. Via Consoli del Mare

In
"Notiziario della Soprintendenza per i Beni Archeologici della Toscana", 3, 2007

Pagina	Luogo/Data di pubblicazione
281-290	Firenze, 2008

4.1 The Intervention Record form as shown on the user interface.

4.2 The AIS Mappa platform

The AIS platform was developed using ArcGIS 10.0 software produced by ESRI. This software was chosen[19] because it was already used by various project partners and was also perfectly compatible with The MS Access database (since they both use Visual Basic language); furthermore, it allowed greater command by the work group when using the software and easier use by users formed mostly of researchers with good IT knowledge, but not experts.

ArcGIS is among the most common GIS software used globally[20], to such an extent that it has created a standard for all vectorial data formats (shapefile o .shp)[21] which allows data to be exchanged and processed even with open source software.

Data are handled inside a geodatabase containing:

- Description of the environment;
- Geological and geomorphological description;
- Description of the contemporary city;
- Description of the historical city;
- Archaeological description.

4.2.1 Interoperability: formats and metadata.

Interoperability is characterised by three problems: IT (format), semantic (metadata) and identification standards (alpha-numerical data). In IT terms, the problem is purely technical and regards which format to choose for archiving mapping information and allowing wide dissemination and exchange opportunities. For this reason, output files[22] were developed in native ESRI format (.shp), which can be read or modified with a large range of open-source software such as GRASS, OpenJump, gvSIG and QuantumGIS.

From a semantic viewpoint, instead, the concept of absolute objectivity needs to be abandoned in an attempt to make subjectivity objective. It is possible to compare data collected by different researchers only if we consider their history and intellectual background (TERRENATO 2006:19). Nevertheless, this requires the codification of data through scientifically-shared procedures that ensure their future use. We must not abandon the idea to create standards[23] but rather be aware that data collection by archaeologists is partly

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[19] This pragmatic choice was made after studying which software was most suitable for the Project needs on the basis of experience, research development timing and internal skills. Although we firmly believe in open source options, we also believe that pondered choices should be made according to the objectives to be attained and that ideological reasons should be left aside. The latter have often influenced debates (not only in Italy) regarding the use of commercial or open source software, which have prevented serious examination of which software is best for one's needs.

[20] In our opinion the alternative to ArcGIS is mainly represented by the open source software GRASS (with the addition of the QGIS interface and R analyser). We do not intend discussing which software is best, both have pros and cons. Some initial differences have been smoothed out, regarding the fact that GRASS software places greater attention to raster data processing and ESRI software to vectorial aspects, (WHEATLEY, GILLINGS 2002: 56-57), on the one hand with QGIS implementation, which allows better management and analysis of vectorial data and provides a user friendly interface compared to GRASS, on the other with the introduction of powerful tools devoted to raster data analysis. The greater stability in Windows environment, compared to GRASS (created in UNIX environment), is however balanced by the high cost of ESRI software.

[21] A shapefile is a non-topological model, composed of three main files which contain spatial information and attributes and are included in a dBase file. ESRI published this format to favour data exchange among different systems. ESRI Shapefile Technical Description http://www.esri.com/library/whitepapers/pdfs/shapefile.pdf and for a general description http://en.wikipedia.org/wiki/Shapefile

[22] The input files were handled as a feature class inside the Geodatabase, from which exporting to .shp format is easy.

[23] "With reference to a mainly industrial definition, standards are mutual agreements on declarations and/or intents that help control an action or product. They may be used to check the compliance of a working and/or organisational process within a professional community or a group of communities at national, international or global level. Standards therefore represent professional consensus to common practices" (D'ANDREA 2006:79).

subjective (although limited by the use of standardised procedures) and that only a full and accurate account of the methodological and scientific procedures used by archaeologists when constructing their data representation system will allow easier data integration and reuse. Objectivising subjectivity means explaining the intellectual and methodological background and the expertise used for digitally codifying the data. This process, called "semantic interoperability" (D'ANDREA 2006: 120), does not provide a basis for the "technical" grouping of data and creates illusory super-standards that group existing standards. On the contrary, since it does not alter the formalisation of data adopted by each single researcher, it ensures the codification of information on more abstract and general formal models, capable of capturing the semantics inherent in the stored data.

To allow semantic interoperability, it is necessary to record the motivations and circumstances regarding the creation of a digital source, the details of its origin, content, structure and of the terms and conditions applicable to its use, both in terms of a complex source (an entire GIS) and digital object (single file). These aspects are recorded (recording allows extensive and continuous use of data by the scientific community) by creating metadata which are used for recording how the data were formed, thus making information freely and correctly accessible, even across time and space, and simplifying search, localisation, selection and semantic interoperability operations.

The metadata of the MAPPA geographical data were developed by referring to the INSPIRE directive, according to the indications of the National Geoportal, in line with the operating guidelines[24] produced by the National Register of Spatial Data (RNDT)[25] in compliance with EC Regulation no. 1205/2008, which implements the INSPIRE directive (Directive 2007/2/EC), and with the related Technical Guidelines edited by the Joint Research Centre of the European Commission[26]. The Ministerial Decree of 10 November 2011[27] outlines[28] the hierarchical structure, taken over from Standard ISO 19115, with which metadata can be organised; it generalises all the information shared by several datasets at series level, maintains information which actually distinguishes it from another at dataset level and provides further details about the information at tile level[29]. A univocal definition of dataset, dataset series or dataset subset does not exist. It may depend on the type of data, the institution that produced the data or the way the data are handled and supplied. The proposed metadata model, therefore, is defined so as to contain a minimum set of elements and to be sufficiently generic, thus making it suitable for different types of data that need to be documented in the Register.

Regarding the identification standards, in agreement with the *Direzione Regionale per i Beni Culturali e Paesaggistici della Toscana* (Regional Directorate for the Cultural and Landscape Heritage of Tuscany), within the scope of the SIGEC experimentation project, the decision was taken to adopt minimum alpha-numerical fields available

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[24] RNDT Manual - 2. Operational guide for the compilation of RNDT (National Register of Spatial Data) metadata in compliance with the INSPIRE regulation - v. 1.0 - 02/04/2012 http://www.rndt.gov.it/RNDT/home/images/struttura/documenti/RNDT_guida_operativa_dati.pdf (last access 6 April 2012)

[25] http://www.rndt.gov.it/RNDT/home/index.php

[26] "INSPIRE Metadata Implementing Rules: Technical Guidelines based on EN ISO 19115 and EN ISO 19119" http://inspire.jrc.ec.europa.eu/documents/Metadata/INSPIRE_MD_IR_and_ISO_v1_2_20100616.pdf (last access 6 April 2012).

[27] The Decree of 10 November 2011 of the Ministry for Public Administration and Innovation, together with the Ministry of the Environment and Protection of Land and Sea regarding "Technical rules for defining the content of the National Register of Spatial Data, as well as the procedures for its establishment and updating", published in the Official Gazette no. 48 of 27 February 2012 - ordinary supplement no. 37

[28] § 3.1.1 of Annex 2

[29] A tile is an additional information level with respect to European standards.

in the catalographic instrument called MODI-Information module[30] created by the ICCD (Central Institute for Cataloguing and Documentation) in order to guarantee a minimum common denominator of alpha-numerical data capable of sharing the identification details of the heritage asset among the different information systems and to make the future implementation of the information collected inside the general cataloguing system possible. Specifically, the MODI fields were included as a table of the vectorial file attributes and subsequently transformed into an ASCII trace with the specifications requested by the ICCD.

4.2.2 Mapping and reference system

Scale-1:2000 and 1:10.000 regional maps (CTR) were used as mapping references, provided in raster and vectorial formats by Regione Toscana and developed according to the geodetic mapping Roma 40 Gauss-Boaga West zone (EPSG 3003 Code). The land register sheets created with Cassini Soldner projections were also used and then re-projected[31] by Regione Toscana on the Roma 40 reference system. The new data were produced with differential GPS according to the World Geodetic System 1984 (WGS84) and subsequently transformed in Roma 40[32] projection. Georeferencing of the archaeological data, partly performed during 2005-2010[33], was carried out with Roma 40 projection.

With the recently published[34] Ministerial Decree of 10 November 2011, however, Italy has adopted, in implementation of Article 59 of the Digital Administration Code (CAD), a new reference system called ETRF 2000 (2008.0.) (Baroni *et alii*, s.d.), aligning itself to the European geodetic reference system ETRS89[35], in order to support applications requiring greater accuracy. This new reference system can be added to the aforementioned Roma 40 and Cassini Soldner systems, and to the European datum 1950 (ED50) and WGS 84. Furthermore, as specified in Article 3: *"Starting from the date of publication in the Official Gazette of the Republic of Italy of this decree, administrations shall use the National Geodetic Reference System for georeferencing their permanent stations as well as for the results of new surveys, new mapping, new products as a result of aerial and satellite photographic imagery, geographical databases and for any document or data that need to be georeferenced".* For this reason, our data will be converted into the new system of projections as soon as the tools freely provided by the Military Geographical Institute will be made available.

4.2.3 Georeferencing archaeological data: how and why

As revealed during the data analysis phase, the great majority of archaeological data is available only in paper format; only a very small amount of the remaining digital data is in vectorial format (no data are in .shp format, but are all in .dwg or .dxf format). 48% of overall data, apart from being in paper format are mainly written texts or lack any accurate geographical reference points and only 52% can be accurately georeferenced. The long span of time covered by the archaeological documentation has a direct impact on these percentages, however, it should be pointed out that even recent detailed documentation is accurate only referring to relative reference systems and it is not linked to a wider mapping context. When addressing these data, the choice of which geometric primitives to use when entering the data is essential both for data

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[30] http://www.iccd.beniculturali.it/index.php?it/211/sperimentazione-normative A similar choice was made within the SITAR project developed for the city of Rome (Moro 2011: 97)

[31] Georeferencing of land register sheets causes problems regarding the correct overlapping of individual sheets.

[32] The new data were collected by Dipartimento di Scienze della Terra (Department of Earth Sciences). Verto3k software of the Military Geographical Institute was used for the conversion.

[33] Anichini 2004-2005, Gattiglia 2010

[34] Official Gazette no. 48 of 27 February 2012 http://www.gazzettaufficiale.biz/atti/2012/20120048/12A01799.htm (last access 6 April 2012)

[35] http://etrs89.ensg.ign.fr/ (last access 6 April 2012)..

management and representation. In the MAPPA project, we decided to vectorise all the archaeological data by referring to two benchmarks: individuality (every non-interpreted object has always been described at geometrical level as a sole and separate entity), and the (almost) exclusive use of polygonal graphs, to avoid any type of symbolic representation (point or linear graph), thus entrusting 'symbolic' characterisations to the table of attributes.

Paper documentation was scanned with scan resolution between 300 and 600 dpi (output in greyscale TIFF format); then, the raster datasets were georeferenced[36] using the definition of associations between the local coordinates of a control point in the raster dataset and the corresponding coordinates of the same control point in the geographical coordinates. The presence of raster data related (in the majority of cases) to parts of details allowed us to use few control points (in any case always more than three) evenly arranged in the corners of the raster dataset. In the majority of cases a first order polynomial transformation was used[37] (including translation, scaling, rotation and shearing of the raster without deformation of the straight lines[38]), which is most frequently used for georeferencing a paper map and requires less calculation time. The accuracy of the transformation is given by the extent of the residual error for each single point and for the set of points, which is equal to the difference between the assigned position and the position obtained from the transformation and is calculated as the root of the mean square error (RMS or Root Mean Square). Averagely speaking, RMS is around a few centimetres, at times less than ten centimetres. Resampling of the raster, i.e. assignment of a value to each cell of the new grid, was performed using the nearest neighbour assignment method, which assigns the new value from the nearest cell and is the quickest and most reliable method for discrete data and images.

Georeferencing took up a large amount of time during the initial project phase: effective georeferencing of raster data is important for a correct vectorisation of the intervention area. The main problems encountered regarded the way the data to be georeferenced were originally produced, especially the scale and mapping base of reference used for producing the data. The majority of raster datasets refer to parts of detail regarding small portions of the urban area, with a nominal scale generally ranging from 1:100 to 1:2000; however, in peri-urban areas, 1:10.000-scale elements can also be found. Smaller scales allowed correct but less accurate georeferencing.

The use of reference maps other than the present one is related, on the one hand, to the period of execution of the interventions, on the other, to self-produced surveys at a scale of 1:20 (or1:50), with land reference points that were difficult to identify on a 1:2000-scale map developed using an aerial photogrammetric survey.

Finally, vectorial data originating in .dwg and/or .dxf formats were acquired in CAD environment using CTR mapping bases which were then imported in GIS environment and vectorised. The georeferencing activities underlined the need to position the archaeological data directly in vectorial format from now onwards, possibly in line with shared standards and according to the ETFR2000 reference system.

4.2.4 AIS data for the archaeological information layer (archaeological description)

The data that define the archaeological description and compose the archaeological information layer are organised in feature datasets called **Subsurface** (subsurface archaeology), **Buildings** (building archaeology) and **Traces**.

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[36] Performed with the Georeferencing tool of ArcGIS 10

[37] Polynomial transformation is based on a polynomial built on control points and an optimisation algorithm built with the least squares fitting method (LSF). This system is optimised for global accuracy, but does not guarantee maximum local accuracy.

[38] In high-order polynomial transformations, in addition to increasing the number of control points, distortion of the straight lines may be seen, which produces a curvature with at least one inflection point.

4.2 Interventions with accurate (red) or uncertain (orange) georeferencing inside the urban centre of Pisa, viewed on the DTM developed upon LiDAR information. All the interventions were depicted using a polygonal graph.

The **Subsurface** feature dataset describes the archaeological data of the subsurface as polygonal feature classes called **interventions**, **context**, **characterisations**, **TU**, **structures**.

The **Buildings** feature dataset describes the archaeology of the architecture through the polygonal feature classes **UAU**, **CA**, **CF** and linear **phases**.

The **Traces** feature dataset manages the polygonal feature classes of the traces related to aerial photography (**Traces_1943_RAF**, **Traces_1945_RAF**, **Traces_1951**, **Traces_1954**, **Traces_1978**, **Traces_1980**, **Traces_1986**, **Traces_2010**, **Traces_satellite**) and that of the **Traces** synthesis. The raster data from which the single traces were vectorised were handled inside the Flights raster catalogue, which contains the georeferenced photos of various flights: 1943 and 1945 RAF, 1951, 1954, 1978, 1980, 1986, 2010 (see § 9.11). All vectorial data are associated to a table of attributes, managed through domains inside the Geodatabase, which in addition to containing specific fields for each feature class, always contains the minimum mandatory MODI fields (see § 4.2.1).

4.2.4.1 Interventions

The **Interventions** polygonal feature class (Figure 4.3) describes the single areas within which any archaeological investigation whatsoever has been carried out and has involved the subsurface, regardless of the quality of the investigation or type of find. Archaeological interventions are the core of the archaeological information layer. Each feature reproduces, from a logical viewpoint, the container holding the main finds and, from a graphical viewpoint, the benchmarks upon which the single excavation maps or TUs are georeferenced, for complete archaeographic data, or the structures for interventions for which only partial documentation is available. Correct georeferencing is an essential aspect and is defined through its attributes. Vectorisation (data entry) of the interventions[39] was performed as a polygonal graph, regardless of the degree of geo-

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[39] Vectorisation was carried out by Antonio Campus, Lorenza La Rosa, Claudia Sciuto and Giulio Tarantino, who also filled in the database. Final review of the georeferencing work was performed entirely by Claudia Sciuto.

referencing reliability. In previous works, we had chosen to exclusively use a polygonal primitive (ANICHINI 2004-5) – which envisaged a 'symbolic' representation obtained through circular objects – for representing inexact locations; subsequently (GATTIGLIA 2010), the decision was taken to use both a polygonal and point primitive, to represent exact and inexact locations, respectively. This final choice offers a series of advantages: data consistency (every intervention has a spatial extension, although it cannot be accurately represented at the moment, which the polygonal primitive maintains), computational analysis (greater potential by using just one file), subsequent predictive calculation (when the vectorial data will be converted into the cells of a raster dataset), and data presentation since this will prevent the confusion generated by point representation, which to non-expert users may appear to be the highest level of accuracy[40].

The reliability of the location of each single intervention was described by distinguishing two different levels of accuracy – defined as "accurate" and "inaccurate", in turn divided into high, medium, low – to indicate the level of georeferencing reliability (PRC). "Accurate" georeferencing means georeferencing where the geometrical surface corresponds to the real location, shape and extension of the area of intervention (PRC= high); "inaccurate" includes all the other cases, divided into medium and low levels. Medium level is assigned to interventions where the location most likely corresponds to the actual one: this includes interventions inside a building or along a road, for which, however, the real surface cannot be defined. Low levels are assigned to interventions within a certain area that cannot be defined: for example, interventions that can be located along a road but cannot be referred to a linear trace (e.g. an intervention in an indeterminable point of a road), or located within a large area (e.g. a village or neighbourhood) or an entire block or group of buildings. Georeferencing of all inaccurate elements is topologically consistent with the

4.3 The Contexts of the excavation in Via Consoli del Mare (2007), georeferenced and viewed on the 1:2000-scale CTR raster map.

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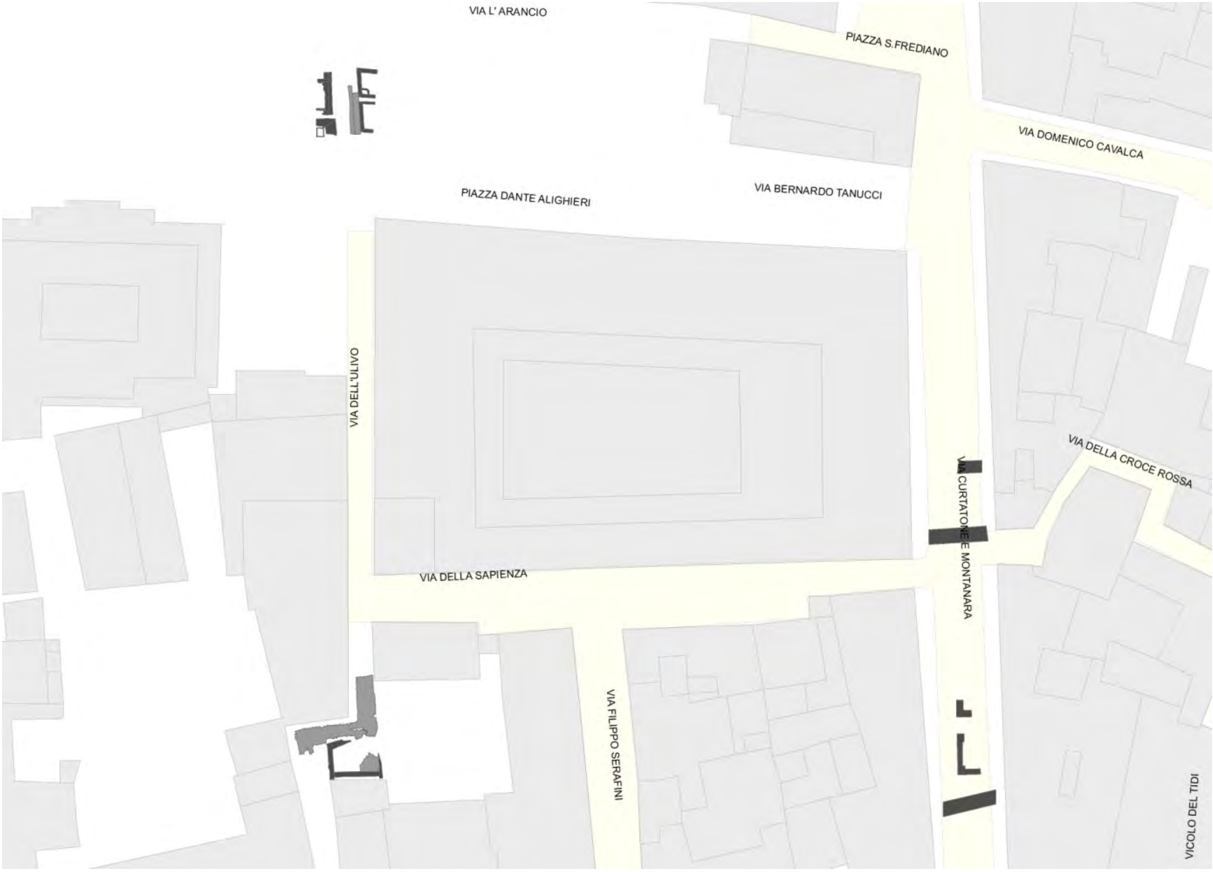
[40] The use of point primitives and symbolic representations was generally abandoned in the SITAN and SITAR projects also.

objects depicted in the 1:2000-scale CTR vectorial map.

The file was then joined to the intervention table of the RDBMS; it currently contains 700 objects.

4.2.4.2 Archaeographic documentation

Thanks to the work carried out in the archives and on published documentation (see § 2) it was possible to retrieve complete archaeographic documentation (greatly related to excavations, but also including survey documentation), containing maps, records, images, etc., and partial documentation, mainly published documents, containing only part of the data, usually already interpreted. The introduction of data from stratigraphic excavations involves, on the one hand, faithfully re-proposing the context's material character and, on the other, collecting data inside an alpha-numerical database. For this reason, we decided to handle stratigraphic excavation data provided with complete documentation and stratigraphic excavation data provided with partial documentation differently, using two different files. All the contexts, both positive and negative, were depicted using a polygonal graph. Initially, (GATTIGLIA 2010) the decision was taken to use a polygonal graph for all positive contexts and a linear graph for negative contexts (NARDINI 2000); however, the difficulty in handling a large amount of data from various excavations led us to using just one polygonal file, which allows greater coherence from the viewpoint of the digital tool and considerably simplifies both research and analysis (Figure 4.4). The separation between



4.4 The Medieval structures (dark grey) and road surfaces (light grey) of the area surrounding Palazzo della Sapienza viewed on the 1:2000-scale CTR vectorial map.

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[41] Object features for which high levels of detail are not needed are excluded from the search and are not viewed, thus shortening data processing time. The decision to use a polylinear graph instead of a polygonal graph is simple to due to the graph's adaptability and not to reasons regarding model coherence.

positive and negative contexts, therefore, was managed at the level of attributes.

Characterisations, instead, refer to strictly graphical principles and define the real aspect of the object. By handling them on a different layer, the conceptual coherence of the platform is observed and practical order is complied with. The differentiation between the polygonal graph, which describes the limits of a context, and linear graph, which describes the aspect of the object, serves the purpose of not generating errors in mathematical consultation and not encountering operating and management difficulties[41]. At the level of attributes, in addition to the identification fields required for the name of each object and for the relation with the RDBMS **Context record** table, a sub-type field was included, managed as domain inside the Geodatabase. Sub-types should be regarded as a macro-classification of contexts (NARDINI 2000) and do not refer to the interpretative level, which is managed through the "synthetic interpretation" field of the **Context record** table of the relational database. The use of sub-types as GIS attributes is coherent with the concept of objectivity, since they are incontrovertible values external to the relational database; consequently, upon varying of the interpretation, contained in the alpha-numerical archive, the material identity of the context will never change

Data vectorisation from stratigraphic excavations provided with complete documentation was divided into two main types:

- **Context**, polygonal graph, divided into sub-types through determination of specific attributes inside the GIS: *opening, hole, erosion/destruction, filling, coating, burial, layer of ashes/carbon, layer of mortar, layer of stones/ bricks, layer of soil, wooden structure, horizontal masonry structure, vertical masonry structure, cut/trench, transformation unit, other*. The objects are joined to the Context table of the RDBMS.
- **Characterisations**, linear graph, divided into sub-types through determination of specific attributes inside the GIS: *opening, hole, erosion/destruction, filling, coating, burial, layer of ashes/carbon, layer of mortar, layer of stones/ bricks, layer of soil, wooden structure, horizontal masonry structure, vertical masonry structure, cut/trench, transformation unit, other*.

Data from stratigraphic excavations provided with partial documentation were handled as finds, by vectorising each type of structure. Each feature was associated to a table of internal attributes. Characterisation of the structures is currently not envisaged.

- **Structures** (Figure 4.5), polygonal graph, an internal table is connected to the objects including the following fields: *base, cesspit, hole for burial, hearth of fire, foundation, furnace, melting pit, plaster, wall, flooring, building site, burial, spoliation, vault, source, initial dating, final dating, minimum height, maximum height*.

The need to vectorise single TUs was extremely rare since there are very few raw data available. Furthermore, since a univocal and standardised filing system is lacking, it was decided to enter both objective data such as the type (e.g. *area of dispersion*) and interpretative data and chronology as attributes.

- **TU**, polygonal graph.

4.2.4.3 Building archaeology[42]

Building archaeology (Figure 4.6) is managed in the Buildings dataset class through **UAU**, **CA** and **CF** feature classes (described with a polygonal graph) and **phases** (linear graph). All the dataset objects can be connected to the homonymous tables in the RDBMS. In addition to the fields referring to the MODI, the attributes include the identification items necessary for linking to the related tables archived in the RDBMS, and the PCR field, which reports the degree of

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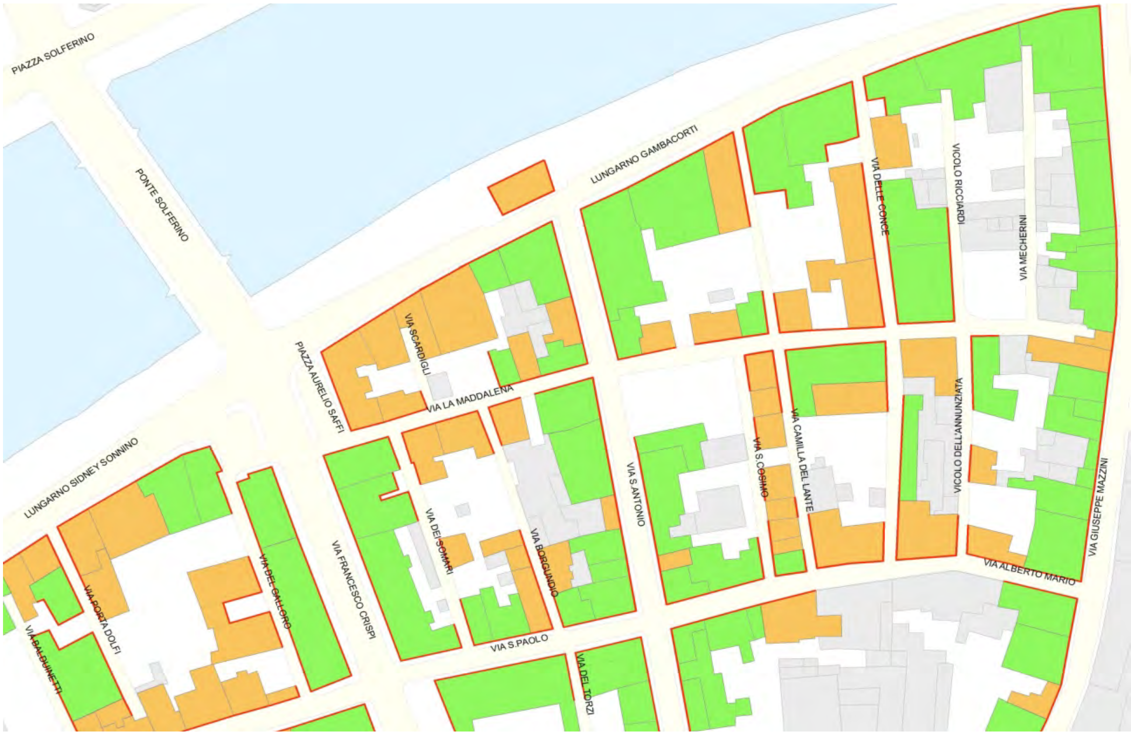
[42] As previously mentioned, (see § 4.1.1.4) this work was conceived and performed for the project purposes by using original material; the overall coherence, therefore, of the structure between RDBMS and GIS is evident, which is not influenced ex-post, as in the case of other sources. The structure was developed together with Mara Febbraro and Fabiana Susini who collected the building archaeology data for the MAPPA project



4.5 Building complexes (green polygons), buildings (orange polygons) and phases (red lines) of the block south of Ponte Solferino and of Chiesa della Spina, viewed on the 1:2000-scale CTR vectorial map.

- INTERVENTI
  - ID_000
    - ID_1_DIS
      - ID_1_Piante
      - ID_1_Progetti
      - ID_1_Sezioni
    - ID_1_IMG
    - ID_1_MAT
      - ID_1_dis
      - ID_1_img_m
      - ID_1_quant
    - ID_1_MATRIX
    - ID_1_REL
    - ID_1_SCHEDE

4.6 Diagram of the directories and sub-directories composing the INTERVENTIONS archive.

georeferencing reliability according to a three-value scale: high, medium and low[43]. Identification of the primitives was based on the actual consistency of the buildings: consequently, only the polygonal graph was suitable for this description, given also the project's general coherence. Instead, phases are represented by a linear graph for two reasons: the masonry phase represents the result of an interpretative process, whilst from a physical viewpoint it represents the readable interface of the masonry stratification to which a thickness cannot be assigned because in the majority of cases the reading only refers to an external interface and also because there may not necessarily be exact correspondence between the interfaces placed on the two sides of a masonry structure.

4.2.4.4 Aerial archaeology

Aerial archaeology data were collected[44] from several aerial photography surveys (see § 9.1). In

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[43] Given the characteristics of the work, accurate data that cannot be georeferenced are not envisaged, for this reason the accuracy field (accurate, non accurate) was not included as in the case of the **interventions**.

[44] Even the photointerpretation activities were specifically carried out for the project. The structure was developed together with Giorgio Pocobelli who dealt with the MAPPA project aerial archaeology activities.

the Geodatabase, the vectorial data of the traces were managed inside the **Traces** feature dataset. A series of polygonal feature classes were created (**Traces_1943_RAF**, **Traces_1945_RAF**, **Traces_1951**, **Traces_1954**, **Traces_1978**, **Traces_1980**, **Traces_1986**, **Traces_2010**, **Traces_satellite**) which represent the single traces/anomalies resulting from the aerial photographs of each flight; an overall feature class was developed (**Traces**) which reports the single traces after the removal of recurring elements (i.e. traces shown in several flights), for which the object with best legibility and georeferencing was chosen. In addition to the MODI fields, the table of attributes includes the identification fields (trace number) for linking to the corresponding RDBMS table, year of flight, flight strip, photo, photointerpretation code[45] and interpretation. The raster files from which it was possible to vectorise the single traces were managed inside the Flights raster catalogue, which contains the georeferenced photos from flights 1943 and 1945 RAF, 1951, 1954, 1978, 1980, 1986, 2010.

4.3 The MAPPA file server (digital archive)

All primary documentation[46], thanks to which the RDBMS was implemented and the vectorial files were developed in GIS environment, was included in various directories inside the MAPPA file server. This consists of all the documents collected (images, maps, projects, reports, etc.), the majority of which were scanned[47] during the project, or originally produced in digital format[48], using different graphical or textual formats. This huge amount of data[49] was only partly archived in the textual database and geographical database, yet represents an incredible source of data/information. The documents acquired were thus entered in various thematic directories, related to their main reference. In the case of subsurface archaeology, the structure revolves around the INTERVENTIONS directory divided into sub-directories related to the single interventions and named with their own ID. The various files were arranged inside these sub-directories (excavation reports, excavation/phase/period maps, matrix, context records, other) in different formats of origin or acquisition, divided into further sub-directories, as shown in Figure 4.7. A similar procedure was followed with all the data produced when analysing the buildings (BUILDINGS directory), with Management of all these files is performed through the mapping data (MAPPING directory) and aerial photography imagery (TRACES directory). XnView[50] software, which allows single files and folders to be tagged

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[45] Alpha-numerical code developed by the *Laboratorio di Topografia Antica e Fotogrammetria dell'Università del Salento* (Ancient Topography and Photogrammetry Laboratory of Salento University) under the direction of Marcello Guaitoli (see §9.1 and respective bibliography)

[46] We prefer speaking of primary documentation rather than raw data, since reference is not only made to archaeographic data but to all available granular data below which it is not possible to identify further data since they have not been produced or have gone lost or missing.

[47] All the collected documents were scanned (reports, records, maps, project designs, images). The scanning of images preserved at SBAT in Florence, took place directly on the Superintendency premises; slides were scanned with an appropriate scanner; large-sized maps were scanned with an A0 scanner, the remaining maps were scanned with an A3 scanner and documents with an A4 scanner. Written documents were acquired in grey-scale .pdf format; maps and planimetries were acquired in grey-scale .tiff format, apart from a few coloured maps which were acquired in millions of colours; images were acquired in .tiff format in millions of colours.

[48] The files acquired directly in digital format were almost always archived only in their original format: .doc, .pdf for text documents or filing apparatus; .dwg, .dxf for vectorial drawing files; .jpeg for images. All the files produced with special software (mainly proprietary software) were transferred to a standard or readable format.

[49] The INTERVENTIONS directory currently contains 41,881 files divided into 4,749 sub-directories for a total of 110 GB disk space.

[150] http://www.xnview.com This is not a real DAM, however, since created for handling digital photography archives, it supports a very high number of formats (over 400) and also allows management of text files such as .doc, .pdf, etc. in addition to graphical files such as .dxf and .dwg. http://en.wikipedia.org/wiki/XnView.

and makes file management easier. Indexing of the single files required 120 man days (2 months of work divided among 3 operators). This is a large amount of time which was necessary, however, in order to rapidly retrieve the data once archived.

[G. G.]

4.4 Data categorisation

The previous methodological considerations made with regard to the categorisation of archaeographic data moved in two directions: on the one hand, we moved from individual objective data to their interpretative abstractions; on the other, we immediately defined, at macroscopic level, the large functional areas of a city and its suburb, in order to fit the recorded traces into these areas. To provide a real and at the same time metaphorical example, this is what happens when tunnels are made and the digging commences simultaneously from the opposite ends of the tunnel: the work is successful and the design calculations prove to be correct when the two crews of workmen meet in the middle of the mountain. In other words, we followed the multi-directional drive that the human mind spontaneously follows and that leads it to abstract from contingent cases in order to grasp their greater underlying meanings, yet also to create large categories of thought within which daily actions find meaning and justification.

Large categories were devised for Level I; they synthetically define the vocational areas of the city which address, for instance, public or private use, production activities, trade or funerary activities. These areas are divided into sub-groups at Level II and define more specific functions; for example, the production areas include the manufacturing of metal, clay, leather, fabric, glass, wood and so forth. The first two levels are "universal" categories which can be applied to any city at any time and of any culture. Conversely, as previously mentioned, we categorised the data taken from the heterogeneous documentation of the investigations carried out in Pisa. The traces or groups of traces, defined by the wide range of Level IV items merge into the large groups composed of Level III typological categories: for example, a layer or several layers of iron slag, possible associated to a furnace, may be categorised as structures for the production of iron. It is at this point that the two crews of workmen must meet in the middle of the mountain: the case of Pisa must fit into the abstractions that we regarded as valid for all cities, and it must be possible to cover the entire route – from full detail to maximum abstraction and vice versa – in both directions. Although Level I and Level II abstractions are valid, Level III and Level IV items are not fully exhaustive: we considered the items necessary to describe the cases we encountered as well as some of the most common items we expect to see as the investigations continue. We are aware that we cannot be fully exhaustive since the system is open and can be continuously implemented.

It is important to remember the diachronic nature of our study – based on "all the evidences of human activity belonging to a more or less remote past and which can be investigated with archaeological research methods" (MANCINELLI 2004) – required the introduction of specific categories suitable also for describing the traces of contemporary cities. For this reason, alongside items referring to monumental categories typical of "historical" cities, terms such 'cinema' or "sports field", among the recreational buildings, or "pharmaceutical" or "chemical industry", among industrial manufacturing, provide the tools to describe the contemporary nature of cities. Furthermore, some items are able to describe quite dissimilar architectural typologies yet used for the same function, for example, a theatre belonging to the Roman or modern ages.

The twelve series composed of Level I items and their respective Level II and Level III items are presented. They are organised according to a hierarchical structure and are suitable for synthesising information from various documentary sources (see table 1 of the Annex; for the organisation of the four synthesis levels, see § 4.1.1.6[51]).

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[51] The items, which are also used in the plural in the text, are only encoded in the singular.

For a more detailed description of Level III items, reference may be made to the definitions of the ICCD (Central Institute for Cataloguing and Documentation) website record; here, we will only focus on the items introduced by us or those requiring an explanation of the meaning attributed to them. In all the series and in all respective Level II categories, the Level III item "construction site" is nearly always present. This refers to the construction site set up for the various buildings or infrastructures and is evidenced by a variety of traces, such as ground surface, holes for scaffolding poles and building waste (stones, lime and carpentry nails).

The extensive Level IV thesaurus, which is the common basis for the twelve series, was designed to arrange the information coming from the archaeological documentation. Since it was necessary to receive data from documentation featuring very different levels of analysis, the synthesis level of the single items is very broad and ranges from a single activity to groups of activities..

4.4.1. Agricultural/vegetable gardening area

Agricultural or vegetable gardening areas (Level I) are not exclusively located outside the city centre; vegetable gardens exist or used to exist in the inner parts of the city too, whereas areas converted into urban built-up land could have been used for agricultural purposes in the past. With specific reference to Pisa, the urban structure of the late medieval city had large non-urban areas that were used as vegetable gardens. This situation may also be seen in other historical periods: the early Middle ages, the Roman age (during this period the city coincided only partly with the medieval city) and the Etruscan age. The Etruscan city is specifically composed of several built-up areas spread over a large surface which were divided by green areas, most probably cultivated areas.

Level II comprises areas featuring "agricultural organisation/centuriation", "vegetable gardens" and "agricultural structures/rural villas".

"Agricultural organisation/centuriation" include, at Level III, interventions that prepare land for agricultural practices and improve its productivity, bordering works and traces of cultivation. These interventions are common to various historical periods, however, given their particular organisation during the Roman age, they belong to the land division system called centuriation. Reclamation in the plain of Pisa mainly comprises "crevasse splays", navigable "canals" and "trenches", the latter two also used for irrigating fields. "Terracing" (characteristic of hilly areas) is also an indicator of agricultural use, as well as elements that define the "boundaries" between properties (boundary stones, walls, trenches, paths or roads) and cultivation traces which belong to the term "agricultural land", such as the holes for planting fruit trees or the furrows for planting vineyards.

The "vegetable garden" category is divided into "enclosure" and "vegetable gardening land" at Level III. "Enclosure" comprises stone walls (dry-laid or held with mortar), or structures made of perishable material and assembled in various ways. "Vegetable gardening land" may be dark in colour due to the decomposition of the organic substances used for fertilisation. These substances are often made of domestic waste which may include fragments of pottery kitchenware. Traces of furrows or holes for plants are other indicators of lands used as vegetable gardens. This type of land differs from a generic agricultural area also due to its context: inside an urban area or close to a rural building.

The "agricultural structure/rural villa" category includes the following items at Level III: "*pars urbana*", "*pars rustica*", "*pars fructuaria*", "farmhouse", "units/rooms", "winemaking cellar", "barn", "oil mill", "sheepfold", "henhouse", "pigsty" and "stable". The first three refer to rural villas of the Roman age comprising a residential area, for the owner, a rural part for the servants and the labourers, and another part for the manufacturing and transformation of the products.

4.4.2 Production area

The large category called "production area" refers to all the districts or areas devoted to craft and industrial activities. The categories that further detail the various production activities, through Level II and Level III items, provide the single traces of the production cycle, from fixed installations to semi-processed products and manufacturing waste, included in Level IV items.

Level II of the "production area" is divided into "metal manufacturing", "clay manufacturing", "stone manufacturing", "leather/fabric manufacturing", "glass manufacturing", "wood manufacturing", "food manufacturing" and "industrial manufacturing".

The areas or structures for "metal manufacturing" include "structures for iron production", "structures for lead production" and "structures for copper manufacturing". Metal manufacturing includes the manufacturing of certain artefacts, such as the "mint", "structures for the production of copper/bells" or "goldsmiths".

The "clay manufacturing" category includes clay extraction areas - "clay quarry/cultivation" as well as "structures for the production of pottery", "structures for the production of bricks" or more generally "structures for the production of pottery and bricks" when specific production is not clear or when the production of both artefacts is ascertained.

"Stone manufacturing" comprises the "lime kiln", the oven used for burning limestone and producing lime, which at times was located next to the ditch used for cooling the quicklime, "stone quarry/cultivation", "lithic industry", with specific reference to pre-historic manufacturing places, "lithic artefact production", in relation to any other activity related to stone manufacturing, including artistic laboratories.

"Leather/fabric manufacturing" comprises "tannery" "woollens factory", "furriery", "weaving mill", "dyeworks", "shoe factory", "tailor's shop" and "*fullonica*/*gualchiera* (fulling mill)". The last item refers to Roman, medieval and post-medieval structures used for felting wool and making it waterproof.

Level III "glass manufacturing" and "wood manufacturing" include, respectively, "glass-works" and "joinery", whereas "food manufacturing" comprises "wine cellar", "dairy", "oil mill", "mill", "bakery", "butcher"; "industrial manufacturing" is composed of "pharmaceutical industry", "chemical industry" and "mechanical industry". A category named "non identified manufacturing" was also introduced ("structures related to non-identified manufacturing") for all those traces generically referable to production activities which cannot be better defined.

4.4.3 Area for private use

This category includes all the city areas for private use including "housing complex", "housing unit" and "non-built areas".

"Housing complex" includes the settlement areas that form the city, located on its borders or distributed across the territory. It includes permanent areas such as "district" or "*insula*", with specific reference to the Roman phase of the city, or areas with temporary or poorly structured features, such as "camp". The generic item "settlement" describes different environments that go back even far in time: for example, this definition may indicate the inhabited areas of a polycentric city (as Pisa perhaps was during the Etruscan period when several settlements were distributed across a rather large area), or the small villages that surrounded the historical centre of the medieval city.

"Housing unit" instead refers to a single unit or group of units ranging from a "shed" to "pile dwelling" and "palace". This category includes houses specific to certain historical periods, such as "tower house" during the Middle ages or "*domus*" and "*urban villa*" during the Roman age. The term "rural house" is referred to buildings that appear to be associated with a vegetable-garden area even if they are located inside the city. The term "house" is used generically when the type of housing unit is not specified. Single elements may also indicate a housing unit, such as a paved "courtyard", which is characteristic of certain types of construction, or a "hearth" which is one of the most evident traces of a shed made of perishable material.

"Non-built areas" may also be areas for private use, such as a "private garden", or non-structured areas defined as simple "clearings".

4.4.4 Funerary area

Level I "funerary area" indicates the place used for the burial of entire communities or, occasionally, single individuals. At Level II, the area is divided into two categories, "tomb(s)" and "cemeterial area", depending on whether reference is made to individual graves or large graveyards in specifically dedicated areas, with individual or collective tombs. Since our intention was to include the areas used for the organised burial of deceased persons in the same category, regardless of the historical period, we used the definition "cemeterial area" which has a larger meaning than the term "cemetery". The word etymologically means a place of rest but it was only after the advent of Christianity that it began to indicate the place where dead people are buried, previously called necropolis. The definition "cemeterial area" must be regarded in a wider sense, comprehensive of the specific meaning of necropolis and cemetery. Level III includes two large categories for both the "cemeterial area" and "tomb(s)": "cremation" and "burial", thus distinguishing the two types of funerary rites practiced. Level IV records the material evidence ascribable to funerary practices, including the types of tombs documented locally and classified on the basis of the association of a number of variables and of the funerary marks.

4.4.5 Area for public use

The "area for public use" is an extremely generic item which includes all the categories of buildings and places for community use. Level II and III are composed of "recreational buildings" ("amphitheatre", "theatre", "circus", "race track", "stadium", "sports field", "gymnasium", 'cinema'), "political/administrative buildings" ("basilica", "Curia", "*comitium*", "forum", "guild hall" "prison", "*curtis*", "palace", meaning a palace where power was exercised), "health and sanitary buildings" ("thermae", "lavatory", "hospital", "baths", from medieval *balnea* to modern baths), "places of worship" ("church", baptistery", "bell tower", "chapel", "oratory", "monastery", "sanctuary", "votive shrine", "synagogue", "temple" and the generic item "sacred area"), "school/educational building" ("nursery", "school", "university", "museum", "library/archive"), "celebrative structure" ("monument", "arch"), "non-built area" ("garden/public park", "clearing for public use").

4.4.6 Infrastructures

"Infrastructures" include various types of structured works, mainly for public use, which are essential for the functioning of the urban system. This large category includes many further Level II categories. A large category is formed of engineering works, such as "road infrastructures" ("alley", "square", "bridge", "road", "centuriation road", "avenue", "railway", "railway station", "post stage", "*mansio*", "hospital"). Road systems are strictly related to water systems – "port/navigation infrastructures" ("river port", "maritime port", "dock/landing place", "waterway", "dockyard" and "shipyard") – and to "service infrastructures", such as "stables", "horse stables", "workshops" or "petrol stations". Engineering infrastructures also include various kinds of networks: "distribution infrastructures" ("telecommunications network", "gas network", "electricity network"); "water infrastructures" which include essential water supply works, such as "aqueducts", "wells", "fountains" (also in monumental form "fountains/nymphaeums") and "collection tanks"; drainage works, such as the "fresh water system" or the "sewage water system", "wash-houses" and various containment works for surface waters, such as "embankments".

Public service works include "disposal infrastructures" ("organised waste dump", the place where waste materials from human activities are systematically heaped) and "storage infrastructures" ("underground storerooms" – silos or cellars –, "warehouses" in general and "*horrea*" specific to Roman-age structures).

4.4.7 Area with military function

Level I of the military area defines the large category of urban and peri-urban areas used for military purposes and includes two large Level II categories: "defensive structures" and "quartering structures".

The "defensive structures" include, at Level III, all the works for the more or less active defence of the city, foremost the "walls". This synthetic definition includes the many works that usually form the defensive walls of the city: the curtain walls, in the strict sense, with battlements and rampart walks, fortified gates with access bridges and the bulwarks guarding them (such as the Sangallo bulwark of Porta a Lucca), trenches and towers running along the walls. The item "tower" refers to the structures that, although part of a larger defensive system, appear to be isolated, such as the Guelfa tower. The item "fortress" refers to structures, in turn equipped with bulwarks, trenches, gates and towers, used for hosting military garrisons. Although associated to the walls, these works may have a specific identity, as in the case of Pisa, where the purpose of the Medicean fortresses are not so much the defence but the control of the city.

"Quartering structures" include "military camps", such as those resulting from the aerial photographs and located in the immediate suburban area of Pisa (although awaiting objective confirmation) and military "barracks" which are part of the historical buildings of the current city.

4.4.8 Indefinite structures

A quite frequent case encountered in the various types of archaeological sources is the case where it is not possible to provide any functional interpretation for various reasons, ranging from the small size of the excavation area to the partial investigation of the stratigraphic deposits. This indefiniteness is at times associated to a similar chronological uncertainty: the specific item "indefinite structures", therefore, was introduced to categorise these data.

4.4.9 Frequentation

The "frequentation" category is rather generic and is not functionally defined. Level III includes "mobile artefacts", "traces of use" and a generic "indefinite".

The "mobile artefacts" item may be used in different cases: for example, when the presence of materials out of context is recorded; although the materials are not sufficient to qualify the type of settlement they belong to, they provide evidence of frequentation of the area during a certain period. Artefacts with very little context are found in cores; since there are no other specific indicators, only generic frequentation can be attributed to these artefacts.

"Traces of use", such as a ground surface, thermal transformation or ash remains, represent generic traces of frequentation, when there are no other elements that can justify their presence.

The "indefinite" item is not due so much to the type of find, but rather to the reticence of the source that briefly refers to "frequentation from a certain period to another" and does not provide sufficient indications for a more detailed categorisation.

4.4.10 Non-place

This inaccurate yet appealing definition introduces the concept of "non-place" in Level I to define city areas that not used. The term is inaccurate, because "non-places" obviously do not exist, but at the same time well-fitting because it describes the way these areas are perceived by the community. City inhabitants frequent and use urban spaces in relation to their specific purposes. There are places, however, that are never used, not even occasionally, and that have no function whatsoever. These places are "suspended" in time: they were certainly once inhabited, frequented and used, and they may be used again in the future; nevertheless, for a certain time, their life was interrupted. "Non-places" can be found everywhere, even in contemporary cities: spaces where vegetation runs wild amidst crumbling walls or spaces enclosed by an old fence and half-hidden by advertising posters, until they disappear from public view. It is important to point out that this category does not include abandoned areas where, even if clearly prohibited, waste is abandoned more or less systematically, thus turning the areas into waste dumps. These places continue to perform their specific function, however much degraded, and their perception is, conversely and regrettably amplified.

Due to these specific features, a "non-place" has only one Level II category, the "defunctionalised area": a place that has lost its previous function, whatever it may have been, and has not acquired another one. At Level III the "defunctionalised area" is divided into: "abandonment", "destruction", "cancelling" and "spoliation". Level IV finds include layers of rubble/ruin, ash/coal, shavings or the formation of natural deposits.

4.4.11 Commercial area

The "commercial area"(of a mainly urban nature) forms the Level I macro group which includes all the trade and hotel areas. These two specific activities belong to Level II categories called, respectively, "sale structure" and "accommodation structure". Each one is divided into different Level III functional typologies.

"Sale structure" is formed of "market", "tavern", "shop/*taberna*" and brothel. The term "market", which indicates the space and structures used for trade activities of every period, is separated from "*macellum*" due to the specific typological nature of Roman food markets, composed of a porticoed courtyard flanked by shops. Likewise, in addition to "tavern", the item "*thermopolium/caupona*" was added, indicating the Roman commercial establishment that featured a counter with embedded jars used for liquids or foods, and cooking facilities for heating drinks or soups. The generic item "shop" is associated to "*taberna*", which indicates the Roman-age construction composed of a large room with a wide entrance; it was often provided with a backroom and stairs leading upstairs to a room used for living purposes (*pergula*). When the *taberna* sells the goods it directly produces, its function is of a workshop. The term "bar" indicates contemporary structures with features that can hardly be extended to those of similar ancient establishments.

"Accommodation structure" includes the "inn" provided with rooms for eating and sleeping; its size and the services provided are quite inferior compared to those of the modern "hotel".

[F. F.]

4.4.12 Natural context

Level IV describes the lithology of the "natural" deposits found, whereas Level I provides a more general and wide-ranging "natural context" to which the acquired data may be referred. Level I comprises various sub-environments which have characterised a given geographical area over time. Very often, however, the heterogeneous nature of the data and the gaps in the description of the deposits, especially from a geological viewpoint, make the reconstruction from Level IV to Level I difficult; it is often not possible to accurately follow the criteria used for classifying the depositional environments well-known and accepted in geological literature (see, for example, Ricci Lucchi 1980).

On this basis and especially taking into account the project's archaeological purposes, a terminology was used that could provide users of any kind immediately with general information about the natural context.

Specifically, Level II includes the following environments:

1) marine-coastal-deltaic } marine/mixed

2) fluvial (plain/cone))
3) aeolian
4) lacustrine
} continental

The term "marine-coastal-deltaic" replaces the terms "marine depositional systems" and "mixed (transitional) deltaic and coastal systems".

The following deposits may be found in Level III, with regard to the "marine-coastal-deltaic" environments:

Deltaic environment
- distributary channel
- interdistributary areas (levee/crevasse splay/floodplain)
- lake and marsh
- bay
- sub-delta

Coastal environment
- surfaced beach
- submerged beach
- beach ridge
- inter-ridge
- lagoon
- marine terrace

“Aeolian deposits” are also attributable to the “coastal environment”, specifically, surfaced beach and/or beach ridge deposits. Aeolian deposits are wind-driven deposits that, due to their origin and position, may be referable to the marine-coastal environment.

A brief description of the single deposits follows.

- “Distributary channel deposits”: mainly sandy deposits, ranging from coarse to fine, which usually present fining-upward sequences with erosive basis. A high content of decomposed organic matter and wood vegetal remains may be seen. Bioclasts may also appear.
- “Interdistributary area deposits”: levee, crevasse splay and floodplain deposits containing features similar to the overbank deposits described further on, in the case of fluvial systems.
- “Lacustrine and marsh deposits”: mainly fine-grain deposits (alternation of clay and silt) with organic matter, particularly abundant in the case of marsh deposits (peat). They have a plastic consistency and their colour normally ranges from grey to dark grey.
- “Bay deposits”: mainly fine-grain deposits (silt and clay), grey in colour and with plastic consistency. Mollusc remains can be seen. Sandy levels may also be present.
- “Sub-delta deposits”: sand-fine sand deposits which represent small coarsening-upward sequences associated with the filling of the lagoon.
- "Surfaced sand deposits”: well-sorted sand and gravel grained deposits. Vegetal fragments, wood and bioclasts are at times present.
- “Intertidal-submerged beach deposits”: quite well-sorted deposits from sandy/gravelly to sandy which reflect the different underground environments (foreshore and upper and lower shoreface).
- “Beach ridge deposits”: deposits composed of well-sorted fine to medium sand, mainly sandy.
- “Inter-ridge deposits”: deposits composed of well-sorted fine to medium sands, associated with fine sediments (clay and silt) and organic matter in the upper part.
- “Lagoon deposits”: fine deposits (clay and silt), with plastic consistency and grey in colour: *Cardium* valves and molluscs may often be found.
- “Marine terrace deposits”: gravelly to sandy fossiliferous deposits.

The fluvial (plain/cone), Aeolian and lacustrine environments together form continental depositional environments.

Since the area under examination only presents a fluvial environment, we will only describe the sub-environments (Level III) of this system:

Fluvial environment (plain/cone)
- fluvial channel deposits
- floodplain deposits
- levee/crevasse splay deposits
- marsh deposits
- fluvial terrace deposits
- alluvial cone deposits

Overbank areas

- “Fluvial channel deposits”: sandy and/or gravelly deposits related to tractive processes, featuring an erosive base and fining-upward sequences. They may contain fragments of bioclasts and vegetal fragments.
- “Floodplain deposits” (drained-non drained): fine deposits (clay and silt) associated with overbank and settling processes. They have light colours (ochre-hazelnut) and moderate consistency and feature Fe and Mn oxides and carbonate concretions in the case of subaerial exposure; they are grey-blue in colour and

when less consistent are indicative of poorly-drained conditions. The term "floodplain" has been used to indicate overbank deposits that characterise the areas furthest away from the channel and are mainly associated with settling processes.

- "Levee/crevasse splay deposits": deposits associated with channel overbank processes close to the channel itself. Cyclic alternation of sandy and fine deposits, with traces of subaerial alteration in the case of levee deposits; sandy deposits that can be associated with channel deposits on a small scale, with thickness usually above 30 cm and organised in small fining-upward sequences in the case of crevasse deposits, and sandy deposits with thickness usually above 30 cm and organised in small coarsening-upward sequences in the case of splay deposits. The term "overbank area" has been used to indicate overbank deposits on the border of the channel, or levee and crevasse splay deposits, featuring find to sandy grain and associated with traction and settling processes.
- "Marsh deposits": fine deposits, associated with settling processes, formed in depression areas of the floodplain and featuring low water and vigorous vegetation. The presence of clay and silt containing abundant organic matter gives the deposit a dark colour and plastic consistency. Freshwater gastropod shells and fragments may be seen.
- "Fluvial terrace deposits": sandy and gravelly deposits passing upward to silts and clays. Pedogenetic deposits may be found in the succession in varying degrees.
- "Alluvial cone deposits": see the specific case. The deposits change features depending on whether they influence the different portions of the alluvial cone (proximal, intermediate, distal).

[S. G., V. R, G.S.]

5. Some like it ‘webGIS’. Practical indications for conscious archaeological use

Francesca Anichini, Gabriele Gattiglia *(DOI: 10.4458/8219-08)*

The MAPPA webGIS is an instrument designed for different purposes that can easily employed by users with a variety of technical and specialised skills and with even basic IT knowledge. The user interface, therefore, was created with easy formulas, user-friendly commands and a number of pre-packaged thematic queries. At the same time, the interface can be used to examine specific details and to carry out targeted and sector-specific searches, if necessary.

To date, MAPPAgis offers some of the elements comprising the archaeological information layer; however, since it has been designed as a three-dimensional puzzle where each level makes the overall image clearer, consultation and analysis opportunities will gradually increase. Forthcoming publications will include the activities carried out on building archaeology, followed by toponymy and historical mapping data, together with the results of the geological and geomorphological research activities. The observations provided below, which focus on the use and potential of the archaeological information layer, will also include brief information about the potential of the instrument once completed.

The MAPPA project was conceived on the basis of previous research and work activities, especially on the desire to create a structure that could represent a real instrument. The guiding principle is “utility”, i.e. creating a product that can have great impact on society, which funded it entirely. Together with the purely experimental aspect regarding archaeo-mathematics, the first project product is a webGIS which directly addresses the components of society: administrators, heritage protection bodies, citizens, technicians, entrepreneurs, researchers and archaeological professionals. We believe that everyone can find a useful application. To achieve best results, all the components must contribute to adequately using MAPPAgis and must cooperate to improve its features and develop its potential. The optimisation of MAPPAgis is intrinsically linked to the development of and connection with the MOD (MAPPA Open Data archive), the open archive of archaeological data. This unification enhances the uses listed below and makes the archive even more effective. We will often point out how important the creation of the archive is to the success of the project, which has the ambition to positively change society’s approach towards management (in all its facets) of the buried archaeological heritage of an urban environment.

At the same time, we wish to clarify that MAPPAgis is an instrument that can be improved and, despite repeated checks, certain aspects may have slipped our attention. For this reason, we ask the archaeological community to provide their critical contribution and users to actively take part in the development of the platform by reporting any malfunctions or errors.

Finally, we would like to point out that the records presented in MAPPAgis, are the result of the shared work of the entire MAPPA archaeological staff, but have come to light thanks to the efforts of a group of young collaborators[1] who

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[1] Antonio Campus, Lorenza La Rosa, Claudia Sciuto and Giulio Tarantino.

passionately collected, reviewed and catalogued all the published and archived material[2].

5.1 The field of professional archaeologists

In Italy, 90% of archaeological interventions and investigations are carried out by freelancers or specialised firms. The profession of the archaeologist, although still not fully acknowledged, differs from that of other subjects since it combines technical skills and research activities. Discovery is inherent to archaeological activities, whether investigation or monitoring activities; archaeologists need to be both professionals/entrepreneurs and, to a certain extent, researchers to better perform their work. It is important, however, to distinguish research (a prerogative of universities or of individual researchers) from professional work which more often than not exclusively regards the collection and correct registration of archaeographic data. The so-called law on preventive archaeology assigns this double role to a category of archaeologists[3]. Drawing up a VIARCH (Valutazione di Interesse Archeologico, i.e. Archaeological Interest Evaluation for the planning phase of a public work) requires historical and archaeological research work so that the archaeologist may predictively suggest the impact that a public work may have on any buried heritage. The investigation must be carried out (depending on the features of the work) on a more or less wide range of the area. Urban contexts are of course a case apart: the range obviously includes greater part of the city (apart from Rome and large cities, of course). Although the format and angle of incidence around the area where the public work will be developed is not perfectly defined, archaeologists who must prepare a VIARCH in an urban context will certainly need to analyse the majority of existing data/information. For this reason, MAPPAgis intends simplifying archaeologists' work thanks to the overall view it provides of the interventions registered in the area of interest and to the continuous updating of information. Archaeologists can carry out an initial screening of the area of study and check the quantity and quality of the interventions. It is possible to immediately perceive the level of accuracy of the georeferencing procedure carried out on the area of intervention and to understand if and how this information can be used for the evaluation that is being drawn up. At the same time, the attributes of the intervention provide a series of indications that can be used as a discriminating factor for the reliability of information. The degree of reliability associated to each category of a find within the intervention is also a further indicator. This first approach allows archaeologists to easily assess how complex the evaluation will be (before performing the work) and to convert this complexity into an appropriate cost. Situations could arise in which the majority of the interventions registered are topographically inaccurate or much information cannot be used for the evaluation. Archaeologists could propose, and quantify, new investigations to the client in order to obtain more detailed information. At the same time, the webGIS would allow both the chronological and typological synthesis of each intervention to be viewed, indicating the presence of documentation in the Superintendency archives, where possible. This function would clearly be improved by the connection between MAPPAgis and the MOD: the possibility to freely and immediately view original documents and the raw documentation of interventions, would lead to an immediate saving of time and costs.

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[2] The understanding, verification, synthesis and categorisation of the interventions and finds was without doubt one of the most constructive moments of this first project phase. Opportunities to reflect upon a series of methodological topics were offered and our 'eager and crazy' visions of possible future scenarios in the world of archaeology were discussed; the unavoidable collisions (which thankfully occurred) always resulted in agreement and general laughter.

[3] Only archaeologists in possession of a specialisation or PhD degree and a number of University Departments are authorised to undertake this role, Decree no. 60 of 20 March 2009, published in the Official Gazette no. 136 of 15 June 2009 (www.archeologiapreventiva.beniculturali.it last access 19 April 2012).

At the same time, aerial archaeology layer would further optimise these aspects; the difficulties and costs for acquiring images and reading them would be overcome thanks to the overall coverage and filing of each trace referred to individual flights, directly provided in the information layer.

The subsequent implementation of the webGIS, which will include building archaeology data, will make this work even easier, especially for the areas inside the medieval walls; here, recognition of full and empty spaces is still highly conditioned by the presence of surrounding buildings which, in turn, may preserve traces on the wall stratigraphy of adjacent structures that have disappeared. Building archaeology data will serve to give importance to building archaeology within the scope of preventive evaluations.

Finally, the MAPPAgis will become a real evaluation tool since it can be used to overlap archaeological levels with toponymic and historical mapping information and with geological (stratigraphic) and geomorphological levels. Overlapping will allow many of the elements that have contributed to shaping and transforming a local area, environment and, consequently, a possible deposit, to be viewed at the same time.

Professional archaeologists, however, are also the individuals who work every day in close contact with buried heritage. They not only make assumptions on its presence but most of all acknowledge its existence and record its features. MAPPAgis is a tool that helps this work phase by rapidly providing professionals with a synthetic but complete picture of the archaeological data acquired up to that point for the area under examination. The webGIS can be used for the following purposes: to verify the presence of similar or completely different structures and/or contexts; to check the reference heights for a certain chronology or the overall growth of a deposit in a certain area; to overlap the proposed dates for specific evidences; and to receive targeted or bibliographical information about the source of the information in order to immediately and precisely search for further detailed data. Even in this case, it may seem superfluous to point out how the connection of the webGIS to the MOD would improve this process: the possibility to view photographs, reports, maps and context or quantification records when, for example, the fragment of a structure or a specific ceramic fragment needs to be understood during hasty urban interventions. What for years has been done *a posteriori* requiring long research time in libraries and archives and the study of material already selected by someone else before us who did not believe it "important" to show that image, fragment or relief… The potential of open data applied to archaeology is inherent in its definition of data collected at the source, without any cuts or modifications. What may not appear to be important in a certain context (therefore, usually not disclosed/published), may be fundamental – or simply complementary – for understanding another context.

An active phase for archaeologists also regards the implementation of the platform, i.e. data entry and positioning of new interventions. Archaeologists may georeference the area of study and fill in the fields using a guided procedure (see §5.5), thus providing the community with basic information about the new finds. The record can be updated in the case of preliminary data or data in progress; it will be acknowledged as a contribution published in the name(s) of the compiler(s) by assigning a DOI and quotation reference. This process will ensure continuous updating and effective system functioning.

5.2 Protection and planning

It is not our intention here to examine and comment on the organisation of archaeological Superintendency archives which (given the lack of funds or due to structural problems) reveal various situations at regional level, but are not in generally good conditions. We do not wish to criticise or find the causes of this situation: our intention is to propose a solution. The agreement entered into between the MAPPA project work group (Università di Pisa - Regione Toscana) and

MIBAC[4] allowed full examination of all the documents available in the archives regarding the area of study. This long and demanding work in terms of time and human resources was converted spatially, into the geographical positioning of every intervention found, and typologically into the attributes of every single spatial unit. In other words, heritage protection bodies are now provided with a quick online tool that is easy to consult and that can be used to rapidly check existing archaeological data (i.e. archived or published) for the entire area of study. During the evaluation of projects or the issuing of authorisations, Superintendency officials will be able to immediately view the entire context of the area to be protected within a more wide-ranging perspective, and to perform this simple and time-saving operation anywhere.

The intervention attributes include the general data of the intervention and related finds, without any subjective translation by the record compiler. The heights and type of finds can be checked and it is also possible to verify if the type of intervention performed actually needs to be further examined, possibly when information is taken from old interventions featuring unreliable methods. This array of instruments is provided to the official to facilitate the protection of archaeological heritage. By overlapping these different levels, for example the building archaeology level, interconnection between the two Superintendencies that operate within the city will be facilitated, for example when a project regarding the subsurface also concerns a building that maintains historical traces. The MAPPAgis does not replace the expertise of Superintendency officials but seeks to optimise their productivity and make their work easier without the need for technical specialisation or technological equipment. It is again important to underline the key contribution of connection with the MOD. Officials may directly and immediately retrieve the archive source without having to physically leave their office (often not in the same place as the archive) and may quickly respond to requests, especially in emergency situations. As a result, archaeological data and cadastral data may be promptly compared.

We believe (and hope) it will be possible to set up a shared practice that requires professionals working in cities to fill in a data template on the MAPPAgis platform and to submit it together with the documentation archived at Superintendencies (see §6). This simple task would keep the system updated and at the same time would allow Superintendency officials to check and monitor the data delivery schedule without using the archive. A system of this type would be useful when transferring duties from one official to another. Being provided with a knowledge base of an area's "archaeological state of the art", of the documentary material available and of any outstanding issues towards the executors of interventions, would benefit both work control and quality. In times like these, it is essential to use technologies to improve working conditions and productivity by optimising the expenditure of energy and public money.

A key stakeholder for the effective use of this instrument is the local governmental authority. The acquisition of maps created with the webGIS within municipal structural plans is a fundamental step towards new political choices which combine governance of the city with the protection and valorisation of buried heritage. A synergy of intents between local administration and archaeological Superintendencies could guarantee the systematic monitoring of the activities that affect the subsurface, especially in areas lacking information, and allow construction and urban interventions to be planned with greater awareness. The analysis of the spatial arrangement of the interventions examined clearly reveals how certain areas have more information than others, where systematic monitoring has not been carried out.

This causes wide gaps in certain sectors. Far-sighted choices are able to forecast whether to

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[4] Direzione Regionale per i Beni Culturali e Paesaggistici della Toscana Soprintendenza per i Beni Archeologici della Toscana, Soprintendenza per i Beni Architettonici Paesaggistici Artistici ed Etnoantropologici per le Province di Pisa e Livorno.

evaluate the archaeological interest of the work to be carried out (as provided for by law) or carefully invest resources to acquire new information in the sectors lacking data; this will optimise the knowledge-based instrument and gradually improve the predictive evaluation achieved by calculating the archaeological potential.

At the same time, examining the registered data will mutually redefine the perimeters of the areas of "archaeological interest" which have partially influenced (both positively and negatively) urban research and protection. New and updated boundaries may be traced starting from current ones and from the presence of protected areas reported as layers within the webGIS, thanks to cooperation with the Direzione Regionale per i Beni Culturali e Paesaggistici della Toscana (see §7).

5.3 A "sketch" for research

As already mentioned, archaeologists are also researchers when they prepare their work, yet there are some archaeologists who are entirely devoted to research, at university level and not only. Research is based on different factors than those driving archaeologists assigned with daily survey or assistance activities. Researchers pose questions about an issue and search various sources – including archaeological sources – for the answer. Researchers can use sources already known or can try and obtain new information by planning an archaeological investigation. In Italy, the number of cases for the funding of new projects continues to fall; in the majority of cases, research is developed from the results of one or more investigations performed for different purposes. This process is what often links the role of the professional archaeologist to the researcher. Another research approach is to not focus solely on a specific case, but attempt to develop wider horizons and synthetically outline specific topics. In both cases research is carried out on data. The MAPPAgis does not offer an interpreted view of the urban archaeological environment under examination, but presents an overall scenario of the possible different approaches. The archaeological information layer synthetically offers all existing information about buried archaeological remains, building archaeology (providing here a significant contribution of new information) and aerial archaeology. Researchers have easy access to all this material and can choose what they are most interested in and what they believe needs to be examined in further detail. MAPPAgis provides access to both typological and chronological aspects of the finds registered and acquires specific thematic frameworks responding to needs. This function also shows which aspects are more lacking in order to focus on specific elements only. There are very high chances that they will be expanded when uploading subsequent information layers, especially with direct linking to the MOD. It is important to point out once more how the opportunity to access raw data is an endless source of new branches of research and gives a large number of archaeologists the chance to actively contribute to the historical knowledge of their territory. This is not a question of removing the authorship of primary data from the individual who produced them, but recognising authorship, fully and promptly, and allowing data to multiply their information potential countless times via countless creative processes. Recognition to the archaeologist who produced the data can be given in two ways: the first by attributing authorship by quoting him or her (ANICHINI *et alii*, 2011), the second by making the data become the first step towards many different interpretations of historical topics and issues. This is the only way to give full value to the archaeographic work originally carried out and to the economic resources that the private individual or, in the majority of cases, the community has invested in that process.

MAPPAgis can be regarded as a "preparatory sketch", not well focused or outlined yet, which researchers must complete and turn into the image whose borders they are seeking; a sketch with more or less clear areas that planned research may attempt to fill in through a responsible use of public funds.

The aim is to provide a flexible and implementable instrument, a system that may become a container for all those archaeographic or archaeological records ensuing from use of the webGIS and through other different analyses. Today, MAPPAgis is an instrument that provides basic knowledge but may also be used to optimise future research plans. The archaeological information layers do not intend to give an exhaustive and definite picture; they represent what may be retrieved from the archaeological information of the area of interest. We hope this online tool, implemented in agreement with the Superintendency, will avoid the future loss of precious information that has not reached both the scientific and general communities since preserved in strictly private environments. XXI century archaeological research cannot wait years or decades to collaboratively check data. Technology and the Internet have accelerated knowledge production processes and it is no longer conceivable that the scientific archaeological community must respect ten-year rights before using data which, since state-owned by definition, are therefore public. For this reason, interventions that were still in progress when the intervention records were drawn up were included in the MAPPAgis and compose the first set of online data; they are provided with a simple "minimum data record" supplied by the Superintendency official and executors of the intervention.

Finally, MAPPAgis is an ideal tool for the shared planning of research with other institutes operating throughout the territory. Networking simplifies the exchange of needs between Superintendencies, Municipal Administrations and Universities. Common spaces, methods and time can be found to consciously use resources and maximise the social and cultural impact of research activities.

[F. A.]

5.4 A "network" of citizens

The recipients of the MAPPAgis are all the citizens and individuals who study, live or work in the city of Pisa. The platform offers them an easy-to-use approach to the city's archaeological heritage. The MAPPA project was entirely funded with public money and we believe it is important for the project results to be used by all its "investors", the community as a whole. In addition to helping to discover the city's history, it is important to create awareness of the work behind (and also subsequent to) archaeological interventions, which people often relate to the little or big inconveniences they experience: to offer, therefore, the information resulting from that inconvenience. We believe that awareness is the first step towards shared protection and valorisation which drives citizens to becoming the prime custodians of their environment. We do not share the position of those who consider shared knowledge a danger for buried archaeological heritage. We believe, instead, that this exact knowledge will drive many citizens to consciously and actively take part in cultural heritage preservation and development processes. Citizens who are aware of archaeological protection issues will be provided with an instant tool for cooperation and a means to expand their awareness towards less engaging citizens. With this view, making data accessible, including the traces recorded from aerial photographs, increases the perception of the risk of losing important historical and archaeological information caused by excavations that are not monitored by professional archaeologists, and drives towards greater cooperation by the entire community in protecting our heritage.

For this reason, in addition to making information available with the aid of an online tutorial, MAPPAgis is provided with a "reporting" system (*Report* tool). Citizens may communicate with the MAPPA laboratory via web, which will submit all public or private works, which are being carried out throughout the territory and have an impact on buried layers, to the Superintendency for Archaeological Heritage of Tuscany. This is an experimental service[5] for the urban

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[5] The test will last around a year. It has been set up only in the research sample area and is aimed at checking the effectiveness of the service in terms of number and timeliness. In the event of positive results, the aim is to set up a direct connection between citizens and the Superintendency and to expand the service throughout the entire region.

area of Pisa; the test checks the tool's real impact as a tool for cooperation with the peripheral entities of the Ministry for Cultural Heritage that deal with the protection of archaeological heritage. We are aware of the difficulties encountered by the Superintendencies in the management of local areas, especially in times of economic crisis and staff reduction. With a partial view to crowdsourcing of protection, aware citizens may report interventions (especially small interventions that often do not reach the Superintendencies) in a simple, immediate and direct manner. As a result, Superintendencies will be able to monitor the local area more effectively by checking if the reporting corresponds to an intervention already assigned or an unknown intervention, and by assessing which necessary actions need to be taken. The Superintendency may use the service to report the risk of erosion which archaeological heritage is subject to on a daily basis.

Archaeological heritage is a common asset and as such must be freely used by citizens. Urban archaeological finds are often not materially visible, their memory is rooted in the historical knowledge produced by the archaeological intervention. Knowledge must not only address a specialised audience but all citizens, for it to become a feature of belonging. IT devices allow the continuous processing of data and their use also at mainstream level. For this reason, as already in Florence[6], the data will be freely distributed in .kmz format and used through the Google maps. They may be freely used leading to the creation of applications for historical, archaeological and tourist purposes.

5.5 Freedom and "collateral benefits"

Full search and viewing capabilities must be provided within the MAPPAgis to be able to meet the needs of all possible users, whether professionals, researchers or citizens, and to establish efficient cooperation. For this reason, access registration systems were not created, nor gradual levels of detail requiring selective access and passwords. Less expert users will naturally not be able to use more complex data gradually loaded within the webGIS. The system is not provided with an individual user recognition process for whoever wishes to directly cooperate in the data modification or implementation processes[7]. The levels produced within the MAPPA project will be used through creative commons CC BY 3.0 license[8], which allows data to be reproduced, distributed, executed and modified by attributing authorship to them at all times in the manner indicated in the credits, and permits their use also for commercial purposes. This is a key factor: the data made available by the MAPPA project are the result of activities funded with public money, which in turn is the result of public data; it is right for the benefits of this investment to fall on the entire community and for the latter to use them as it considers more appropriate, in the hope for new development and (why not?) employment opportunities. These are just some of the possible "collateral benefits" that research and public culture, regarded as a social utility (which is preferable to the much-used term "common asset"), must attempt to produce or at least make others produce. Restricting the use of data through an NC[9] license would be a contradiction not only generally (as seen above) but also archaeologically: data are used to prepare Archaeological Interest Evaluations (VIARCH) which are requested for preventive archaeology pursuant to Legislative Decree 163/2006 (Articles 95-96) and are very expensive[10]. Whilst in this phase the benefits are limited to the open access to data and their partial re-use on the basis of interface capabilities (§ 5.6), in the future, the same data may be used via the MOD as open data, thus greatly increasing data potential.

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[6] http://florenceonearth.comune.fi.it/index.php; http://datigis.comune.fi.it/MapStore/ (last access 3 May 2012).

[7] For error reporting services or database implementation, the user's name will be requested.

[8] http://creativecommons.org/licenses/by/3.0/ (last access 3 October 2012).

[9] http://creativecommons.org/licenses/by-nc/3.0/ (last access 3 October 2012).

[10] The Legislative Decree explicitly requested the authorised subject to draw up the VIARCH: an exhaustive examination of published and non-published data; why not facilitate this passage?

5.6 Help

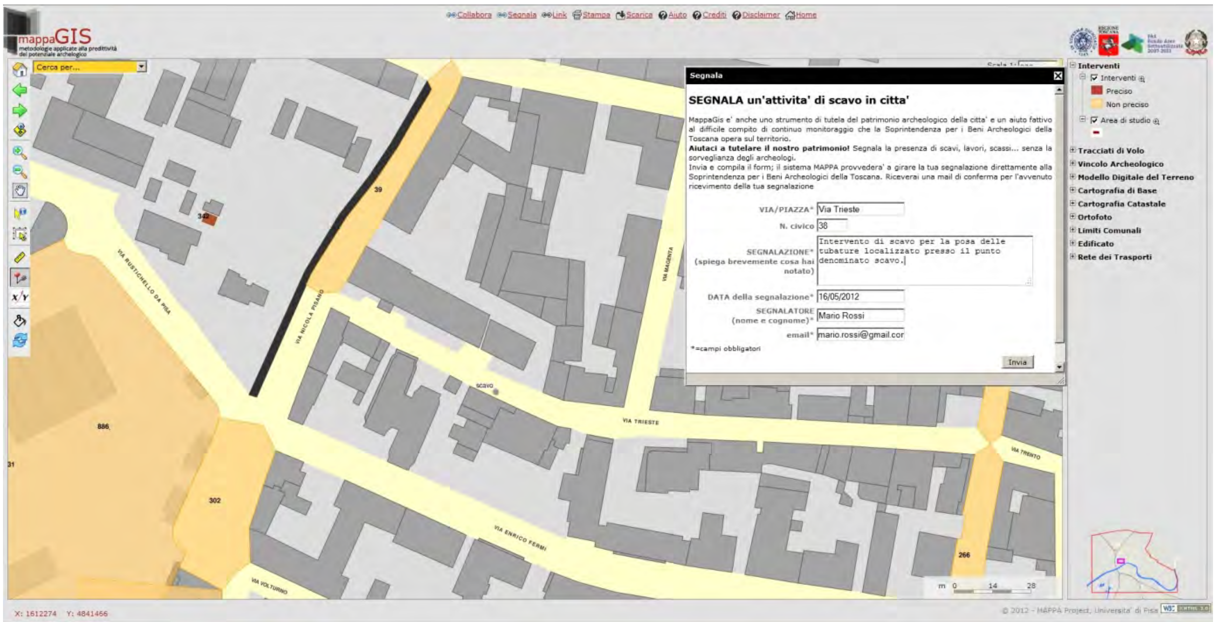
The graphic interface (Figure 5.1) of the MAPPAgis comprises a ribbon, a toolbar on the left, a content window on the right and a centre map.

When opening the webGIS, the map is scaled on the intervention area and the following are visible:

- Area of study;
- Themed interventions on the basis of the georeferencing accuracy;
- Hydrography;
- Built areas;
- Railway network;
- Road system.

The ribbon contains the name of the webIGS and the logos, as well as a series of data exportation, user assistance and active cooperation tools. By clicking on *link*, the URL is displayed on the screen where the user is working, who can copy it and open it later or send it to another user. By clicking on *print*, the user can print the screen display of the map together with the key of the levels viewed, metrical references and scale. By clicking on *download,* the user can download the screen display of the map as an image file in .png with different resolutions or as a georeferenced raster image in .geotiff format. The *help*, *disclaimer* and *credits* assistance tools guide the user through the webGIS functions, the rules regulating use of the webGIS and correct quoting of data, and the information about the workgroup that developed the MAPPAgis, respectively. The *cooperate* and *report* tools (see §5.4), allow direct cooperation with the Project (with an eye towards archaeology 2.0) and active participation by the user in improving the webGIS, updating it and improving its effectiveness. The two links address highly specialised archaeological users and active citizens, respectively. The link *cooperate* allows users to report an error both in the positioning of an intervention and in the respective database, and/or to implement the data with new interventions, by downloading a .shp file for georeferencing the intervention area and a template for entering the textual data (Figure 5.2). Once the update has been acquired by the MAPPA system and checked, it will be uploaded in the webGIS. Finally, the *home* link takes users back to www.mappaproject.org.

The toolbar allows users to move around the map, zoom, obtain information about objects (Figure 5.3), select objects on the basis of a rectangular selection, make linear or surface measurements with the ruler tool, position point graphs which can be named at will, modify the transparency of single layers and update the map.



SEGNALA un'attivita' di scavo in citta'

MappaGis e' anche uno strumento di tutela del patrimonio archeologico della citta' e un aiuto fattivo al difficile compito di continuo monitoraggio che la Soprintendenza per i Beni Archeologici della Toscana opera sul territorio.

Aiutaci a tutelare il nostro patrimonio! Segnala la presenza di scavi, lavori, scassi... senza la sorveglianza degli archeologi.

Invia e compila il form; il sistema MAPPA provvedera' a girare la tua segnalazione direttamente alla Soprintendenza per i Beni Archeologici della Toscana. Riceverai una mail di conferma per l'avvenuto ricevimento della tua segnalazione

VIA/PIAZZA* Via Trieste
N. civico 38
SEGNALAZIONE* (spiega brevemente cosa hai notato) Intervento di scavo per la posa delle tubature localizzato presso il punto denominato scavo.
DATA della segnalazione* 16/05/2012
SEGNALATORE (nome e cognome)* Mario Rossi
email* mario.rossi@gmail.cor

*=campi obbligatori

Invia

Fig. 5.1 The webGIS may be used for reporting excavations that are not monitored by archaeologists by filling in a form and highlighting the position of the excavation with the pointer (red pin on the toolbar).

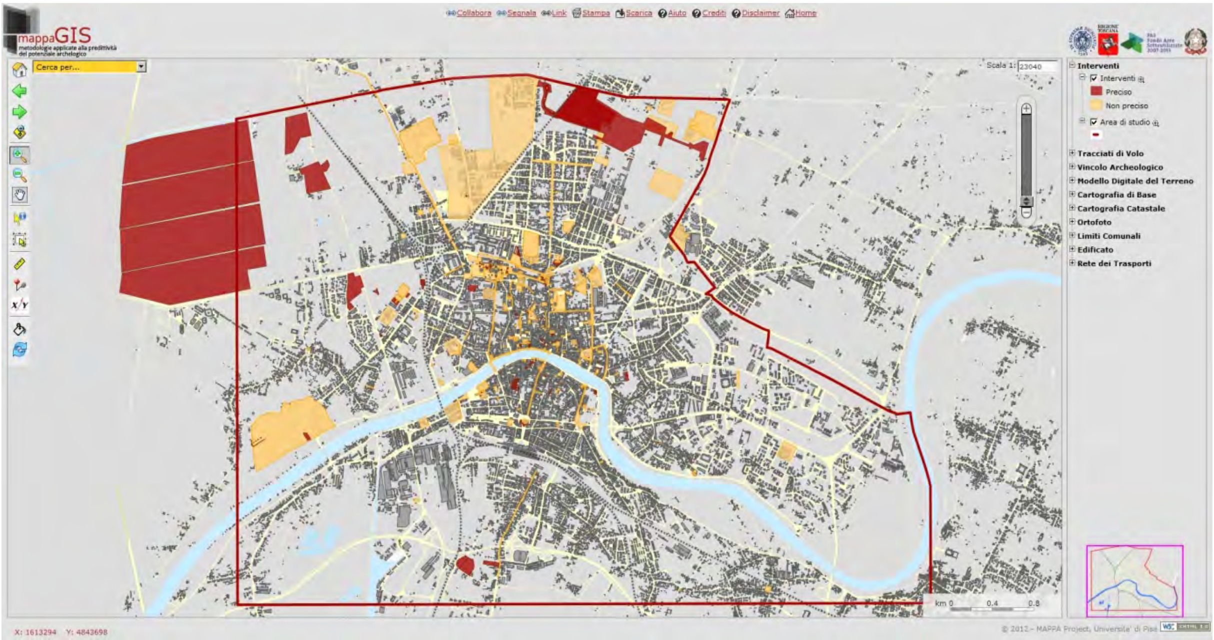


Fig. 5.2 The initial screen display of the MAPPAgis. The horizontal ribbon at the top, the toolbar and the *Search by…* tool on the left, the content window with the active thematic queries and those that can be enabled on the right, and the map in the centre.

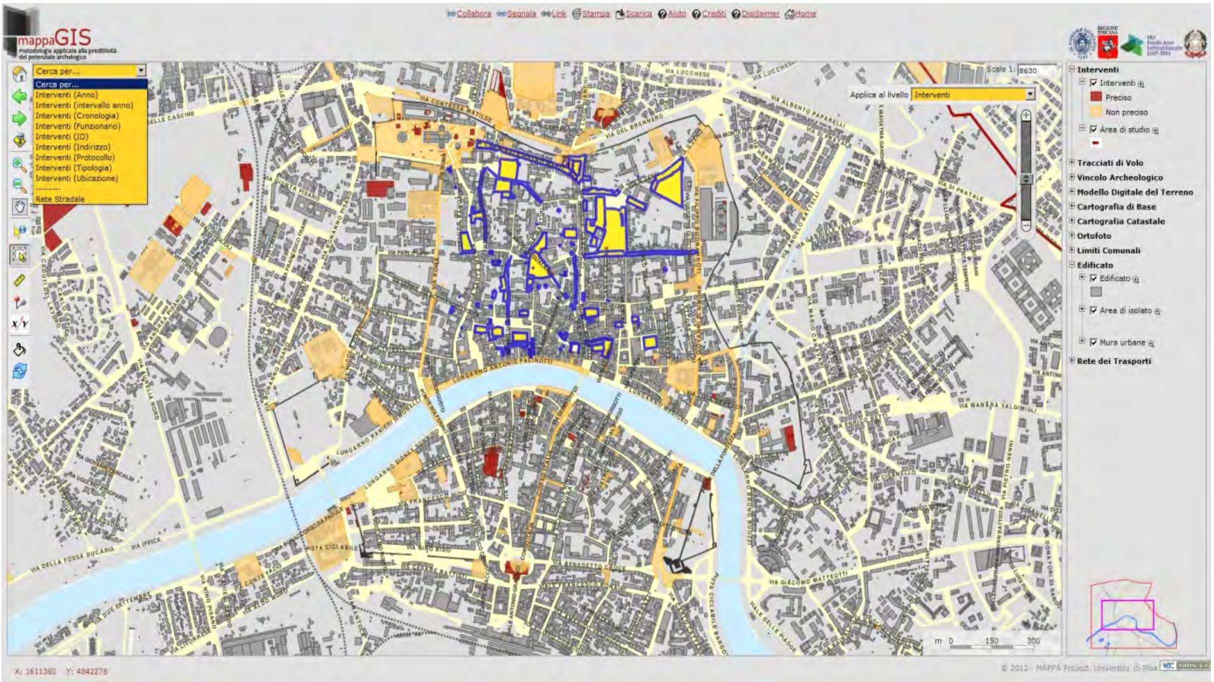


Fig. 5.3 The *Search by…* menu on the left and view of the interventions selected (yellow with blue edges) in the centre.

The content window shows all the levels within the webGIS and allows users to activate and/or disable them at will and zoom on them.

The map is provided with a numerical scale that can be modified by users, with a zoom bar and with a metric scale.

Two different searches can be made in the MAPPAgis: simple search and advanced search. Simple searches can be made using the *Search by* menu underneath the ribbon. Users can choose between various levels and then individual fields within the levels.

5.6.1 Interventions

Regarding the interventions, a simple search can be made related to the following fields:

- *Intervention:* for searches by intervention number;
- *Location*: free search allowing users to enter the name of a road, building, etc. and check whether there are any interventions related to it;
- *Road/Square:* a guided search based on the city's toponymy that shows all the interventions carried out in a specific road or square;
- *Type of intervention* (see § 8.3): a guided search allows user to view interventions by type of intervention carried out;
- *Year of execution*;
- *Protocol no.:* free search by protocol number;
- *Official of reference:* a search can be carried out on the official of reference for the intervention.

The last two searches were specifically created for institutional users who wish to trace the location of the intervention and the categories of finds from the document available in their archives.

Once the search has been made, the map shows the location of the interventions; a summary window opens making it possible to zoom on the result and open the detailed record of each single intervention.

The advanced search allows users to make searches on several fields at the same time. In addition to the simple search fields, searches can also be made on the chronological period (Prehistory, Protohistoric age, Etruscan period, Roman period, Late Antiquity, Early Middle ages, Late Middle ages, Modern age, Contemporary Age), the three different levels of categorisation of finds, from general (Level I) to more specific (Level III), and the numerical fields regarding initial and final chronology, in order to define the chronological intervals[11] (table 5.1).

Chronology Thesaurus	**Numeric conversion**
Bronze age	-1900/ -901
Late Bronze age	-1150 / - 901
Iron age	-900 / - 721
Etruscan age	-720 / - 90
Etruscan orientalizing period	-720 / - 581 First* -720/-681 Medium* -680/-631 Late* -630/-581
Etruscan archaic period	-580 / - 481
Etruscan classical period	-480 / - 324
Etruscan hellenistic period	-323 / - 90
Roman period	-89 / 192
Late roman republic	-89 / -28
Roman imperial age	-27 / 192
Roman early imperial age	-27 / 68
Roman mid imperial age	69 / 192
Late Antiquity	193 / 600
Early Middle ages	601 / 1000
Early Middle ages VI-VIII century	601 / 800
Early Middle ages IX-X secolo	801 / 1000
Late Middle ages	1001 - 1491
Late Middle ages XI-XIII century	1001 / 1300
Late Middle ages XIV-XV century	1301 / 1491
Modern age	1492 / 1814
Modern age XVI century	1492 / 1600
Modern age XVII century	1601 / 1700
Modern age XVIII century	1701 / 1814
Contemporary age	1815 / data intervento
Contemporary age XIX century	1815 / 1900
Contemporary age XX century	1901 / 2000
Non identified	

Tabella 5.1

The download button (Figure 5.4) downloads the search results in .csv and .pdf format.

The complete record of the intervention contains a series of data which will be explained below so that they can be correctly understood by users and consistently used by them. This first part of the record contains the intervention details: a number that univocally identifies the intervention and must be used for a correct bibliographical citation of the record in a publication or document; its location and correct topographical

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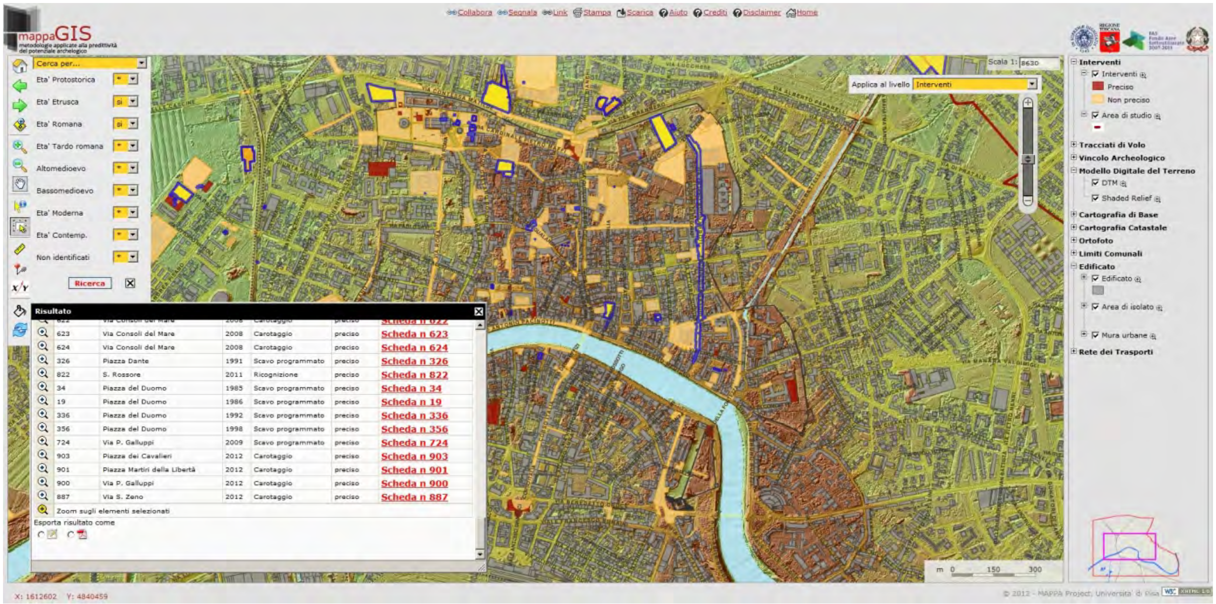
[11] The decision to use numerical fields rather than textual fields (see § 4.1.1.6.2) is due to the need to avoid cultural incomprehension.



623	Via Consoli del Mare	2008	Carotaggio	preciso	Scheda n 623
624	Via Consoli del Mare	2008	Carotaggio	preciso	Scheda n 624
326	Piazza Dante	1991	Scavo programmato	preciso	Scheda n 326
822	S. Rossore	2011	Ricognizione	preciso	Scheda n 822
34	Piazza del Duomo	1985	Scavo programmato	preciso	Scheda n 34
19	Piazza del Duomo	1986	Scavo programmato	preciso	Scheda n 19
336	Piazza del Duomo	1992	Scavo programmato	preciso	Scheda n 336
356	Piazza del Duomo	1998	Scavo programmato	preciso	Scheda n 356
724	Via P. Galluppi	2009	Scavo programmato	preciso	Scheda n 724
903	Piazza dei Cavalieri	2012	Carotaggio	preciso	Scheda n 903
901	Piazza Martiri della Libertà	2012	Carotaggio	preciso	Scheda n 901
900	Via P. Galluppi	2012	Carotaggio	preciso	Scheda n 900
887	Via S. Zeno	2012	Carotaggio	preciso	Scheda n 887

Zoom sugli elementi selezionati

Esporta risultato come

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Fig. 5.4 The interventions that have brought to light both Etruscan and Roman finds highlighted (yellow with blue edges) on the DTM (with shaded relief) developed by LiDAR. The result record (bottom-left) may be used for exporting the list of results as .csv or .pdf, opening the complete record (red link on the right) or zooming each single intervention (zoom tool on the left).

positioning according to the municipality's official toponymy in the road/square field; year of execution; maximum depth reached (when known) expressed in metres from the surface; and the Principal Investigator of the intervention and its executor. A second part describes the source(s) used for registering the intervention and points out whether the information was taken from documents preserved in archives or published documents, and details of the primary source: protocol number, type of document, official of reference if coming from the Superintendency archives, bibliographical record in the case of published data. Some records contain both archived and published documentation, always reporting the main source of information. The bibliography item either repeats the bibliography already cited or expands it with the main bibliography of reference dealing with the intervention. The drawn, photographic and written documentation fields inform users about the presence, or less, of different types of documentation inside an archive, without detailing, however, its quality[12]. The categorisation of finds is divided into three different levels (see Table 1 Appendix), associated to the related chronology expressed as text or numbers.

5.6.2 Aerial archaeology

The traces level contains the synthesis of all the traces recorded from the aerial photographs (see § 4.1.1.5). Simple searches can be made on the following fields:

- *Trace no.;*
- *Year of flight;*
- *Photo-interpretation code (see § 9.1.1)*
- *Description of trace;*
- *Interpretation;*

0 *Type of trace.*

5.7 Spatial analysis

MAPPAgis is a continuously evolving tool, conceived to improve its functions over time. The progress of research will increase the levels published, possible searches and analysis tools. Alongside searches that allow the desired features to be located, it will be possible to carry out simple spatial analyses directly on the web,

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[12] Quality may be deduced from the "reliability" item described further on.

without the need to possess specialised knowledge of GIS software. For this reason, although not upon the first release of the webGIS, it will be possible to make searches on the basis of a buffer; starting from an accurate location, such as an area in which an intervention must undergo a VIARCH, the buffer will identify the location of nearby interventions and evaluate the archaeological interest of the area under examination.

[G. G.]

6. The mappa project webgis: system architecture and future scenarios

Valerio Noti *(DOI: 10.4458/8219-09)*

6.1 Introduction

The MAPPA webGIS platform (MAPPAGIS) was designed as a digital mapping tool for making the publication of the archaeological, geological and geomorphological data produced during the project freely accessible on the web. Its aim was also to significantly contribute to ensuring knowledge of Pisa's archaeological heritage. Specifically, thematic queries of scientific and public interest regarding archaeological information, geological and geomorphological mapping, and the map of archaeological potential will be made available.

The main objective is to develop an interactive and user-friendly tool for local governmental institutions, heritage protection bodies, professionals, researchers, enthusiasts and the civil society as a whole, without distinctions or priorities. We believe this approach is essential not only with the aim to access and share knowledge but also to use the platform as a decision-making support for protecting local areas and also for governance and research purposes. Bearing this in mind, it is important to remember one of the main advantages of a webGIS, i.e., its user friendliness, making it therefore, highly accessible to a large array of users that would otherwise not be reached.

6.2 Technological platform and general architecture of the system

MAPPAGIS was developed using Open Source technologies. The general architecture is composed of:

- An Apache web server[1]
- A webGIS Application Server (MapServer[2])
- A front-end framework (p.mapper[3]) of MapServer

The system is currently installed on a machine inside the MAPPA laboratory intranet, at the Polo Didattico "Ex-Guidotti" of Pisa University.

The server is exclusively dedicated to the webGIS application and is provided with a Quad Core 64bit processor with 3.4 GHZ frequency, 8 GB RAM and 1 TB Hard Disk. The application was installed on a virtual machine with Linux Ubuntu[4] Server 10.04 LTS (Lucid Lynx) operating system, with dedicated hardware resources: 5 GB RAM and 300 GB disk space. The physical host machine is provided with a Microsoft Windows Server 2008 Web Edition[5] operating system, the only non Open-Source resource of the infrastructure. Virtualisation is managed using Oracle Virtual Box[6] 4.1. Since this configuration uses just one virtual machine, load balancing was not necessary.

Regarding the networking configuration, the physical host machine is provided with an IP address published by Servizi di Rete dell'Università di Pisa - SerRA[7] (Network Services for Pisa University). In order to avoid exposure to the outside world of two network interfaces with public IP, a port forwarding service was implemented using rinetd[8] open source software, which redirects calls

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[1] http://httpd.apache.org/.

[2] http://mapserver.org/.

[3] http://www.pmapper.net/.

[4] http://www.ubuntu-it.org/.

[5] http://www.microsoft.com.

[6] https://www.virtualbox.org/.

[7] http://www.serra.unipi.it/.

[8] http://www.boutell.com/rinetd/.

to the virtual machine on a specific port. Network performances towards the webGIS server were improved by increasing the TCP buffer and ensuring optimal throughput. Monitoring of both access speed and transfer of files was carried out using control tools. Despite the latency unavoidably introduced by the network interface virtualisation process, the monitoring results were very positive with a good University network speed and excellent browsing experience when using the webGIS.

The decision to install the system on a virtual machine was basically due to the obvious advantages of virtualisation technology, in terms of platform management, optimisation and maintenance. This technique allows easier duplication, updating and debugging-activities that require transfer of just one file from the development to the production machines. Furthermore, at the end of the project (set for June 2013), the application will probably have to be transferred to a new server located at one of the partner's premises. Virtualisation will allow the infrastructure to be easily transferred and installed on the physical servers with MS Windows, Linux or Unix operating systems without the need for specific technical configurations. Further benefits will also be achieved due to the extremely short disaster recovery time in the case of server malfunctioning; this is particularly important after the end of the project because less specialised human resources will be needed. Finally, virtualisation will allow easy replication of the application by the working team for similar projects, which may be handled with more rapid IT-technical procedures.

The MAPPA webGIS is based on MapServer[9] 6.0.2 software, an open-source mapping rendering engine for the publication of spatial data, which was originally developed by the University of Minnesota (UMN) in cooperation with the Minnesota Department of Natural Resources (MNDNR) and NASA. The project is currently managed by an international team, directed by OSGeo[10] (Open Source Geospatial Foundation). MapServer is widely used in production environments and is currently considered a world reference for open-source web mapping solutions. The web interface is based on p.mapper[11] (release 4.2), a framework developed by Armin Burger and distributed with GNU General Public License. P.mapper uses PHP/MapScript, a module that makes MapServer functions and classes available in a PHP environment. The database services of the webGIS application are provided by PostgreSQL 8.4[12], an object-relational database based on SQL language and strictly conformant to ANSI-SQL:2008 standards, equipped with PostGIS[13] spatial extension, developed by Refractions Research and in compliance with Open Geospatial Consortium specifications. The Linux virtual machine exposes the network services through Apache HTTP Server 2.2 software (Apache Software Foundation)[14] to listen on a specific TCP/IP port.

With regard to the programming tools, the following server-side scripting languages are used: PHP 5.3, Javascript and Ajax technology (Asynchronous JavaScript and XML)[15].

All software packages were compiled manually in Debian-Ubuntu environment using GCC (GNU Compiler Collection)[16]. Pre-compilation of additional software libraries[17] was also necessary to guarantee compatibility with various data formats and to improve rendering in MapServer environment.

The webGIS returns a XHTML 1.0 Strict validated code and may be consulted from any web

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[9] http://mapserver.org/.

[10] http://www.osgeo.org/.

[11] http://www.pmapper.net/.

[12] http://www.postgresql.org/.

[13] http://postgis.refractions.net/.

[14] http://www.apache.org/.

[15] http://en.wikipedia.org/wiki/Ajax_(programming).

[16] http://gcc.gnu.org/.

[17] libPng 1.5, libecw 2.3, libgd 2.0, libproj 4.7, libcurl 7.23, giflib 4.1, GDAL 3.3, AGG 2.4, pdflib (lite) 7.0.

browser compatible with W3C (World Wide Web Consortium)[18] standards: Mozilla Firefox 7+, Google Chrome 10+, Microsoft Internet Explorer 7+, Safari 4+, etc.

6.3 Security

The network of Pisa University is not provided with routing devices or NAT (Network Address Translation) interfaces for securing the machines exposed to the outside world with a public address. For this reason, system security measures were taken with the aim to check and block any anomalous incoming traffic or accesses. The machine upon which the webGIS is hosted is placed behind a Linux firewall server specifically set up with scripts for the definition of the access policies. A DMZ (demilitarized zone) was generated, which may be accessed from the MAPPA laboratory local network – for updating the data through a file system with controlled access – and from the Internet for web consultation. Furthermore, the firewall was set up on the physical server with a Microsoft Windows Server operating system using highly conservative security policies; the IIS (Internet Information Server) software was disabled since only port forwarding towards the virtual machine is necessary.

Regarding the back-up strategies, strict redundant saving and disaster recovery procedures were created in the intranet network with RAID disks, periodical backups and automated backups on NAS placed in another structure of the university.

Finally, a remote server status monitoring system was set up. Email alerts are sent if the service is interrupted or the network cannot be reached.

6.4 WebGIS interface functions

The MAPPA project webGIS is based on p.mapper[19] framework. This is a MapServer client solution which is frequently used by the Italian Public Administration; processing is mainly assigned to the server mapping engine and PHP/Mapscript scripting is extensively used. This technological platform was considered suitable for the project purposes given the availability and quality of its browsing or search tools, and for the fact that the interface can be easily personalised. Subsequent webGIS releases will include implementation of specific custom routines and the development of additional functions than those provided by standard platforms.

The p.mapper/MapServer solution is managed by dynamic development teams and supported by a reliable international community. It also guarantees compatibility with common data formats (PostGIS, Shapefile, etc.) and full compliance with OGC[20] (Open Geospatial Consortium) WMS and WFS standards, as well as the possibility to easily implement a multi-language system.

The easy-to-use interface (Figure 6.1) has a large number of functions, most of which are typical of web mapping systems: users can view data with usual map browsing tools (zoom and pan), extract information from features using point or areal queries at various levels, export results, analyse and interpret data, perform searches on database attributes, and measure distances and surfaces interactively.

The MAPPA webGIS also has external plugins for p.mapper, such as zoom commands on the overall area of a layer, the possibility to change the transparency of single layers (raster and vectorial) for easier overall viewing, the introduction of points of interest and the search by coordinates. PDF printing is also available with setting of scale, format and paper orientation. The portion of the area viewed can be exported in PNG image format and an interactive localiser is also provided to help users browse the area of study.

All application functions are based on Dynamic HTML (DHTML) technology which avoids the

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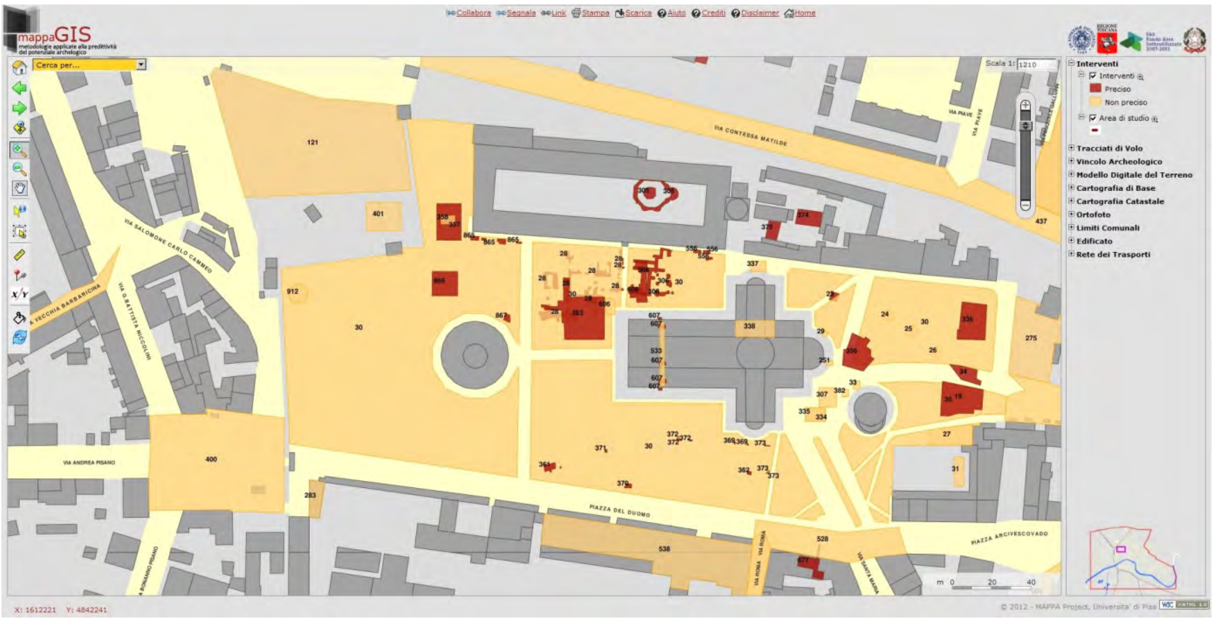
[18] http://www.w3.org/.

[19] http://www.pmapper.net/.

[20] http://www.osgeo.org/.



6.1 User interface of the MAPPA webGIS.

need to refresh the page after the browsing tools have been used; this considerably enhances consultation and increases user interactivity.

The spatial layers (raster or vectorial) are structured in categories and checkboxes can be used to make them visible or non-visible. Their management and the definition of graphic attributes and intervals of visibility for each single layer are performed by the MapServer engine through configuration of a classic mapfile (edited and set up manually) and by the p.mapper interface with XML files.

6.5 Infrastructure of the geographical data

The information layers produced by the research team and the basic mapping available for the city of Pisa are collected and accessible in the webGIS. The infrastructure of geographical data is directly related to that implemented in the MAPPA laboratory intranet and workstations. The geo-spatial layers produced are initially provided in shapefile or ESRI Geodatabase format and subsequently archived in the PostGIS database after validation and final testing. With regard to non-geographical data related to the webGIS levels, pre-existing software applications in Microsoft Access format are used in the laboratory; in this case also, a gradual conversion to PostgreSQL format is envisaged.

The first release of the webGIS included publication of the following main information layers:

- "Archaeological Information Layer": thematic query used for representing subsurface archaeological interventions. The intervention attributes, which are archived on a postgreSQL database, can be called through point or areal query buttons which allow viewing of a DHTML window containing summary data from which a detailed information record can be opened, using Hyperlink, which contains the categorisation of the findings in a one-to-many connection (Figure 6.2)
- "Map of aerial photographic anomalies", developed by interpreting the traces determined from buried items and recorded from aerial photographs from 1943 onwards.
- "Archaeological constraints", including the constraints contained within the MAPPA investigation area (provided by Consorzio LaMMA[21] and supervised by the Direzione Regionale toscana del Ministero dei Beni Cul-

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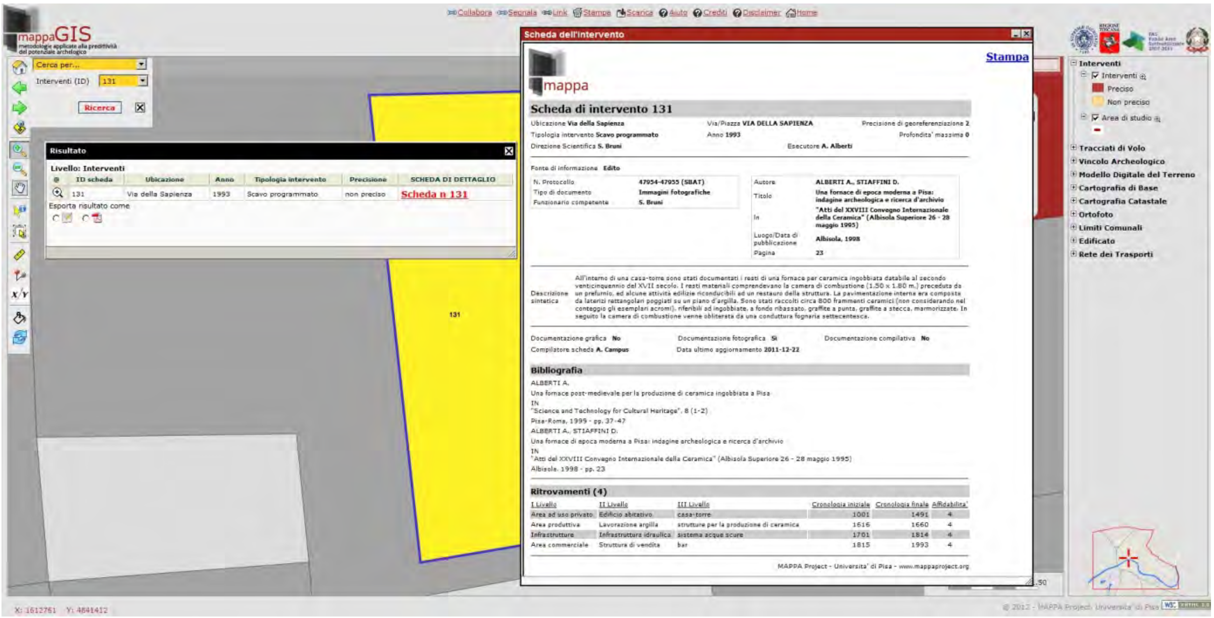
[21] http://www.lamma.rete.toscana.it/ (cfr. §7).



Risultato

Livello: Interventi

@	ID scheda	Ubicazione	Anno	Tipologia intervento	Precisione	SCHEDA DI DETTAGLIO
	131	Via della Sapienza	1993	Scavo programmato	non preciso	Scheda n 131

Esporta risultato come

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Scheda di intervento 131

Ubicazione **Via della Sapienza** Via/Piazza **VIA DELLA SAPIENZA** Precisione di georeferenziazione **2**

Tipologia intervento **Scavo programmato** Anno **1993** Profondita' massima **0**

Direzione Scientifica **S. Bruni** Esecutore **A. Alberti**

Fonte di informazione **Edito**

N. Protocollo	**47954-47955 (SBAT)**
Tipo di documento	**Immagini fotografiche**
Funzionario competente	**S. Bruni**

Autore	**ALBERTI A., STIAFFINI D.**
Titolo	**Una fornace di epoca moderna a Pisa: indagine archeologica e ricerca d'archivio**
In	**"Atti del XXVIII Convegno Internazionale della Ceramica" (Albisola Superiore 26 - 28 maggio 1995)**
Luogo/Data di pubblicazione	**Albisola, 1998**
Pagina	**23**

Descrizione sintetica: All'interno di una casa-torre sono stati documentati i resti di una fornace per ceramica ingobbiata databile al secondo venticinquennio del XVII secolo. I resti materiali comprendevano la camera di combustione (1,50 x 1.80 m.) preceduta da un prefurnio, ed alcune attività edilizie riconducibili ad un restauro della struttura. La pavimentazione interna era composta da laterizi rettangolari poggiati su un piano d'argilla. Sono stati raccolti circa 800 frammenti ceramici (non considerando nel conteggio gli esemplari acromi), riferibili ad ingobbiate, a fondo ribassato, graffite a punta, graffite a stecca, marmorizzate. In seguito la camera di combustione venne obliterata da una conduttura fognaria settecentesca.

Documentazione grafica **No** Documentazione fotografica **Si** Documentazione compilativa **No**

Compilatore scheda **A. Campus** Data ultimo aggiornamento **2011-12-22**

Bibliografia

ALBERTI A.
Una fornace post-medievale per la produzione di ceramica ingobbiata a Pisa
IN
"Science and Technology for Cultural Heritage", 8 (1-2)
Pisa-Roma, 1999 - pp. 37-47
ALBERTI A., STIAFFINI D.
Una fornace di epoca moderna a Pisa: indagine archeologica e ricerca d'archivio
IN
"Atti del XXVIII Convegno Internazionale della Ceramica" (Albisola Superiore 26 - 28 maggio 1995)
Albisola. 1998 - pp. 23

Ritrovamenti (4)

I Livello	II Livello	III Livello	Cronologia iniziale	Cronologia finale	Affidabilita'
Area ad uso privato	Edificio abitativo	casa-torre	1001	1491	4
Area produttiva	Lavorazione argilla	strutture per la produzione di ceramica	1616	1660	4
Infrastrutture	Infrastruttura idraulica	sistema acque scure	1701	1814	4
Area commerciale	Struttura di vendita	bar	1815	1993	4

MAPPA Project - Universita' di Pisa - www.mappaproject.org

6.2 Detailed record of an intervention.

turali (Regional Directorate of the Ministry for Cultural Heritage).

- Hillshade from DTM (Digital Terrain Model), a result of LIDAR 2008 surveys (provided by Regione Toscana, 1m resolution).
- Vectorial cadastral cartography (provided by Centro Servizi "GIS.CA."[22], agreement between Regione Toscana and ANCI Toscana).
- Buildings, transport systems (road and rail) and water networks (taken from the Regional Technical Map 1:2.000 in shapefile format).

The application will be further updated and new thematic layers will be entered: from building archaeology to historical mapping, geomorphological mapping and publication of the Map of Archaeological Potential.

The p.mapper interface also provides advanced query functions which may be set up through XML files and which define search parameters within the geographical layers. Specifically, it is possible to search interventions by type, location and chronology. The possibility to make advanced queries by opening a specific form inside the database connected to the categorised findings will also be implemented.

Regarding the basemaps, the Technical Map of Regione Toscana was mainly used. The map is available in both raster and vectorial formats (shapefile and CAD) and was entered in the webGIS through the WMS Geoscopio[23] regional service.

The raster levels in 1:2.000 (rev. 3) and 1:10.000 scale of the Regional Technical Map can be consulted, together with the related vectorial index maps. Orthophoto maps in 1:10.000 scale, dating back to 1954 (black and white) and 2010 (coloured), were entered using the WMS system once again.

The WMS services of Regione Toscana guarantee consultation of geographical layers that are essential to the project purposes. A few limitations must be pointed out however. First of all, the minimum viewing scale (1:5.000 or 1:15.000) cannot be reduced. This means that maps (especially ortho-rectified aerial photographs) with lower scales cannot be consulted and that it is not possible to have a better global vision of the area. The Furthermore, the coverage areas cannot be de-

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[22] http://www.ancitoscana.it/servizi-ai-comuni/acquisizione-servizi-e-forniture/gisca-centro-servizi-regionale-sul-catasto/.

[23] http://www.rete.toscana.it/sett/territorio/carto/repertorio/geoscopio.htm. .

duced for many layers: cases in which data are missing (e.g. in the Regional Technical Map 1:2.000) are frequent despite the presence of index maps. Finally, good quality orthophoto maps are hampered by the slow loading times of the WMS servers, probably due to inadequate compression of the image files.

6.6 Reference system

The geodetic-mapping system used by Regione Toscana is the Roma 40 Gauss-Boaga West zone (Code EPSG 3003), to which the webGIS aligned all mapping and thematic data. However, at the end of February 2012, a measure was issued in the Official Gazette (no. 48 of 27 February 2012, Decree of the Presidency of the Council of Ministers of 10 November 2011) regarding the adoption of a new national geodetic reference system called ETRF2000 (2008.0). The measure requires Public Administrations to use this system for new surveys and for converting previous data. In the light of this recent directive, all MAPPA thematic layers will be converted into ETRF2000 using the conversion tools provided by the Military Geographical Institute. The webGIS will implement the system once Regione Toscana has made the WMS service layers available with the updated EPSG codes.

6.7 Inspire directive and international standards

The webGIS was designed in compliance with OGC[24] (Open Geospatial Consortium) standards with reference to the requirements of interoperability with the European Parliament INSPIRE[25] directive specifications (INSPIRE, 2007) and with the indications of the National Register of Territorial Data DigitPA former CNIPA (National Centre for IT in the Public Administration). The layers generated by the MAPPA research group will be available according to web services based on OGC standards (OGC, 2010) such as WMS (Web Map Service), WFS (Web Feature Service) and WCS (Web Coverage Service). Users can use these services to consult and question geographical layers through other GIS desktop software or servers.

Since these services need suitable side-server performances, the technical possibility to use the WMS Geoscopio[26] service of Regione Toscana (MAPPA partner) for their diffusion will be considered. OGC standards will be implemented immediately after the first issue of the webGIS. A specific web section will also be created that will describe the procedures needed to use the web services and will provide the links for GetCapabilities requests and the URLs to access the server.

The National Register of Territorial Data[27] portal has been online since April 2012; it was set up at DigitPA under Article 59 of the Code of Digital Administration and in compliance with the aforementioned Ministerial Decree of November 2011. The technical specifications required for compiling the metadata are being published on the portal, as also the procedures for data supply from public administrations. As soon as they will become available, the MAPPA webGIS information layers will be provided with meta-information in compliance with standard ISO/TC211 and EC regulation no. 1205/2008 implementing the INSPIRE directive regarding metadata.

6.8 The webGIS lifecycle. Maintenance and updating problems.

The choice of a totally Open Source platform significantly reduces implementation costs and guarantees independence from individual suppliers or proprietary data formats. In the webGIS field, Open Source technologies have become stable and reliable over the years, often more than proprietary systems. In our opinion, this

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[24] http://www.osgeo.org/.

[25] http://inspire.jrc.ec.europa.eu/index.cfm/pageid/3.

[26] http://www.rete.toscana.it/sett/territorio/carto/repertorio/geoscopio.htm.

[27] http://www.rndt.gov.it/.

choice allows long-term planning, otherwise not possible in conditions with limited resources.

This is certainly a very delicate aspect: one of the main critical aspects (and often reason for debate) of webGIS applications is the duration of the system's life cycle. Unfortunately, a large number of systems implemented over the past years by various subjects and in different territorial management sectors have become rapidly obsolete, have not been updated and as a result have been abandoned. The reasons for this are numerous: incorrect design, lack of resources, system scalability not envisaged, or portability to other hardware or software platforms not planned.

Because of the nature of webGIS, if the data are not updated after the first releases and if the systems are not open to the outside world, this leads to obsolescence and death of the applications, although still accessible.

To prevent these risks and guarantee long life to the webGIS tool even "after the IT experts have gone away", the research team has undertaken a journey that started with the decision to use Open Source technology and that seeks to facilitate data exchange with other operators, even after the end of the project in June 2013. The aim is to respond to the critical aspect of short-term projects such as MAPPA, i.e. system maintenance, data updating and interoperability between external entities and project partners. This is certainly an ambitious goal which will call for technical and scientific meetings, evaluation of necessary resources and activity planning, including also the portability of the application to other platforms, with quite minimum technical efforts.

The first release offers the possibility to report archaeological interventions that are not present on the maps and to request an inspection by the project participants. The webGIS, however, has been conceived to enable maximum participation and interoperability: external entities must be entitled to actively contribute to updating the geographical database, thus delivering a gradual and continuous flow of data towards the application. The procedures required to ensure this flow are being studied by the research group and will take shape during the subsequent releases with the definition of specifications made available on the website. Among the suggestions, providing a template layer in shapefile format which has the same structure as the database of the webGIS geographical levels. External users will thus be able digitise geographical features in GIS desktop environment and upload the data through the project website, together with the meta-information. After technical and conceptual checking, an automated procedure will integrate the updates inside the official database.

Another possible solution is strictly based on participation, originating from international experiences such as FixMyStreet[28] or national projects such as IRIS[29] of the Municipality of Venice; although these projects were set up for reporting problems of a different nature, they can certainly be taken into consideration for our purposes. This choice would lead the application towards a web 2.0 solution and to the possibility to easily integrate contents created by users into the database, thus increasing involvement by citizens and operators of the sector as well as general interest in the application. A participation-oriented solution would probably guarantee a long life cycle and make the application gain greater visibility both on the web and on traditional information channels. A 'social mapping' approach – technically and scientifically screened by the project participants – would make the webGIS fit into an information-oriented 'smart city' which will become more and more important in local governance and management policies.

6.9 System scalability

The webGIS architecture has high hardware and software scalability. The platform currently implemented is suitable for a light workload, with a low number of contemporary accesses. The project team will make every effort to gradually in

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[28] http://www.fixmystreet.com/.

[29] http://iris.comune.venezia.it/. .

crease the number of system contacts and users. Virtualisation ensures easy portability to more powerful hardware systems than the current one, especially in cases requiring distribution of the application over several virtual servers, for example separating the MapServer from the DB Server.

A potentially critical aspect is related to the "server oriented" technology of the solution adopted. A high number of contemporary accesses can cause overloading, which the current architecture would find very difficult to handle, with excessive use of the servers' hardware resources and services slowing down or not being executed due to timing out. The p.mapper development team recently released a beta of the 5.0 version with integration of the Javascript OpenLayers[30] framework and a substantial transfer of the workload from the server to the client browsers; in substance, transfer to Google web mapping services (e.g. Google Map) technology.

Possible webGIS porting to version 5 of p.mapper, with an essentially client-oriented approach, will be evaluated on the basis of the performances of the current webGIS, of the access statistics and of the current beta roadmap. In IT terms, porting is not a particularly costly activity because the configuration files do not need to be newly designed or modified.

This reveals the high scalability of the technological solution adopted as well as the activities of the team developing the framework used.

6.10 Conclusions

The archaeological webGIS of the MAPPA project further confirms the reliability and performances of Open Source web mapping systems in general and of the p.mapper/MapServer solution specifically.

The platform was designed by giving utmost importance to the system's scalability, with initial hardware and software sizing suitable for circulating the first webGIS versions and the expected amount of use. Virtualisation guarantees low implementation costs and future portability, as well as easy system debugging and updating activities. It is important to point out that, already from its first publication, the webGIS is highly interoperable thanks to the use of WMS services; data may be consulted from different sources located on external servers or locally on the MAPPA server.

Online publication of project GIS data highlights the main advantages of webGIS technology: less assistance and maintenance, data exchange and sharing, and access to a potentially larger public guaranteed by a user-friendly tool. These potential benefits, however, must not make us forget the relative difficulty in updating these tools and the need to define measures capable of lengthening the system's life cycle, with a view to sharing information and actively involving all interested parties.

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[30] http://openlayers.org/.

7. The Geographical Information System for the Cultural and Landscape Heritage of Tuscany

Roberto Costantini, Luca Angeli *(DOI: 10.4458/8219-10)*

7.1 Introduction

During the three-year period 1999-2001, Regione Toscana, together with the Laboratorio per la Meteorologia e la Modellistica Ambientale - LaMMA (Laboratory for Meteorology and Environmental Modelling), currently Consorzio LaMMA, took part in the European INTERREG IIC Medoc Project called "Carta del Rischio" (Risk Map), jointly with other Italian and European regions and the Istituto Centrale per il Restauro - ICR (Central Institute for Restoration) of the Ministry for Cultural Heritage and Activities (MiBAC)[1] (COSTANTINI 2001 a).

The experience gained during the European project revealed that it was not easy to quickly or accurately retrieve information regarding the amount or exact location of cultural heritage in Superintendency archives, due to the enormous amount of documentation produced over a century of work (the first protection deeds refer to Law 364 of 1909) and to the toponymic and registration changes brought about over this long period of time. (COSTANTINI 2001 b).

This context was the basis for the subsequent regional project "Carta dei Vincoli" (Map of Restraints) (2001-2003), which developed into the Territorial Information System for the Cultural and Landscape Heritage of Tuscany. This tool is used today to consult the digital maps and alphanumerical archives relating to archaeological, architectural and landscape heritage subject to restraints throughout the region.

Given the exceptional amount of data (over 17,000 measures taken up to present day, amounting to over 85,000 pages scanned) and their historical overlapping, in order to obtain a uniform product capable of providing clear indications, the decision was taken together with MiBAC to focus on the identification of heritage subject to protective measures and to consider other catalogued or registered remains subsequently. Local administration bodies have thus been able to directly use a product that provides information (including geographical information) about all measures having legal effect and resulting in a specific administrative discipline.

7.2 Short historical overview of cultural heritage legislation

Prior to the unification of Italy, all the states had already issued more or less organic laws regarding the protection of antiques, works of art and archaeological heritage. The State of the Church, nevertheless, boasted a long tradition of regulations, for example, edits establishing police inspections on the preservation and trading of antiques and art. The edits aimed at preventing the destruction and dispersal of the masterpieces and works gathered in Rome more than in any other city: the extensive legislation of the Pontifical State includes the edit of Cardinal Pacca (1820), which was issued under the pontificate of Pius VII and is generally recognised as being the first organic legislative measure for the protection of artistic and historical heritage. It inspired similar measures taken by the Kingdom of Naples, Tuscany and Lombardy-Veneto. Piedmont, instead, lacked important legislative interventions, with

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[1] *Geographical system for the integration of the cultural and environmental heritage archives of Tuscany*, communication by Costantini R. during XII edition of the Public Administration FORUM (Rome 2001).

the sole exception of the Council for antiques and fine arts, created in 1832 with the aim to propose measures for the preservation of antiques and art. This period, therefore, was marked by the recognition of an artistic and historical heritage, however, apart from the State of the Church and the Kingdom of Naples, which were the only states to develop rules regulating preservation, restoration and excavation work, the notion of community cultural wealth cannot be found in the other states; for this reason, legislative deeds chiefly aimed at preventing heritage being carried out of the country.

After its unification, the Kingdom of Italy lost almost complete interest in cultural heritage. The prevailing ideology – which confirmed the inviolability of all properties through the Albertine Statue – did not favour public interference, which would have unavoidably led to the imposition of limits to individual and private initiatives. The only exception to this picture was the possibility to expropriate monuments in a state of ruin due to neglect by owners, granted to the State by Law 2359/1865.

The first codification of the principle of public interest, duty of preservation and instrumental powers of the public administration, with regard to artistic, historical and archaeological heritage, dates back to the start of XX century, when the public nature of artistic heritage and the need for it to be safeguarded by the State were set out for the first time through the enactment of Laws 185/1902 (Nasi) and 364/1909 (Rosaldi). However, it was only in 1939 (Laws 1089 and 1497) that the first important attempt was made to give an organic and well-defined structure to Italy’s cultural and landscape heritage legislation, by establishing a Council for education, science and arts, and reorganising the Supertintendencies. The aim was both to protect and valorise cultural heritage and activities, especially through funding and the use of credit facilities; the measures taken to guarantee heritage use and valorisation, however, were still relegated to the sidelines compared to the prevailing measures which sought to ensure preservation, protection and the imposition of limits to circulation.

The State started to protect and promote culture only after the Constitution of the Republic of Italy: Article 9 does not simply contemplate the “protection” of cultural heritage, but confirms the State’s “cultural duty” and the protection of “interests” inherent to cultural heritage. The expression “cultural heritage”, however, was introduced only recently, following ratification of the international conventions following the Second World War: it first appeared in the 1954 Hague Convention. Ten years later, the Franceschini Commission made an important contribution to the definition of cultural heritage as “all the assets […] which may be used collectively – regardless of public or private property – as material evidence of a value of civilization”.

The great novelty of most recent legislation is the passage from essentially restraining regulations (as in 1939) to the dynamic role of cultural heritage policies ensuring wide-ranging use of the cultural value of heritage. For the first time, the State is charged with the costs of restoration if the owner cannot bear them (Law 1552/1961); the term “valorisation” is introduced (used for the first time in Presidential Decree no. 805 of 1970) and tax relief (Law 512/1982) and donations are envisaged for the promotion of cultural events and for interventions improving the safety conditions of museums and cultural institutes. Furthermore, private individuals are allowed to directly participate in the management of ancillary paid services in museums, galleries and libraries (Law 4/1993). New important measures were subsequently introduced with the Consolidated Law on cultural and environmental heritage (Legislative Decree 490/99), which introduced the guarantee mechanisms and the procedures envisaged by Law 241/90 in the restraining proceedings. The Decree attributes greater responsibility to local authorities and broadens the scope of heritage protection to photographs, music scores, cinematographic and audiovisual works and other heritage which, although not listed, represents “evidence having a value of civilization”.

The new Code of Cultural and Landscape Heritage, which entered into force on 1 May 2004, replaced the Consolidated Law (Decree Law 490/90) and implemented important innovations. Its aim was to review cultural heritage legislation and to regulate in an organic and systematic manner the protection of cultural heritage, i.e. assets with historical and artistic qualities and with great landscape value. These innovations also envisage a broadening of the concept of Cultural Heritage towards new categories, such as rural architecture. The Code also simplifies the protection regime, as in the case of authorisations regarding interventions on cultural heritage and innovative preservation measures. The latter do not simply focus on restoration but also include prevention and maintenance, with emphasis placed on the new system of contributions. Another important aspect is the distinction between protection and valorisation: the former is a matter of exclusive legislative competence of the State, the latter of the Regions. A distinction is also made between public valorisation and private initiative, which is also considered an activity of social interest.

Another important novelty regards landscape heritage, whose protection and valorisation is attributed to both the Ministry and the Regions. With regard to landscape planning, the Code (Article 135) appoints the Regions with the duty to approve landscape plans, i.e. urban-territorial plans with specific regard to landscape values involving the entire regional area (COSTANTINI et alii 2004).

7.3 Creation of the "constitutional" archive

Following conclusion of the European project in 2001, Regione Toscana decided to fund the Carta dei Vincoli (Map of Restraints) project in cooperation with the former Regional Superintendency, currently the Direzione Regionale per i Beni Culturali e Paesaggistici della Toscana (Regional Directorate for the Cultural and Landscape Heritage of Tuscany). It appointed LaMMA to carry out as thorough an inventory as possible of the cultural heritage under protection and subsequently produce a database containing details of all the heritage and of the restraining architectural, archaeological and landscape measures; it also requested a GIS map of all protected areas and a catalogue containing the scans of all the documentation related to the restraining measures available in the regional Superintendencies.

This phase, which ended in December 2003, provided a picture of the restraining measures up to that date and produced a "constitutional" archive formed of over 15,000 protection measures which, overall, protect almost 7,000 immobile cultural assets of archaeological, architectural and landscape significance.

From an operational viewpoint, the following activities were addressed (COSTANTINI et alii 2005):

1) Analysing and choosing material in the Superintendency archives.
2) Photocopying all the documentation, including the plans, historical and artistic reports and notes related to all the protection deeds preserved in the offices of the regional Superintendencies.
3) Scanning the documentation acquired, creating a catalogue of images, indexed by deed identification number and heritage asset identification number (each heritage asset may have more than one restraining decree) and creating a catalogue containing around 60,000 images.
4) Creating an alpha-numerical database ("heritage assets" archive), providing information about the protected heritage asset (name, address, registration references, type of protection deed, etc.).
5) Creating an alpha-numerical database ("decrees" archive), providing indications on all protection deeds related to each single heritage asset.
6) Developing a GIS digital map of the protected areas, in line with the Regional Technical Map in 1:2.000, if existing, or 1:10,000 scale.
7) Creating a web portal for consulting the archives.
8) Creating an Internet Map Server, for consultation of the digital map, integrated in the web portal.

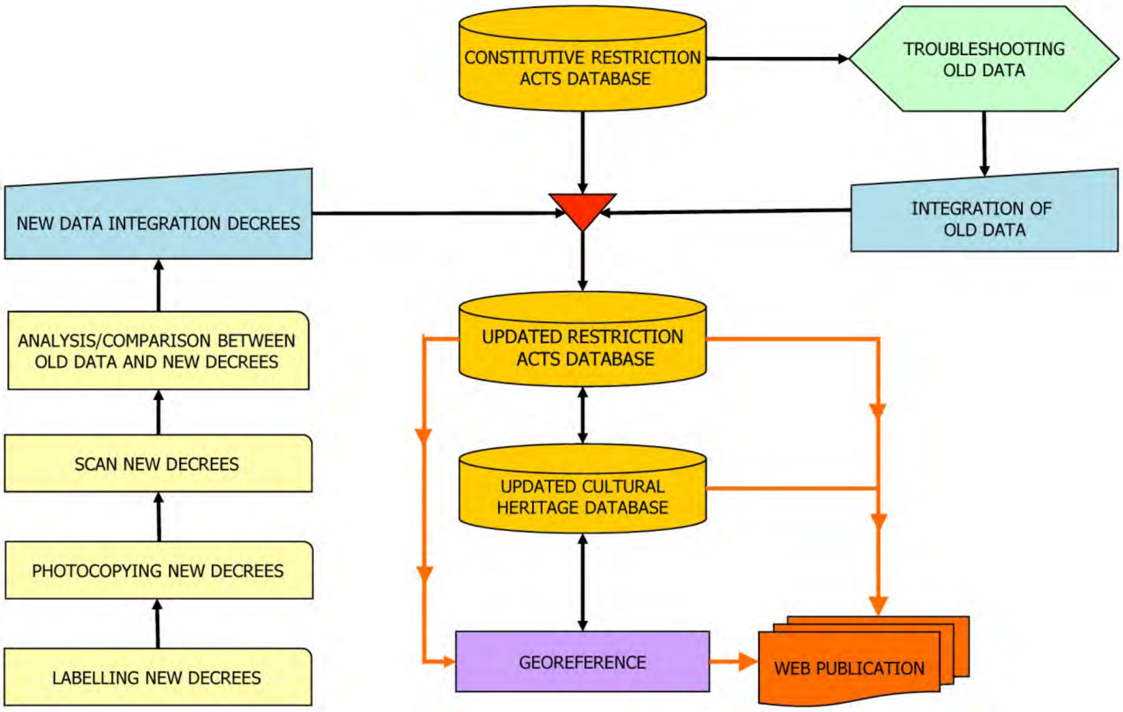
7.4 Continuous updating phase

Regione Toscana and the Direzione Regionale per i Beni Culturali e Paesaggistici del Ministero per i Beni e le Attività Culturali (Regional Directorate for Cultural and Landscape Heritage of the Ministry for Heritage and Cultural Activities) set up an agreement protocol (April 2004) with the aim to make the system maintain its validity and utility. In compliance with the protocol, a copy of all new protection deeds issued must also be sent to the regional offices and then to Consorzio LaMMa. The latter updates both the digital archives and the maps, making them easily accessible on the web[2]. Thanks to this agreement, Consorzio LaMMA has updated the entire Information System since 2004 on a quarterly basis, by computerising and georeferencing the new protection measures, gradually provided by the Regional Directorate.

As a result of the continuous updating activities,the measures amounted to 17,523 in December 2011, with a yearly average increase of around 250 measures, allowing the protection of over 9,000 archaeological, architectural and landscape heritage assets.

7.5 Consultation of products

The web portal of the Territorial Information System for Cultural and Landscape Heritage of the Region of Tuscany, which may be accessed via the homepage of the Regione Toscana (www.regione.toscana.it) or LaMMA (www.lamma.rete.toscana.it) websites allows free consultation of both GIS maps and computerised archives containing information of protected heritage and the respective measures taken. Authorisation to consult the



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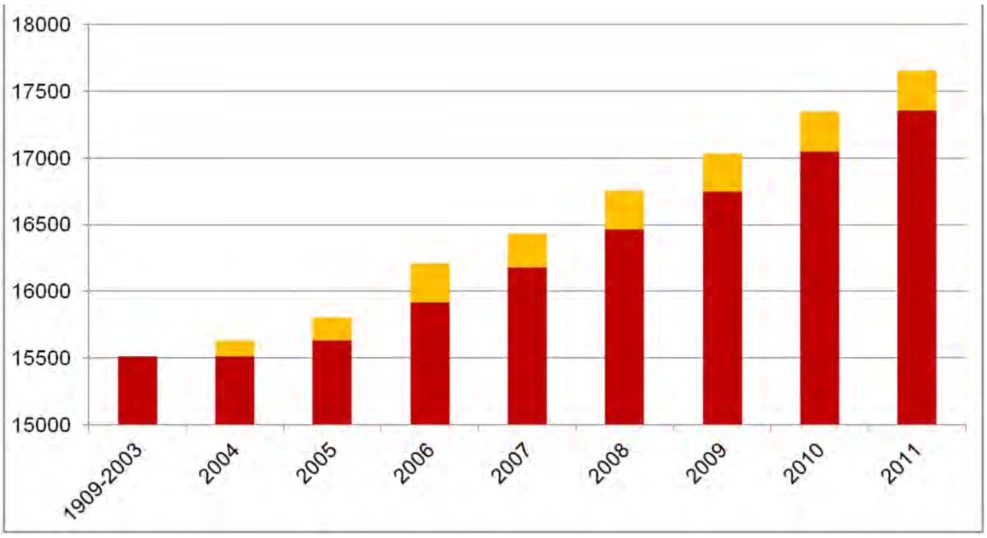
[2] *Strumenti e metodi per la tutela, la valorizzazione e la gestione del patrimonio culturale: verso il Sistema Informativo Territoriale per i Beni Culturali della Regione Toscana (Instruments and methods for the protection, valorisation and management of cultural heritage: towards a Territorial Information System of the Cultural Heritage of Tuscany)*, communication by Costantini R., Angeli L., Costanza L., Gregorini M. to the XVIII edition of the Public Administration FORUM (Rome 2007). *Il Sistema Informativo Territoriale per i Beni Culturali e Paesaggistici della Regione Toscana-* Dire & Fare (The Territorial Information System for the Cultural and Landscape Heritage of Tuscany), communication by Costantini R. to the XII exhibition on innovation in the Public Administration (Florence 2009).



7.2

La Regione Toscana (Direzione Generale Politiche Formative, Beni e Attività Culturali), avvalendosi delle competenze tecniche del LaMMA, ha predisposto un Sistema Informativo Territoriale per l'integrazione, la gestione e la consultazione in remoto degli archivi dei beni culturali immobili, finalizzato a supportare le funzioni di tutela e gestione amministrativa e quelle di promozione e valorizzazione.

Le principali banche dati presenti nel Sistema Informativo Territoriale dei Beni Culturali sono:
1. Beni architettonici vincolati, ai sensi delle leggi 364/09, 1089/39 e dei decreti legislativi 490/99, 42/04.
2. Beni archeologici vincolati, ai sensi delle leggi 364/09, 1089/39 e dei decreti legislativi 490/99, 42/04.
3. Beni paesaggistici vincolati, ai sensi delle leggi 1497/39 e dei decreti legislativi 490/99, 42/04.
4. Luoghi di culto.

Tutti questi "oggetti" sono georeferenziati, in formato poligonale, in modo tale da poter interagire con altre tipologie di archivi geografici.
Relativamente agli archivi e alle cartografie riguardanti i beni archeologici, monumentali-architettonici e paesaggistici, essendo beni soggetti a specifico vincolo, l'attività si è svolta in collaborazione con la Direzione Regionale per i Beni Culturali e Paesaggistici della Toscana (Ministero per i Beni e le Attività Culturali).

Saranno successivamente implementate anche le seguenti categorie di beni:
5. Architetture del '900.
6. Musei.
7. Teatri.
8. Parchi e giardini d'interesse artistico e/o storico, o di non comune bellezza.
9. Complessi fortificati.
10. Paesaggi geologici.

AVVERTENZA IMPORTANTE: I dati riguardanti i beni soggetti a provvedimento di tutela presenti nel sistema non hanno ancora valore di certificazione ufficiale. Sull'esattezza di tali dati è infatti in corso il controllo da parte della Direzione Regionale per i Beni Culturali e Paesaggistici della Toscana.
Le cartografie sono state realizzate a partire dai provvedimenti di tutela, con una rielaborazione per renderli coerenti con la base topografica regionale, operando quindi una trasformazione da cartografia catastale a cartografia tecnica, in scala 1:2.000 o 1:10.000.
La banca dati non comprende di norma le aree e gli edifici vincolati ope legis, quali le chiese e gli edifici pubblici, anche se di significativo interesse storico artistico.
Figurano tuttavia alcuni beni di proprietà di Enti che, in via di prima ricognizione, risultano tutelati ope legis: si tratta di una prima inventariazione non esaustiva riportata per fornire una visione più esauriente del patrimonio culturale della Regione.

7.3

scanned original documentation stored in the offices of the Tuscan Superintendencies, instead, is only granted to the staff of the Ministry for Heritage and Cultural Activities and of Regione Toscana, subject to the issuing of specific access credentials.

7.5.1. 'Decrees' database

A specific table was drawn up in agreement with the Direzione Regionale (Regional Directorate) of MiBAC (COSTANTINI *et alii* 2005), in which each record corresponds to a specific protection deed (decree, declaration, acknowledgment letter, authorisation for alienation).

The table fields are composed of:

- *Univocal identification code of the measure*, which univocally identifies the single deed
- *Univocal identification code of the heritage asset*, which identifies the asset referred to in a specific measure
- *Name* of the protected heritage asset, as reported in the text of the measure
- *Province* to which the protected heritage asset belongs
- *Municipality* to which the protected heritage asset belongs
- *Address,* which indicates the location as reported in the text of the measure
- *Date* in which the protection measure was issued
- *Notes*: any specific details found in the text of the measure by the compiler during the data-entry operations

7.5.2 'Heritage assets' database

Since heritage can be subject to more than one protection measure, this table is structured on a one-to-many ratio; this means that an asset can be associated with several protection measures, whereas a measure can only be associated to one heritage asset.

This database table is more complex than the 'decrees' database table because the identification data of a heritage asset can be the result of many different measures; an example is the name of protected heritage that changes over time (Palazza Gaulfonda, formerly Palazzo Giuntini, for instance), or when heritage is composed of several sub-parcels (or sub-sections) belonging to different owners.

The 'heritage assets' database is structured as follows:

- *Univocal identification code of the heritage asset*, which univocally identifies the asset at regional level
- *MiBAC univocal identification code*: the code with which a file related to a specific heritage asset is archived at the Superintendency office
- *Name* of the protected heritage asset, as reported in the text of the measure
- *Type*: indicates the "architectural" type of the heritage asset (e.g. abbey, fort, building, etc...)
- *Area of observance*: indicates whether the heritage asset is subject to direct or indirect protection
- *Province* to which the protected heritage asset belongs
- *Municipality* to which the protected heritage asset belongs
- *Address,* which indicates the location as reported in the text of the measure
- *Cadastral references*: the cadastral parcels which, if broken up over several decrees, constitute the area subject to protection
- *Legislation of reference of the first measure issued*: this field reports the law referred to by the first protection deed issued for that specific heritage asset
- *Date of issue of the first measure*: the date reported on the first protection deed issued for the specific heritage asset
- *Reference legislation of the most recent measure issued*: this field reports the law to which the most recent protection deed issued for that specific heritage asset refers to
- *Date of issue of the most recent measure*: the date reported on the most recent protection deed issued for the heritage asset
- *Notes*: any specific details resulting from the protection measures of the heritage asset

7.5.3 Maps

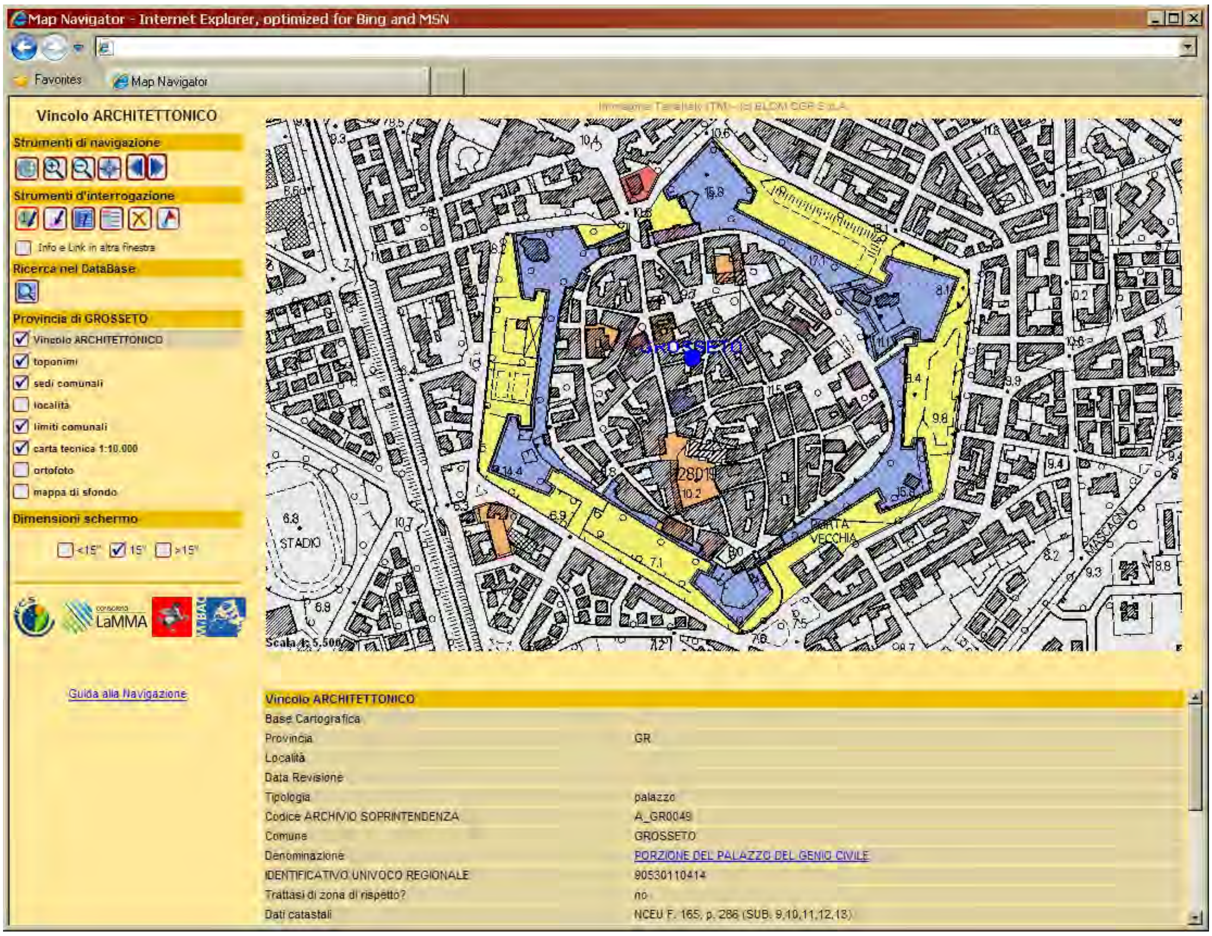
Given the complexity of the planimetric evolution of heritage, polygonal georeferencing was performed to accurately identify the areas subject to protection (MONTI, BRUMANA, edited by, 2004). The areas subject to archaeological restraints were mapped on the basis of cadastral maps because the perimeter elements often do not have a corresponding topographic item in technical maps and refer to parcel limits in extra-urban areas lacking artefacts.

Although identified in the decrees, the areas subject to architectural restraints were delimited using the regional technical map (usually 1:2,000 scale in urban areas and 1:10,000 scale in extra-urban areas) and by interpreting/converting the delimiting elements. Consequently, the maps produced are of a technical nature and can be directly used for territorial planning purposes (PIT, PTC, PSC, etc…).

Finally, the areas subject to landscape restraints, although mainly delimited through the description of items found on IGMI (Military Geographical Institute) 1:25,000 maps, were delimited using the regional technical map in 1:10,000 scale (ANGELI *et alii* 2010). The delimiting elements were accurately interpreted/converted and allowed up-scaling. The maps produced are again of a technical nature and may be directly used for territorial planning purposes (ANGELI et *alii* 2007).

7.5.4 'Scans' catalogue

The catalogue contains the scanned images of all the documentation related to heritage assets subject to restraining measures (decrees, plans, historical and artistic reports, etc.). Every paper document, photocopied in the Superintendency, was indexed using a specific label with a univocal progressive numerical code.



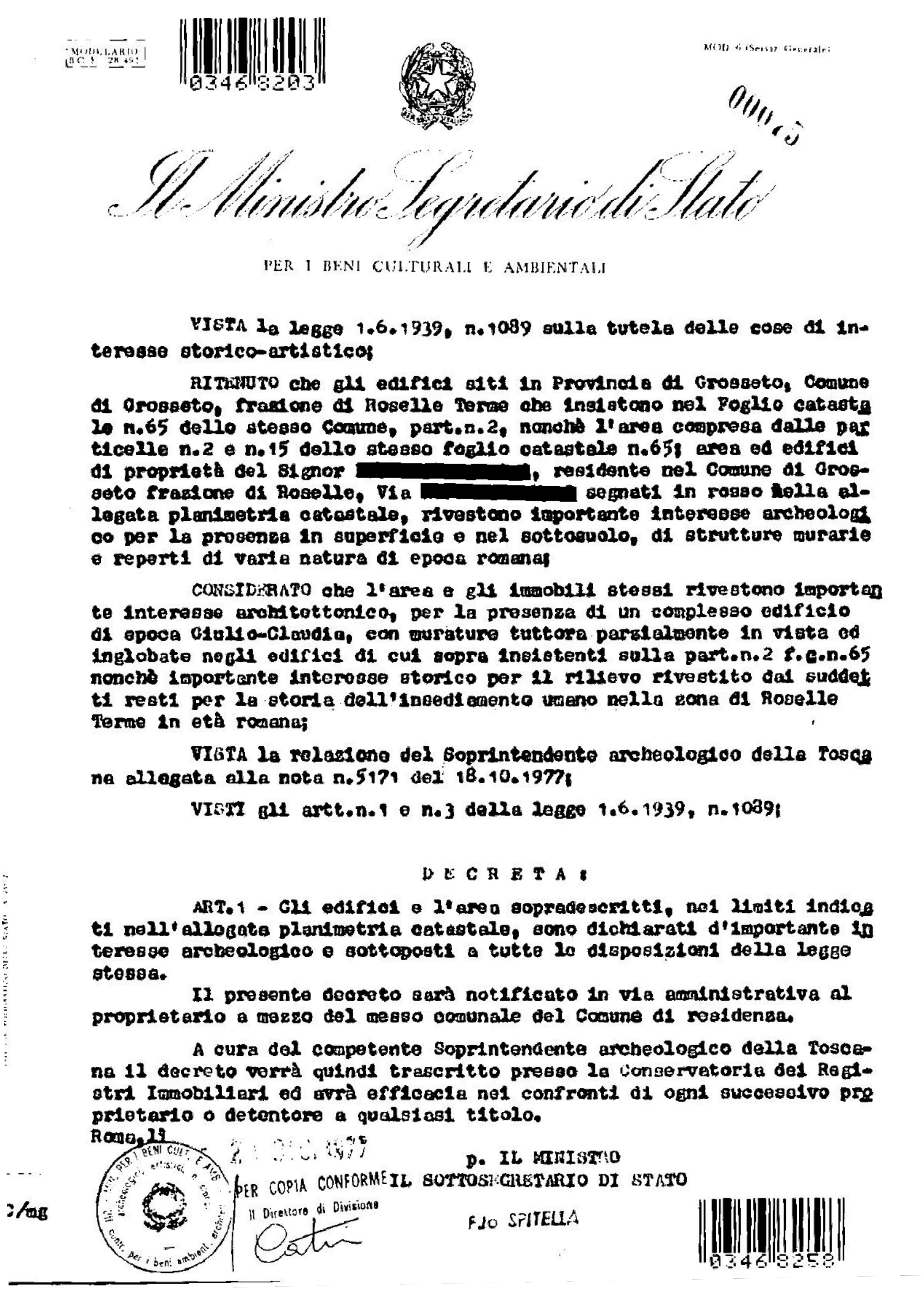
☐ Info e Link in altra finestra

☑ Vincolo ARCHITETTONICO
☑ toponimi
☑ sedi comunali
☐ località
☑ limiti comunali
☑ carta tecnica 1:10.000
☐ ortofoto
☐ mappa di sfondo

☐ <15" ☑ 15" ☐ >15"

Vincolo ARCHITETTONICO	
Base Cartografica	
Provincia	GR
Località	
Data Revisione	
Tipologia	palazzo
Codice ARCHIVIO SOPRINTENDENZA	A_GR0049
Comune	GROSSETO
Denominazione	PORZIONE DEL PALAZZO DEL GENIO CIVILE
IDENTIFICATIVO UNIVOCO REGIONALE	90530110414
Trattasi di zona di rispetto?	no
Dati catastali	NCEU F. 165, p. 286 (SUB. 9,10,11,12,13)

7.4



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MOD. 6 (Serviz. Generali)

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Il Ministro Segretario di Stato

PER I BENI CULTURALI E AMBIENTALI

VISTA la legge 1.6.1939, n.1089 sulla tutela delle cose di interesse storico-artistico;

RITENUTO che gli edifici siti in Provincia di Grosseto, Comune di Grosseto, frazione di Roselle Terme che insistono nel Foglio catastale n.65 dello stesso Comune, part.n.2, nonchè l'area compresa dalle particelle n.2 e n.15 dello stesso foglio catastale n.65; area ed edifici di proprietà del Signor [redacted], residente nel Comune di Grosseto frazione di Roselle, Via [redacted] segnati in rosso nella allegata planimetria catastale, rivestono importante interesse archeologico per la presenza in superficie e nel sottosuolo, di strutture murarie e reperti di varia natura di epoca romana;

CONSIDERATO che l'area e gli immobili stessi rivestono importante interesse architettonico, per la presenza di un complesso edificio di epoca Giulio-Claudia, con murature tuttora parzialmente in vista ed inglobate negli edifici di cui sopra insistenti sulla part.n.2 f.c.n.65 nonchè importante interesse storico per il rilievo rivestito dai suddetti resti per la storia dell'insediamento umano nella zona di Roselle Terme in età romana;

VISTA la relazione del Soprintendente archeologico della Toscana allegata alla nota n.5171 del 18.10.1977;

VISTI gli artt.n.1 e n.3 della legge 1.6.1939, n.1089;

DECRETA:

ART.1 - Gli edifici e l'area sopradescritti, nei limiti indicati nell'allegata planimetria catastale, sono dichiarati d'importante interesse archeologico e sottoposti a tutte le disposizioni della legge stessa.

Il presente decreto sarà notificato in via amministrativa al proprietario a mezzo del messo comunale del Comune di residenza.

A cura del competente Soprintendente archeologico della Toscana il decreto verrà quindi trascritto presso la Conservatoria dei Registri Immobiliari ed avrà efficacia nei confronti di ogni successivo proprietario o detentore a qualsiasi titolo.

Roma, lì 2[illegible] 1977

p. IL MINISTRO
IL SOTTOSEGRETARIO DI STATO
F.to SPITELLA

PER COPIA CONFORME
Il Direttore di Divisione

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7.5

8. Data analysis: archaeology without adjectives

Francesca Anichini *(DOI: 10.4458/8219-11)*

Over 30,000 documents provided the information we are about to examine: 20,500 photographs, 2,200 maps, 6,900 Context records and around 580 reports were searched, acquired and catalogued with great patience and many hours of work[1]. Although the figures may seem stunning[2], as already explained (see §2), they are only part of the immense documentary heritage that has most probably been produced. In addition to consulting and filing this huge amount of archival documents, a very detailed study of published documents[3] was also necessary, in order to cover the gaps encountered and to reconstruct the interventions and findings going furthest back in time[4].

The journalist Ettore Mo once stated: "If it were possible […] I've tried doing it but haven't been able to […] the ideal thing would be (to write) a story without adjectives" [5]. A beautiful provocation and very difficult challenge: making reality speak on its own through the crude – and far too synthetic for our patterns of reasoning – objectivity of facts. This statement does not mean that we should remove the subjective component of narration, which is inherent in the decision to narrate the fact, but remove the part of narration that is a result of our strategic, cultural and educational superstructure which each of us has and which we drag into our story with more or less enthusiasm. Data may be regarded as such only when their features and the methods used for their collection are clearly detailed *a priori*. Data analysis is also the result of subjective choices originating from the need to search for tangible answers and from the creativity of the persons making these choices. In our profession, where we are called to bridge the gaps between one set of data and another, by providing interpretations and hypothetical reconstructions of historical events that have left no tangible traces, the risk of embellishing the story with adjectives is very high. Hence, it is necessary to retrieve primary data and return to the most simple information item; to reach numbers in order to compare, check and create new records, in an increasingly rich system that multiplies information; to enter the system to make relationships emerge.

Commonplace yet statistically proved issues arise from this type of work: trends of action, ways of thinking, forms of knowledge that go beyond archaeological data in the strict sense, thus tracing the picture of a parallel and finally consolidated story, made of choices and at times conquests.

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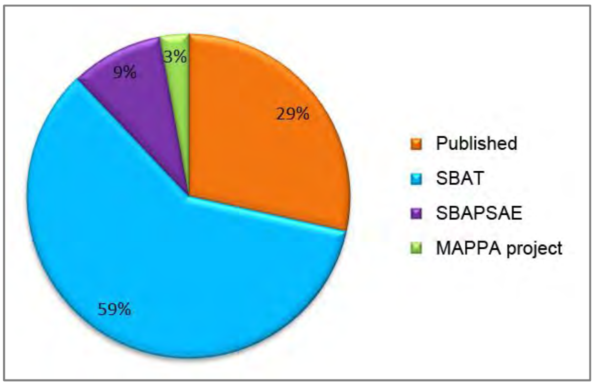
[1] We would like to thank Antonio Campus, Lorenza La Rosa, Claudia Sciuto and Giulio Tarantino for their previous cooperation and critical contribution to the work.

[2] Overall, 30,808 documents were analysed including: 583 of a written-narrative nature (documents, correspondence, reports, communications, etc…); 2,172 maps; 6,914 Context records; 20,556 photographs; 561 quantification records regarding ceramic material and only 36 stratigraphic diagrams.

[3] The term 'published' generically includes different types of contributions: brief reports, articles published in reviews and monographs. The greatest amount of information does not come from detailed excavation publications which are a very small percentage.

[4] Overall, 29% of the interventions were found in published sources; of these, 4.6% were performed before 1900 and 6.77% between 1901 and 1950. No reference data were found for 2.44% of interventions.

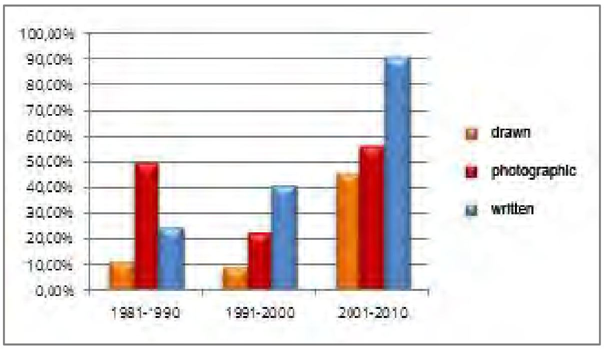
[5] http://www.rai.tv/dl/RaiTV/programmi/media/ContentItem-49cdfe83-0c3b-4cd0-a46e-0affbf6b36be.html.



8.1 Provenance of information sources.

8.1 Inside the source: the lack of water

The problem of producing and preserving documentation significantly emerges in the data examined[6]. If we exclude early XX century finds, for which we may assume that documentation was not produced or that there were many reasons for its dispersal (detailed recording drawn up by XIX and early XX century experts, together with fully detailed sketches, do however exist); if we also exclude the years covering the last two wars and the years immediately after them, and if we consider that in the 1960s and 1970s only 25% of interventions were in some way recorded[7], we reach the 1980s, where the situation however still continues to be quite worrying. We are in the years of the steady blooming of medieval archaeology and gradual strengthening of stratigraphic methodology, however, in the years from 1981 to 1990, there is not even one investigation provided with complete documentation and 44.2% of interventions were not documented whatsoever: no drawing or photograph, no description. Should we assume that the registration of archaeological information was not considered necessary during the Eighties? What kind of "cultural heritage" was considered worthy of being documented? What was the Superintendency's actual position towards the territory? How much did the research carried out by archaeological officials influence heritage protection? During this and the subsequent decade, the information obtained was sporadic and occasional, and in some cases could only be reconstructed through publications of interpreted synthesis. It is important to point out how the total absence of documentation in the Superintendency archives is a true loss for the entire community; if the documentation of an intervention is not preserved in the State archives, this means that the intervention was never carried out. This situation cannot be alleviated by recovering part of the material, after decades, in places that are not the natural ones (see §2).



8.2. Percentage distribution of type of documentation existing between 1981 and 2010 .

During the 1990s (1991-2000 decade) certain negative trends continued: 46.3% of interventions lacked any type of documentation whatsoever, whilst thorough documentation was available for 3.6% only. An upturn was recorded between 2001 and 2010, when the percentages significantly changed: interventions without any sort of documentation sharply dropped to 7.08% and those with complete documentation rose to 37.6%. What happened? Can the reason for this reversal simply be in the strengthening of archaeology – regarded as the systematic application of stratigraphic methods? We will see further

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[6] The sample examined consisted of 694 interventions and 1960 finds attributable to Level III categorisation (see § 3). Apart from data prior to 1900, we decided to carry out almost all the studies by decade (1901-1910/1911-1920/1931…); this time interval appeared to be the most suitable for representing the changes and influence of the events analysed and also for making the results visible and understandable on a detailed yet not too specific scale.

[7] 19% photographic, 2% drawn and 4% written documentation (reports).

further on that several factors contribute to answering this question. An interesting figure comes from a partial analysis of the type of documentation found. Although many interventions are not provided with complete documents, they have at least partial documentation; if we divide documentation into three macro-categories – drawn, photographic and written documentation – we can see that whilst written documents rise proportionally to the overall increase in registration activities – rising from 25% in the 1981-1990 period to 40.9% between 1991-2000, and definitely consolidating this situation during the 2001-2010 decade, rising to 90.6%, the other categories reveal different fluctuations. Photography was the means most greatly used during the 1980s (50% of interventions), against a low percentage of drawn documentation (11.5%). In the following ten years, photographs sharply dropped to 22.7% as also drawn documentation to 9%; between 2001 and 2010 both categories settled to around half the number of interventions (45.5% and 55.9%, respectively), although well below written documentation. Photography, therefore, is initially privileged despite its costs. Drawn documentation, instead, requires specific expertise and decidedly longer time, and appears to be used in privileged situations: research excavations, significant presence of masonry structures and evidence of a specific nature.

The digital revolution of the last decade does not seem to significantly influence the reproduction of documentation; it is still not customary to submit a paper and digital copy (the latter is not specifically requested) to the Superintendency, unlike other public institutions which are often the clients of the work and tend to privilege digital rather than paper formats, used only for archival purposes. In fact, the digital documents are then usually integrated and re-used by other technicians for project reviews (in cases of preventive archaeology) or for further processing at later stages; digital formats, therefore, make work easier. Should we assume that Superintendencies do not require digital formats because they do not expect anyone to reuse them? Examples of complete documentation are few and sparse in Italy. Until a few years ago, photographs taken with 6x6 cameras and black and white prints continued to be requested in some places. The reuse of raw data appears to be exclusively limited to interventions – often large areas or research excavations – that already envisage an exhaustive publication of results; investigations, that is, involving in the majority of cases a well-defined team who holds and works on the documentation until its publication. It is not expected that transversal, territorial, thematic or diachronic research activities may need all the available information however thorough or minor the data may be.

While paper documentation allows physical archiving in just one state-owned establishment, at the same time this strongly limits the access and reuse of information. Furthermore, if the information is not disclosed or if it is disclosed after many years, doesn’t it lose part of its information potential? Part of this potential is its role as accelerator for the production of new data, as well as the use of these data by other archaeologists with the purpose of determining, comparing, interpreting and developing research activities, and lastly the unique character of the data in the historical moment of their discovery. Creating a "digital deposit" alongside the paper repository would facilitate information retrieval and reuse as well as the checking and monitoring of the documentation by officials. An online, open and freely accessible digital archive would guarantee utmost transparency for the documentation submission procedures, optimise the verification of its completeness and accuracy, and set up an effective data control, diffusion and reuse system.

Another interesting aspect is provided by the comparison between the percentage of missing documentation and the different types of intervention[8] (Figure 8.3). Bearing in mind that the

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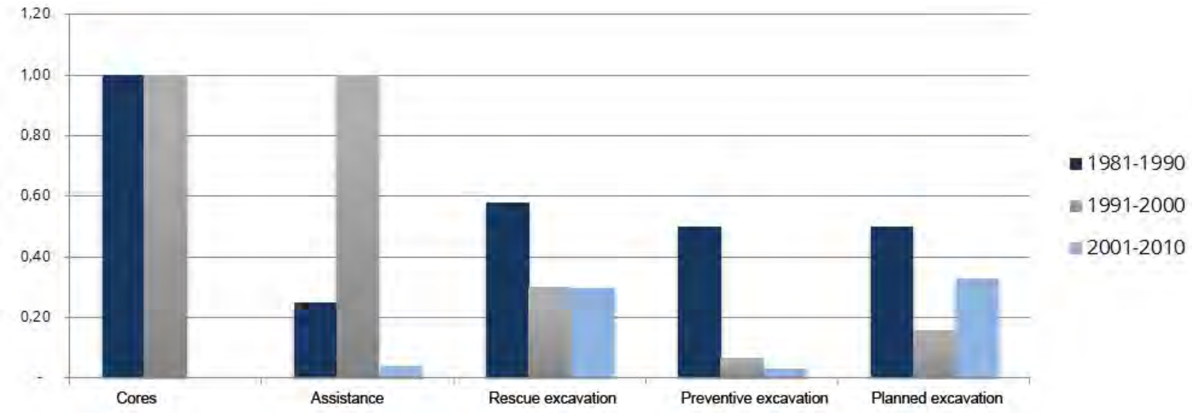
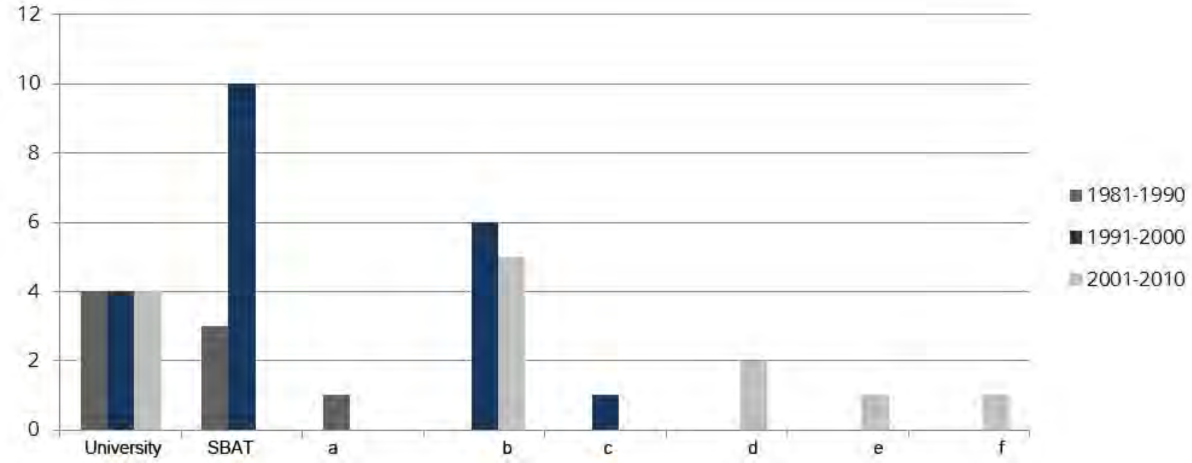
[8] "Occasional finds" have not been included in the calculation because they are not provided with any type of documentation, except for cases regarding ancient finds where sketches and detailed descriptions are found in association with the find.

percentage of missing documentation has fallen throughout the years and considering the 1981-2010 period, a univocal trend is not reported, i.e., a type of intervention for which documentation has never been drawn up or recovered does not exist.

Significant data, however, can be found; during the 1981-1990 decade, all the interventions were documented quite consistently, apart from planned excavations which, contrary to what expected, are the least documented type of intervention in Superintendency archives or scientific publications. Gaps in documentation increased in all types of interventions throughout the following decade, especially with regard to archaeological assistance; finally, in XXI century, the threefold increase in preventive excavations led to a considerable lack of documentation in percentage terms in this sector also. Data must obviously be represented as a percentage with respect to the overall number of interventions carried out for each category: preventive excavations without documentation between 2001-2010, although reaching a peak, are only 3.6%, whereas the data of planned excavations for 1981-1990 amount to 50% and assistance activities during 1991-2000 to 100%. If documentation is not delivered, therefore, this does not depend on the type of intervention carried out; it is not true that greater attention is given to excavations when drawing up documentation than assistance activities, nor that planned excavations are less important, in terms of documentation, than emergency interventions. If we overlap these results with the executors of the interventions, we notice that the lack of documentation characterises investigations carried out by Superintendencies, Universities or professional archaeologists.



8.3 Complete absence of documentation for the various intervention categories from 1981 to 2010.



8.4 Interventions lacking documentation divided by executor from 1981 to 2010.

Another element that must not be underestimated when examining information that should provide archaeographic data records is the topographical location of the intervention. The use of mapping tools or geographical coordinates to accurately position the intervention area unfortunately appears to be optional. A diversified situation is revealed: 48% of interventions recorded are not related to any kind of mapping reference that would allow their accurate positioning; indications tend to be very general – "area north of the city" or "in the district of…" – to averagely general – "in …. Road" or "near a certain building…" – including a very wide range of options. Accurate references are only rarely provided: the street number of a building, the stretch of road between two known points, etc… In all these cases, no mapping support is provided. Two "inaccurate" positioning levels may be identified: from the areal macro, which lacks indications capable of defining the perimeter (low), to the linear trace that exactly corresponds to a road but does not accurately define the area of intervention and to the entire building where the portion investigated is not specified (average). Information dating very far back into history is naturally included in this extremely high percentage, as well as occasional finds, for which detailed documentation is hardly possible[9]. Many interventions carried out during the most recent decades are also included, even though the methods and equipment used would have allowed adequate geographical positioning of the data. Many archaeologists regard themselves as working in small microcosms, shut off from the rest of the world. Archaeological interventions are too often trapped in a self-referential system, where each component is related exclusively to the system itself; the significant contribution of the data collected at macro scale is at times not fully understood. This takes place both with mapping (positioning, context maps, etc.) and depth indications. Where complete documentation is available – especially drawings – we realise that a full in-depth description of the investigation never corresponds to an equally accurate description of the intervention area; in some cases a small part of a land register map or of the Regional technical map is attached, with brief indications of the interested area. In other cases, mapping references consist of the surveys provided by the client, often lacking connections with larger scales. The heights attesting the depth of the archaeological remains are always related to a zero reference level which only rarely corresponds to a known point or is easily identifiable at the end of the investigation, and even more rarely corresponds to an absolute height at sea level. Regarding cases providing georeferencing of the intervention area, various methods are used for recording the geographical and altimetric data: graphical methods, ranging from manual to instrument-assisted surveys with various mapping bases of reference, to descriptive methods where it is necessary to historically reconstruct the urban context at the time of the investigation in order to understand the spatial references provided. Even for this type of problem, there are no standards that define exactly how this fundamental part of documentation must be delivered.

Such an irregular practice inevitably leads to the partial loss of information; the position of archaeological evidence is certainly no secondary matter when gathering information about a site or when reconstructing the development of a city

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[19] Among the interventions that can be precisely located, those less represented are obviously occasional recoveries (9.72%), whereas the highest (100% of the sample) are geochemical/geophysical investigations and cores which since carried out by specialised personnel usually with a geological educational background, nearly always produce georeferenced data. Regarding subsurface activities (excavations and assistance), the percentages reflect the general trend settling at 48.3% in the case of emergency excavations, 60% for planned excavations, 65% for archaeological assistance and 76.8% for preventive excavations. The difference registered in this latter value, in addition to confirming the reliability of the preventive strategy, is partially related to the interaction between archaeologists and designers; during the design phase, technicians often request detailed maps for the positioning of archaeological evidences, which are functional to reviews or technical activities.

or local area. The depth of a find is not a marginal detail when evaluating the archaeological potential of an area or tracing the DTMs that will predictively reconstruct the growth of the buried deposit. Adopting a unique and standardised system, which allows accurate data to be analysed and, at the same time, the "buried world" to interact with the real one, is of crucial importance. This is evidenced by the difficulties encountered when drawing up a VIARCH report: in the event of large-scale projects, extensive areas need to be examined and spatially distant and uneven data need to be compared, for which there is no common denominator capable of guaranteeing their interoperability.

The need to encode the production of archaeological mapping data is all the more necessary following approval of the Decree of 10 November 2011 (Official Gazette no. 48 of 27 February 2012 - Ordinary supplement no. 37), stating the obligation to produce "any new document or data to be georeferenced" in compliance with the new national geodetic system called ETRF2000 (2008.0). Although the SITAR project has already launched an initial geographical standard for all the new maps produced for Rome (DI STEFANO V. *et alii* 2011: 187), clear and univocal requirements which establish rules in line with Italian and European standards are still missing at national level.

Alongside these considerations, the reliability of the figures analysed must also be taken into account. We know that part of the documentation, although produced, is not available in the Superintendency archives because it is still held by archaeological officials, principle investigators or executors of the intervention. The Superintendency itself is aware that part of the material has never been delivered and another part is still being studied (see § 2), in some cases for over thirty years! Despite officials' efforts to recover the material, the majority of documentation continues to be locked away in researchers' drawers in the name of a presumed intellectual "property" – quite different from intellectual "authorship" – which should not exist in the world of science.

8.2 A restraining restraint, urban background

The term "restraint" is commonly perceived with a slight negative meaning; it implies a restriction, a bond between contracting parties with mutual obligations, a mandatory relationship in which the passive entity is subjected to the active entity. With regard to Archaeological Heritage, it is defined as a limitation of the right of ownership to an asset, with an obligation governed by legislation. With this view, public institutions and private citizens are more or less aware of their position as restraining entities and are obliged to comply with the terms of the relationship. The law establishes that every find of archaeological value belongs to the Italian State; "cultural heritage" is composed of "movable and immovable property". The "important interest of objects", upon which the restraint is established is the conceptual foundation of the law. If interest is not given to "objects", they are not subject to the law (GUZZO 1996: 19).

In the most recent revision of the code of Cultural Heritage (2008), the articles of the code of public works establishing the VIARCH, include an article[10] which envisages the possibility for the Superintendent to request the execution of preventive archaeological samples in the event of public works in areas of archaeological interest: this is the only reference to the preventive management of buried heritage. All other archaeological references, among the few that still appear in the Code of Cultural Heritage, are related to the "object". The concept of "heritage" is exclusively referred to "objects"; there is never any reference to soil, deposits or traces. This great limitation inevitably restrains dialogue with non-experts: administrators and entrepreneurs have no legislative reference to understand how to protect and document a story written in the ground. What is exclusively regulated is the "fortuitous find" which implies a conservative logic, not one of

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[10] Article 28(4) of Legislative Decree no. 42 of 22 January 2004. Code of Cultural and Landscape Heritage, pursuant to Article 10, Law no. 137 of 6 July 2002 and reviews of Legislative Decree no. 62 of 26 March 2008.

understanding; alternatively, "research concessions" are issued by the Ministry to public institutions or private citizens having qualified and acknowledged scientific experience which/who, often together with the Superintendency archaeological official, act as Principal Investigators[11].

In order to understand the choices and strategies adopted for protecting and acquiring knowledge of the heritage of the area examined, it is necessary to briefly outline the situation in Pisa, which moreover is common to other Italian urban centres.

In 1986 and 1993 two declarations of "important archaeological interest" were designated for Pisa; the rulings delimited an area inside the city and set up a sort of agreement between the Superintendency and all public citizen institutions for management of these areas[12]. The rulings established that institutions were to submit projects falling within these areas to the Superintendency's authorisation, consequently complying with the investigation requirements issued. Although this "agreement" was not observed as initially hoped for and it continued to be necessary to intervene in emergency conditions after building permits had already been issued, successful cooperation has gradually been achieved over the years, thus allowing the Municipality and the Superintendency to jointly and preventively plan a large number of public works. The delimitations of the two rulings were defined on the basis of the topographic location of a series of finds which, throughout the years, extended the area of interest from the historical centre (1986) to external parts to the north and to the west (1993). The perimeters were traced where information was already available, excluding altogether the southern and eastern sectors because still little known; at the time, and also over subsequent years, a more detailed study was not carried out with a view to understanding more precisely the city's development over the centuries. Whilst this activity, on the one hand, monitored (and continues to monitor) the areas included in the rulings, on the other, it partially diverted attention from the remaining areas for which the collection of information (whether existing or not) was not considered.

The spatial distribution of the documented interventions confirms this situation: only 9% of interventions fall outside the 1986 and 1993 perimeters. Of the 91% falling within the areas delimited by the declarations of archaeological interest, 72% falls within the 1986 declaration, whereas 18% in the 1993 declaration. The majority of interventions are focused within the perimeter of the city walls (63.8%); of these, 85.5% are excavations (of different kinds) and assistance activities (Figure 8.5). We have no information about the southern and eastern parts of the city, even where there has been extensive construction due to the gradual development of the new industrial and commercial area. Has the restraint become too restraining?

8.3 Strategies and methods

As comprehensively explained, the minimum recording unit used in the MAPPA project is the archaeological intervention. If we consider only subsurface investigations[13] whose intervention areas were accurately georeferenced, the overall urban areas sampled amount to 75,609.36 square metres[14]. The average width of the interventions is around 40 square metres, although over 20% are small (between 1 and 10 square metres) and 30% are over 100 square metres.

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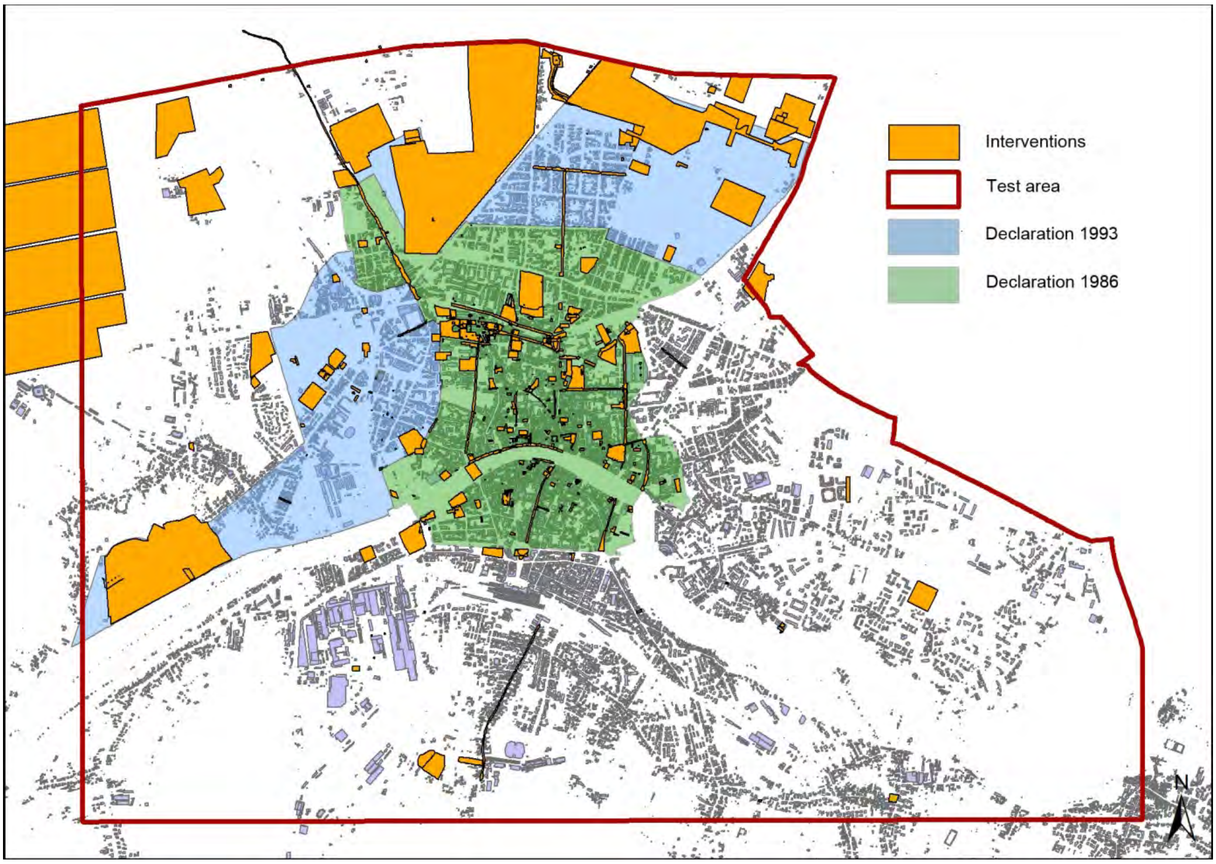
[11] Articles 90 and 89 of Legislative Decree no. 42 of 22 January 2004, n.42. Code of Cultural and Landscape Heritage, pursuant to Article 10, Law no. 137 of 6 July 2002 and reviews of Legislative Decree no. 62 of 26 March 2008.

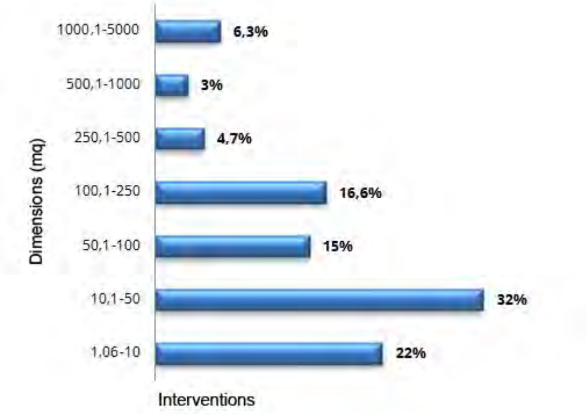
[12] SBAT Historical Archive, Florence, Pos.9 Pisa 4, Prot. No. 4585 of 10 April 1986 and Prot. No. 10610 of 29 June 1993

[13] This calculation does not include surface investigations, occasional finds and cores (given their very small range).

[14] The overall area of study is around 27 square kilometres.



8.5 Distribution of documented interventions in the areas falling within the two rulings of 1986 and 1993.



8.6 Size of interventions.

694 interventions were attested between 1562 and 2011; they reveal various types of investigations which, considering their distribution over time, delineate the strategies adopted over the decades and clearly describe the methodological development of this discipline.

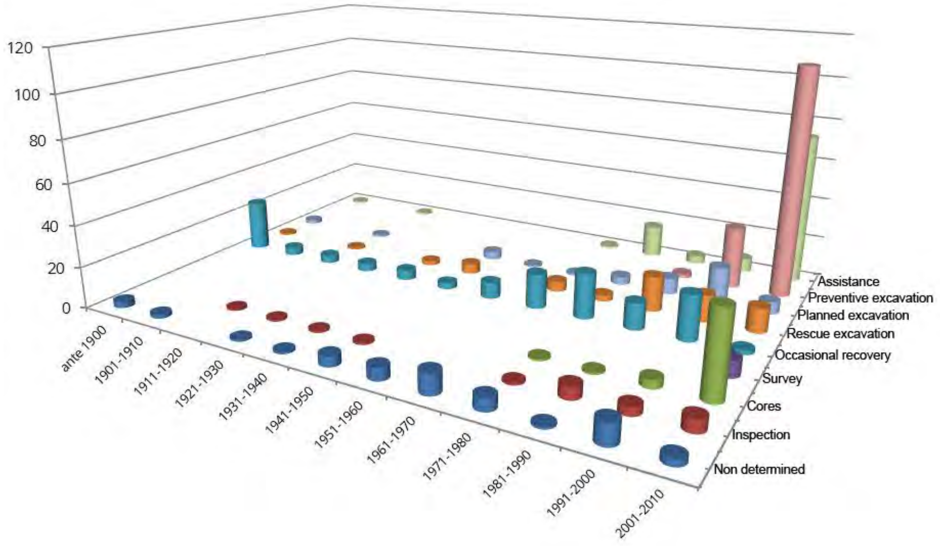
The interventions are divided into 10 different types:

- Assistance: definition usually used to indicate works, especially construction or road sites (public subservices) where the supervising presence of an archaeologist is required during all excavation and earth moving phases.
- Cores: in urban contexts, usually in correspondence with the geological cores performed before the construction of a property for the purpose of studying the soil and carrying out suitable structural calculations. The archaeologist intervenes when the core is extracted or after the geological reading. The work is rarely carried out jointly by the archaeologist, geologist and geomorphologist.
- Geochemical/geophysical investigation: indifferently includes phosphate and trace metal analysis, and geoelectric, electromagnetic, magnetometric, GPR, seismic, microgravimetric and acoustic surveys.
- Occasional recovery: includes all the reports, usually by private citizens or associations, of fortuitous discoveries or removal of mobile artefacts, found in temporary dumps, ploughed

fields, unauthorised trenches, unassisted works, etc.

- Survey: non-invasive surface investigation mainly performed in agricultural or woodland areas, rarely in urban contexts.
- Rescue excavation: excavations carried out following a fortuitous discovery during construction works and public or private works, where the intervention is assumedly carried out after an initial "loss" of the information deposit. Rescue excavations are usually carried out quickly and the archaeologist works in the presence of mechanical equipment and other teams of workers. Non-preventive excavation sampling is also included in this category for gathering more in-depth information about an area during assistance activities.
- Preventive excavation: this term includes excavations related to the recent law on preventive archaeology and interventions preventively planned for a work involving the subsurface.
- Planned excavation: this type of excavation corresponds to the commonly-used term "research excavation" and also presumes a timing schedule; its aim is to search for the answers to historical-archaeological questions and, most of all, it is not associated with the performance of a work.
- Inspection: definition especially adopted for the assignments carried out by the Superintendent and Superintendency officials to check a reported situation or view the status of works.
- Non determined: this definition includes interventions whose documentation does not provide information about the exact type of intervention.

Paradoxically, the most represented types of intervention are those at the opposite ends, that is, occasional recovery (21%) and preventive excavations (22%), followed by assistance activities (18%), which are often the consequence of an initial check. At urban level, geophysical/geochemical investigations and surface surveys are carried out very occasionally[15]. Although both are usually used in extra-urban contexts, in the area under examination, they are used very little even in the peri-urban areas where the former agricultural lands were gradually subjected to intensive urbanisation. A significant percentage (9%) relates to interventions whose sources do not specify the type of intervention in any way whatsoever; this figure is quite steady during the entire period considered[16].



8.7 Representativeness of the various types of intervention over the decades.

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[15] Geophysical/geochemical investigations 1%; surface surveys 2%.

[16] For other categories that have not been mentioned: 10% cores, 8% rescue excavations, 6% planned excavations, 3% inspections. .

The analysis of data over the past thirty years reveals a trend that is consistent with the national trend: the development of urban archaeology, and at the same time of medieval archaeology, increases the opportunities to carry out investigations, leading to a twofold increase in the number of interventions recorded between the 1981-1990 decade and following 1991-2000 decade (+111.53%), and a 142% increase between 2001-2010 and the previous decade.

If we diachronically examine the distribution of the various intervention methods, some general considerations can be made. Occasional recovery, representing practically the only type of intervention from XVII century to 1940, continues to be carried out until 2000; in the 1991-2000 decade it represents 26.8% of interventions, whilst in the following decade only 0.9% (Figure 8.7). Since the majority of reports come from Archaeological Groups, should we assume that this radical change is due to a noticeable drop in the attention paid by civil society towards archaeological heritage; it would be more reasonable to consider how the Superintendency's protection strategy has changed over the past decade and, at the same time, the role played by single citizens and Archaeological Groups. Throughout the nineties, these groups efficiently monitored the local areas and were often directly involved in the excavation activities. This practice ceased from 2001 and, not by chance, this period coincides with the handover between Superintendency officials and the definitive consolidation of professional archaeology in the city. Volunteer in archaeology are replaced by professional archaeologists, often freelancers, who play a leading role in supervising a wide range of public and private works involving the subsurface and also other aspects[17]. Reporting changes thanks to a different way of thinking that is no longer satisfied with just the material recovery of the object: the execution of works is reported and every trench made in the ground is checked regardless of the presence or visibility of archaeological remains. A transition may be seen from the culture of the object – the asset itself that is recovered and handed over – to the culture of the stratigraphic deposit and to the awareness of the need to document the multiple facets of a multi-layered and diachronic environment. The "new" reports are issued during the works – thus reducing the percentage of rescue excavations (from 32.7% during the 1981-1990 decade, to 11.8% between 1991-2000, and 4.5% between 2001 and 2010) – or often before them – thus supporting the city's building policies, urban choices, etc., and tripling the amount of preventive excavations[18]. This highly effect system allows professional archaeologists to take up an active role and play an important part in protecting the city's archaeological heritage (Figure 8.8).

Another aspect that should be pointed out is the scarce impact that the aw on preventive archaeology[19] has during the years after its approval (post 2006). 151 interventions were recorded between 2001 and 2006, 159 between 2007 and 2011: a meagre +4% increase. The procedures for implementing and adopting the operational rules described in the Law Decree differ according to the intervention areas, the officials in charge and the sensitivity and preparation of the local administrators. It is not clear whether public works, in whose regulation the articles of law are included, refer to large works (that address the need first and then reflect on the work to be carried out) or to public works in a wide sense, i.e. automatically regulated as such for their clients. Does the law apply to linking infrastructures (for example, railways) as well as to new sewage systems developed in the city? After six years, the ground is still uncertain, thus allowing each Superintendency to have a certain amount of discretion. There are various suggestions as to why the

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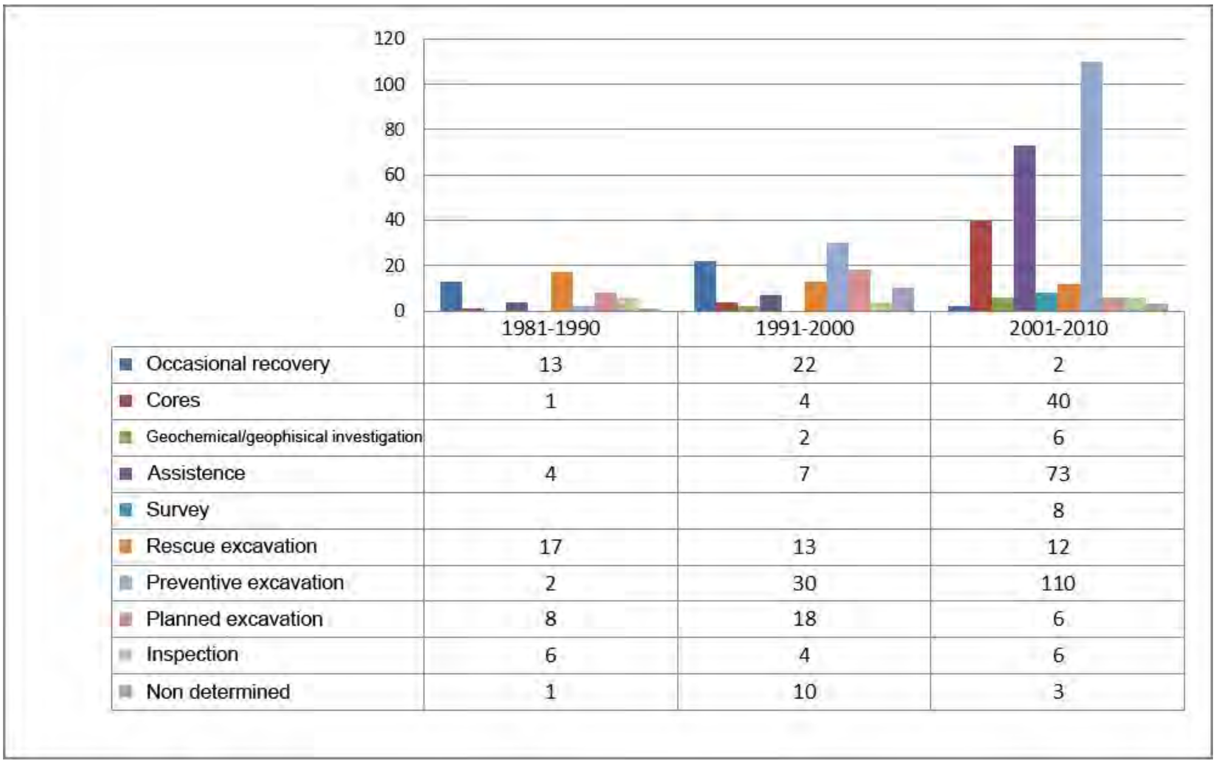
[17] It is exactly during this period that extensive stratigraphic reading of buildings is recorded featuring systematic activities and the development of specific research.

[18] Preventive excavations rise from 3.8% during the eighties, to 27.2% between 1991 and 2000, and reaches 41.3% in 2001-2010. Archaeological assistance stands at 7.7% between 1981 and 1990, at 6.3% between 1991 and 2000, and at 27.4% during the 2001-2010 ten-year period.

[19] Legislative Decree 163/2006, Articles 95-96.

percentage of interventions has remained practically unvaried. The first is that for every intervention in which a public client was involved, a VIARCH was drawn up within the deadlines established by the decree (therefore, during the preliminary planning phase) and, as a result of this activity, planning variations were made that prevented any interference whatsoever of the work with the buried heritage, thus excluding the need to intervene during execution of the work and leaving no impact on the number of interventions carried out. This is barely credible: apart from the low number of VIARCHs submitted, all the evaluations should supposedly have been drawn up without the need for field surveys (cores, explorative surveys, etc.) or non-invasive investigations (surface surveys), given the lack of documentation providing evidence of these kinds of intervention. The second suggestion is that the decree has not been applied. What we believe to be more credible is that the decree has strengthened a practice already in use during previous years. The substantial equivalence of preventive archaeological interventions, and to a lesser extent the type of intervention adopted[20], demonstrates that where there is active cooperation between institutions, the law has partially responded to an already established practice, defining a different schedule (during the planning phase) in order to optimise the results from a scientific and heritage protection viewpoint and in terms of the costs (time/money) of the work.



	1981-1990	1991-2000	2001-2010
■ Occasional recovery	13	22	2
■ Cores	1	4	40
■ Geochemical/geophisical investigation		2	6
■ Assistence	4	7	73
■ Survey			8
■ Rescue excavation	17	13	12
■ Preventive excavation	2	30	110
■ Planned excavation	8	18	6
■ Inspection	6	4	6
■ Non determined	1	10	3

8.8 Type of intervention adopted between 1981 and 2010.

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[20] The data point out how the types of intervention, more strictly related to preventive archaeology practices, do not reveal flows that particularly diverge from one period to another. Taking into account that the two periods are not the same (six years between 2001 and 2006, five between 2007-2011), preventive excavations drop from 61 to 54, with a yearly average of 10 units for both periods; archaeological assistance activities increased by 30%, rising from 42 to 50, that is, 7 units/year to 10 units/year. Likewise, cores increase from 18 to 22, around +25% compared to the years; planned excavations drop from 11 to 2, rescue interventions rise from 6 to 7, whilst surface surveys significantly increase from 1 to 11. This latter figure must be considered by bearing in mind that 4 interventions regard a university research programme and the remaining are related to only two public works.

8.4 Who does what

Apart from a few famous people, the custom to record the name of the material executor of an intervention appears only after 1980. Up to that date, for over 50% of data, we do not know who actually carried out the intervention and recorded the archaeographic data. From 1981, this percentage sharply dropped to 12% and disappeared in XXI century.

From the post war period to the start of 1990s, investigations were directly carried out by Superintendency officials and their assistants. The role of an "external co-operator" was not defined until approximately 1990; ministerial archaeologists availed themselves of voluntary workers, students or internal co-operators and in some cases co-operated with universities. They often supervised the works carried out by construction firms and most of all were in charge of planned excavations.

In the sample analysed, the first excavation carried out by an archaeological firm only appears in 1986. Although the 1980s witnessed the arising of urban archaeology, together with the gradual discovery of the archaeological value of post-classical data and the increase in interventions throughout the territory, in Pisa – between 1981 and 1990 – out of 46 interventions of which the executor is known, only 3 were entrusted to private companies (6.52%). During the 1991-2000 decade, this percentage considerably increased (49.09%)[21] and 75.92% of interventions were directly carried out by individual professionals, against 24.08% entrusted to firms. Freelancers started to carry out urban interventions in 1992 in Pisa. The role of the professional archaeologist, which is still not fully acknowledged today, was identified over these years with archaeologists who had graduated from local universities and, upon indication of the Superintendency, received assignments from public or private institutions; the majority of interventions was carried out by just one archaeologist or at times by a group of 2 or 3 archaeologists.

Superintendency officials and their assistants continued to directly perform a number of investigations; compared to the previous decade (1981-1990), the percentage fell from 48% to 17.27%. The activity carried out by archaeological officials began to take the form of what would be the trend of the following years: control and checking of activities (not directly by the staff of the ministerial offices but by qualified third parties), and the constant role as Principal Investigator for almost all the investigations. The Superintendency's direct role as executor of the interventions continued in the case of planned excavations[22] carried out in areas considered crucial for the construction of the city's history; data show how these interventions are equally carried out by firms/professionals and Superintendency/ University departments. Indeed, it is during these years that the participation by universities in urban archaeology increases.

The active role of universities in city archaeology is difficult to assess by analysing the case of Pisa alone. The national scenario offers a wide range of situations: some university departments are very active in urban centres and establish cooperative arrangements with both the Superintendencies and local administration; others are involved mainly in research activities that stretch across larger areas and deal with different topics. In some cases universities – institutionally designated for research and training – are involved in the archaeological occupational market with urban sites called "educational" sites, but which are not implemented for research or student training purposes: universities thus replace professional work, offering a low-cost service in a system already highly affected by economic factors.

We have no intention of entering into the merits of a matter that would require greater discussion; nonetheless, it is important to point out how the

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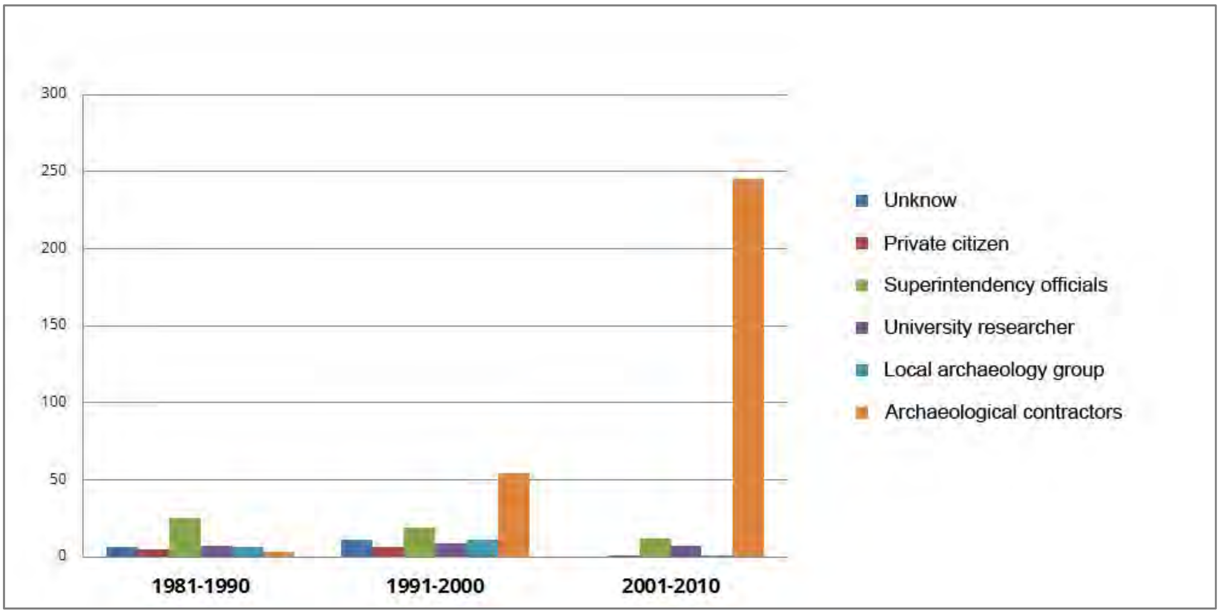
[21] 110 interventions were carried out in this period; the executor is unknown for 11 of them, whilst 54 were carried out by archaeological professionals and firms.

[22] In the other types of intervention, evidence of execution directly by the Superintendency is more limited: assistance 14.28%, rescue and preventive excavations 13.63%, and cores entirely assigned to external parties.

role of universities as the executors of archaeological investigations in many cities and regions has put a brake on the development of archaeological businesses and the profession, leading to a paradox: the State invests a large amount of money in training professional figures destined to promote and guarantee the management of its archaeological heritage and, at the same time, restrains occupational opportunities.

In the case of Pisa, a series of interventions supervised and/or directly performed by university staff was recorded at the end of the Seventies. Alongside "classical" research, control activities supported by medieval archaeologists began to be performed during this period on building and road interventions (called 'minor' interventions) in the city: development of new sewage and piping systems, laying of electrical and telephone cables and restoration of buildings. Over the following decades, the university's involvement decreased, except between 2001 and 2006 during which educational sites were opened and university teachers, acting as principal investigators, carried out a series of preventive excavations and assistance activities with the aid of their own co-operators. An aspect that should certainly be analysed is how professional archaeology became a tangible reality during the 2001-2010 decade; compared to previous years, the number of interventions carried out by firms or freelancers registered a three-fold increase reaching 92% of the total (Figure 8.9)[23]. An aspect that arises is the way in which the working assignments were distributed among the different subjects operating in the test area. It is also interesting to notice how there were only 10 operators between 1991 and 2000, yet professional interventions reached almost 50% of the investigations carried out in the city. Archaeology regarded as a real profession – independent and unrelated to universities and Superintendencies – was still at an early stage and took shape through important companies and cooperatives, which were established during the Eighties and were the only employment opportunity other than working for a public body. Archaeologists still did not realise that they could place themselves on the market exactly like any other professional (architect, engineer, land surveyor …); since there was no trade register or association recognising their full



8.9 Intervention executors between 1981 and 2010.

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[23] 3 out of 52 interventions from 1981 to 1990, 54 out of 110 between 1991 and 2000, 245 out of 266 from 2001 to 2010.

legitimacy, individual archaeologists were few and they developed direct and fiduciary relationships with Superintendency officials. A gradual increase in the number of qualified operators increased from 2001, which rose with the first graduates from the new degree in Cultural Heritage Science. Towards the end of the 2001-2010 decade, especially after the economic crisis that started in 2008, the fall in building activities and the cost of labour resulted in less hiring (and more dismissals) by medium and large-sized archaeological companies. In order to avoid constant job insecurity and extreme flexibility, making archaeologists moved from one end of the nation to another over a few months, the role of freelance archaeologists took shape.

The data referring to Pisa during this decade shows that the number of operators increased from 10 to 34, also in relation to the greater number of interventions carried out. Although some archaeologists worked on a continuous basis, it should be pointed out that in other cases, the alternation of officials led to variations in the professional archaeologists working throughout the territory (Figure 8.10). By reading the histogram, it should be assumed that the archaeologists involved in the greater number of interventions and in some cases longer work, were those capable of guaranteeing the highest quality of work. Is that really so?

8.5 Quality does not pay

To perform this analysis, we compared the data regarding the executors of the interventions (relating to the 1980-2011 period, Figure 8.10) with those taken from the evaluation regarding the reliability of the information of single finds. Studying the interoperability of data taken from heterogeneous sources full of gaps entailed the need to enter data that, with clear and objective parameters, were able to assess the overall reliability of the archaeological record analysed. The source, intended as the archaeographic documentation of the interventions, was the crucial aspect of this process; consequently, a table was created for evaluating the documentation of each intervention[24]. The absence of recognised standards that define the type, digital formats and, more generically, the characteristics needed for correctly drawing up the documentation of an intervention, allows this evaluation to be carried out only from a quantitative, not a qualitative viewpoint. As expected, the qualitative level of such a broad-ranging production is exclusively determined by the operator's expertise (whether the material executor or the principal investigator) and, more rarely, by the subsequent review of the archaeologist official in charge. Without attempting to answer the awkward questions related to this gap, it is important to underline how it should be a leading issue in Italian archaeological debate. We firmly believe that a shared, accurate and unmodifiable reference is a necessary methodological step requested by the entire scientific community, with a view to strengthening archaeological discipline and expertise through a clear and verifiable legislative reference, which subjects to penalties but at the same time rewards the quality of work; this is what happens in other administrative procedures involving different aspects of research and the management of cultural heritage (for example, the documents that an architect is required to produce for an intervention on a protected property or simply in a historical centre). Returning to the data analysis, since we only needed to base our evaluations on quantitative elements, the presence/absence parameters of the documentation were summarised in a calculation table in which a value was obtained for each intervention, according to a series of simple and previously-established steps. In order to limit interference of the operator's subjective opinions when assigning the values, the control parameters were encoded and each value was assigned to the single find without knowing the name of the executor of the intervention. The number of interventions carried out was calculated for each subject working in the area of

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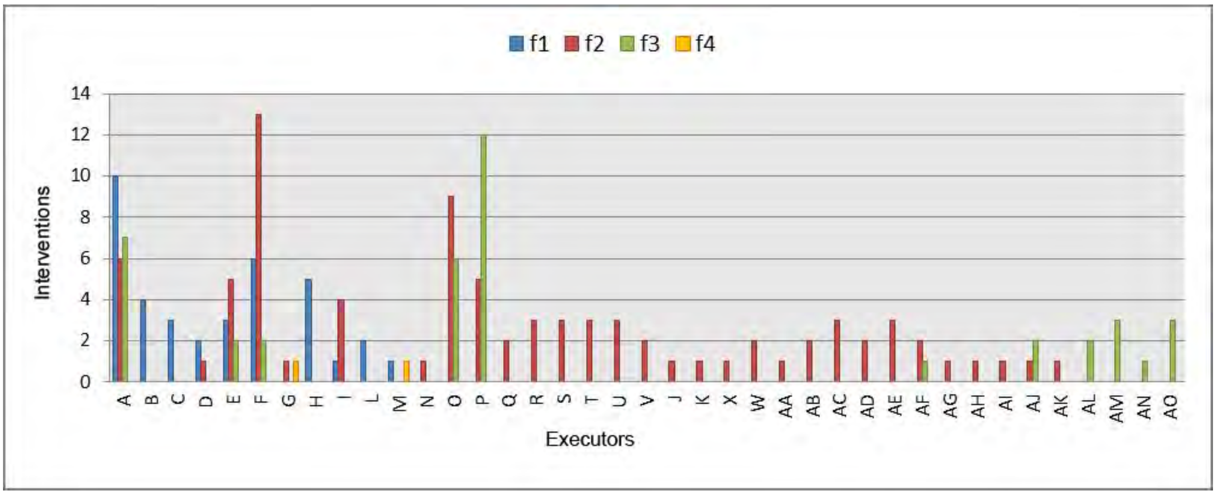
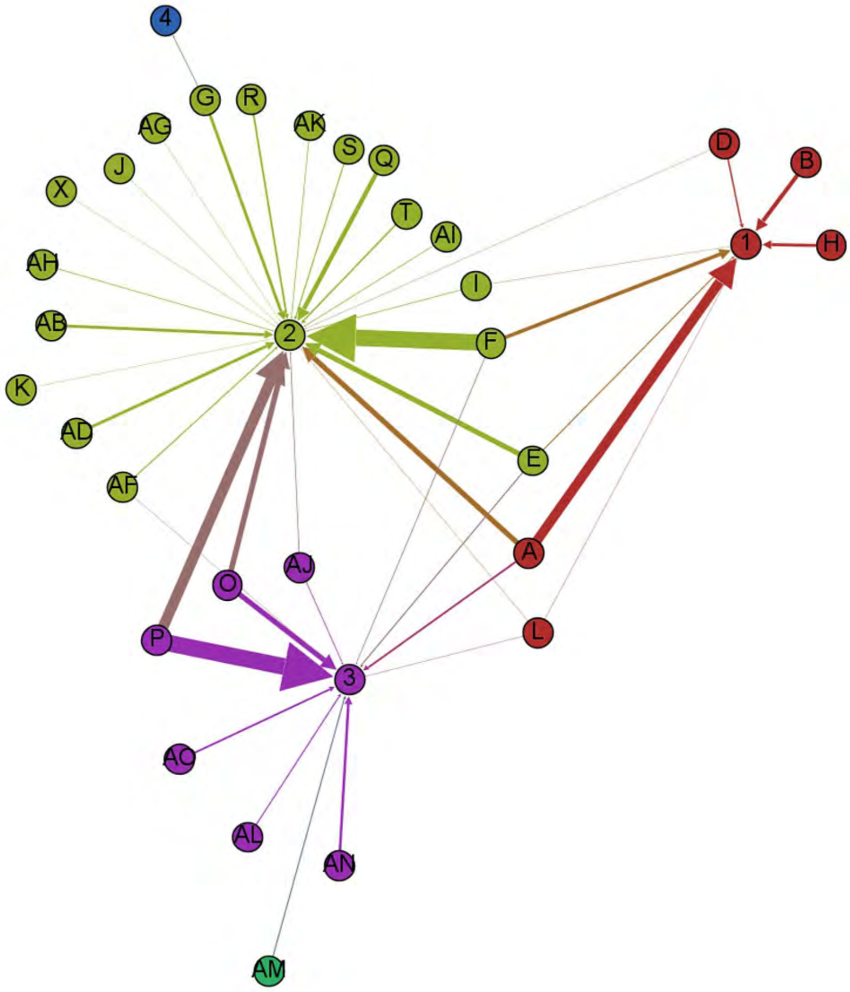
[24] For a complete description of the analysis methods and parameters see § 4.1.1.6.3



8.10a The histogram shows the number of interventions carried out for each subject (indicated with letters) that has worked in the sample area from 1981 to 2010. The different colours refer to the period of reference for each archaeological official in charge of the area and are numbered casually, not according to a chronological sequence.

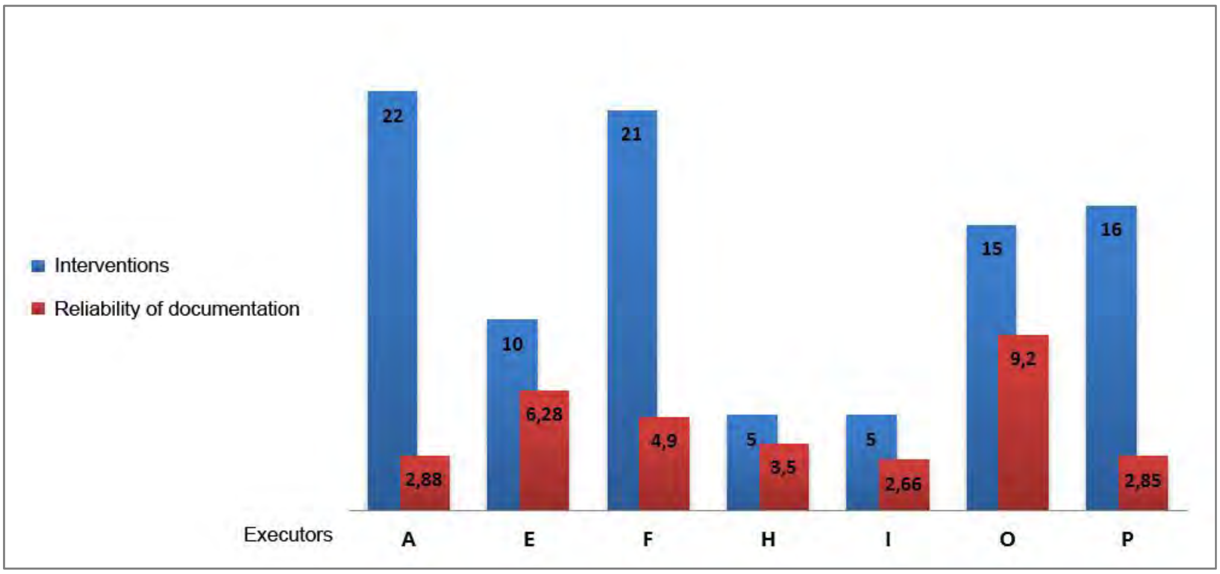


8.10b The same data presented using a grid graph, where the relations between officials and executors may be seen.

study, and at the same time the value expressed by the calculation of the reliability table was assigned to each intervention. A mathematical average was obtained from the algebraic sum of all the values related to the interventions of a single entity, divided by the number of overall interventions carried out by that entity; this allowed us to acquire a reference value for each executor. The data are not reassuring. On a reference scale between 1 (minimum) and 12 (maximum), out of 36 entities (firms, freelancers, professional offices, companies), only 30% reached a value between 9 and 11 and of this percentage, only 15% are close to the highest value (11.33). Almost half of the subjects (46%) obtained a value between 1 and 3, and the remaining 24% between 4 and 7.

To better visualise this trend, the analysis was reproposed by screening the subjects that were involved more sporadically and whose value may not appear credible from a statistical viewpoint. In the first case, all the subjects that achieved a number of interventions lower than 3 were eliminated, in the second those that achieved a number less than 5. The percentages were confirmed. In the second case, the subjects dropped to 7; of these only two had carried out a number of interventions lower than 10. The minimum value rose to 2.66 whilst the maximum dropped to 9.2.

What is surprising – or maybe not – is that quality, intended as a complete archaeological recording system does not correspond to a greater number of assignments. More simply, quality does not pay. A series of factors, which cannot be ignored, obviously contribute to this statement. We know that a certain number of executors (for the majority freelancers) have abandoned the archaeological profession and have carried out less interventions than others. It would be reductive to address the reason why the archaeological profession is cyclically abandoned early (by a higher percentage of women) in just a few lines, but it is important to underline how the quality of work is not a secondary aspect. If we look at the situation from the other way round, it must be wondered why whoever works more produces a lower quality product? Since one of the items that contributed to determining the value we are analysing is the quantity of documentation produced, we cannot exclude the economic factor of this production from our considerations. Every phase of work has a cost which influences – in terms of money and time – the quotation prepared for the intervention. Producing complete documentation for an excavation means estimating hours of work for filling in all the context records, hours for preparing the maps, hours



8.11 The relation between the number of interventions carried out and the value attributed to the reliability of the documentation. Case 2. Selection of executors on base 5.

for cataloguing the photographs, hours for drawing up the stratigraphic diagrams of contexts and activities, hours for cataloguing and quantifying the mobile finds and hours for writing a fully detailed report. All this work appears to be optional and left to each operator's discretion, because it is not so strictly requested by the heritage protection body to become mandatory.

If we consider that the only parameter for the awarding of an archaeological tender is usually the lowest price, producing minimum and insufficient documentation is automatically associated with greater success, i.e. with the assignment of more work thanks to the more cost-effective offers. The system is clearly distorted and takes us back to the key issue regarding standards. A banal comparison can be made by considering the documents needed for building a house. Let us imagine that the owner of a property needs to appoint a series of technicians for the preparation of all the documents required for obtaining all the permits and concessions from the specific municipal offices to proceed with the construction. It would be inconceivable for the architect to produce only the elevations and not the maps or for the engineer to deliver part of the structural calculations for the stability of the building. No office would issue a permit and would continue to request integrations to the documents until the entire documentation is complete. All the professionals working in this sector know which documents needs to be produced, how much they cost and how much they wish to earn from the work. The owner can actually compare all the quotations requested. Instead, there are no accurate and univocal references for archaeological services. The cases in which clear rules are laid down and the documentation produced is promptly reviewed are rare; whenever this happens, this is a local or at most regional procedure. Penalties are not inflicted on whoever produces insufficient documentation full of gaps, or who does not produce it at all. This behaviour is not stigmatised, to the detriment of collective historical memory and other professionals who wish to provide a high-quality product. Associating part of the causes for the early abandonment of the archaeological profession with a non-regulated system, which stimulates unfair competition with very low remuneration and earnings, to the detriment of quality, is by no means banal.

At the same time, a serious matter is seeing how little value is generally attributed to the only element that guarantees the reproduction and re-analysis of archaeology; the failure to produce raw data (archaeographic data), often in favour of synthetically attributed data (archaeological data), denies the possibility for the scientific community to fully understand the interpretative process, to re-examine the process where necessary and to reuse the data on different scales in order to find the answers to many questions.

8.6 Dates in the data

Other information that is inherent to the data examined is the chronology of the find. Although attention to post-classical data is rather recent, nevertheless it is interesting to focus on how each chronological phase is represented. If we exclude 15% of finds that are not associated with any kind of chronology and are classified as "non determined", at first sight, the overall percentages provide a quite well-balanced picture. Apart from the protohistoric age (only 2%), the Roman period, Late Middle ages, Modern age and Contemporary age have more or less equivalent percentages between 12 and 18%[25]; they are immediately followed by the Etruscan period (10%), Early Middle ages (7%) and Late Antiquity (6%). Some simple considerations can help us better understand these data.

Firstly, it must be remembered that almost all the interventions carried out in the historical centre of Pisa were strongly influenced by the presence of groundwater which, depending on the seasons

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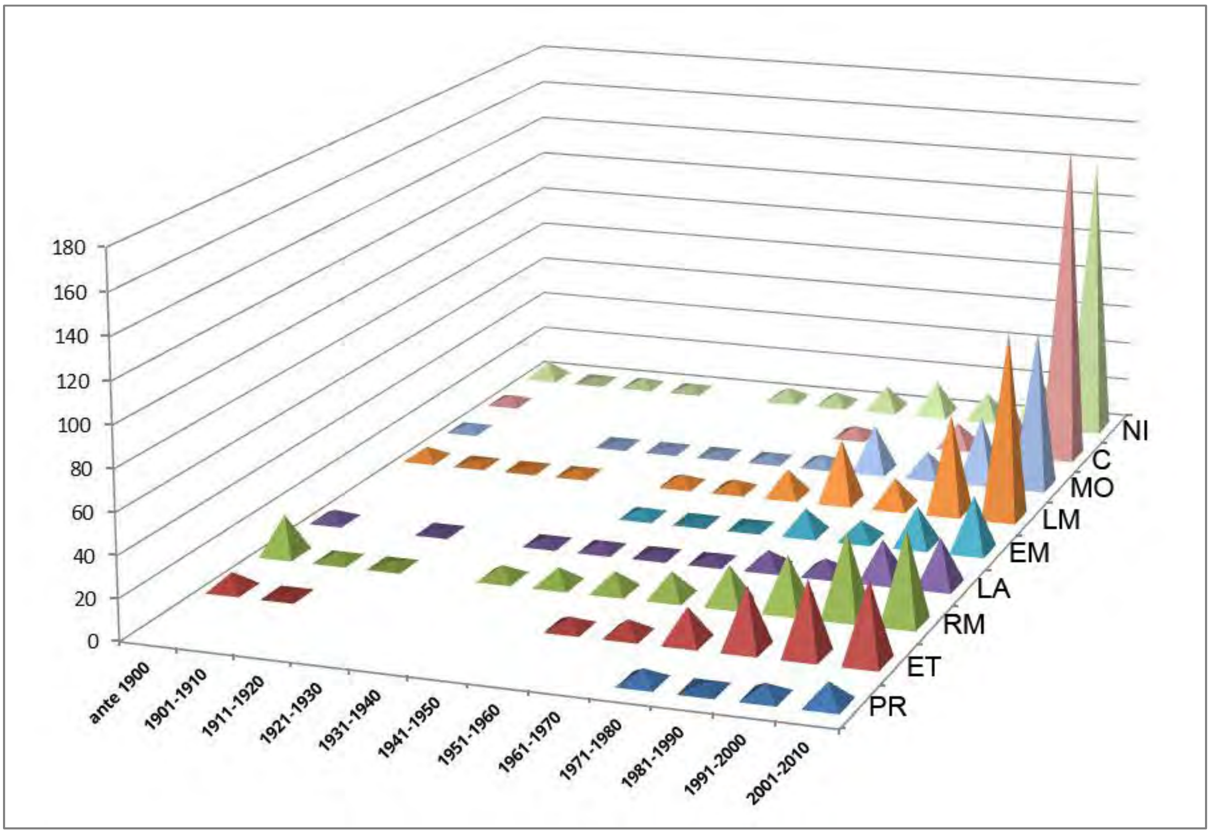
[25] Roman period 12%, Late Middle ages 16%, Modern age 14%, Contemporary age 18%.



8.12 Attestation of the various chronologies of the finds throughout the decades.

Protohistoric finds represent a very small sample, which are mainly represented in assistance interventions and preventive excavations[27]. Since we do not have a sufficient set of data available to accurately analyse the heights[28], it is not possible to provide a general consideration about how much this value influenced the probable evidence of this period. Before 1970, however, no evidences are recorded and only seven excavations were carried out; the remaining data are the result mainly of assistance activities and cores. Within the group of data, out of 132 finds, only 7% reach a value of information reliability between the maximum values of 11 and 12, and another 7% between 9 and 10. The worrying figure, given the small sample available, is that 50% of data are no higher than 4 (36% between 1 and 2); this leads us to assume that of the already little information available for reconstructing the history of the city during the protohistoric age, over half are poorly reliable and cannot be checked through the primary data. In situations such as these, where much research is still needed, the damage that the lack of correct documentation causes to current research is clearly obvious, as also the impact it will have on future research; in fact, when new discoveries will come to light, it will not be possible to use the previous data as comparison parameters in order to confirm or deny possible assumptions and reconstructions.

From a topographical viewpoint, the information is spread across the territory without specific areas of concentration; they are chiefly located in the northern area and are almost totally exclusive of the historical centre. Only one intervention is

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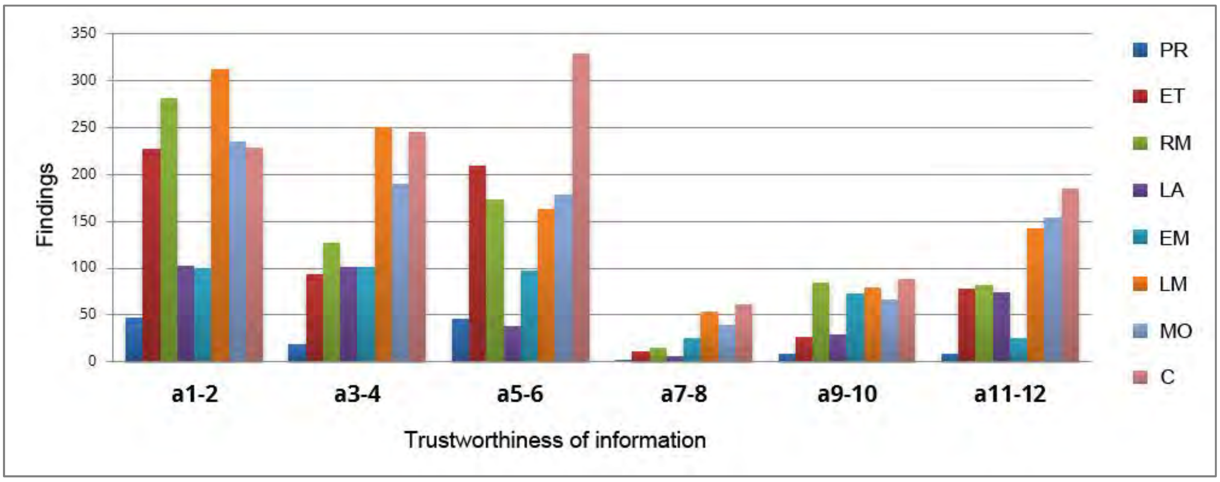
[27] 31% assistance, 23% preventive excavations, 15% rescue excavations, 11% cores, 8% surveys and occasional recoveries, 4% planned excavations

[28] The heights of finds are attested in only 11 out of 27 interventions.



8.13 Reliability of the information about the finds for each chronological period.

attested south of the Arno River[29]. 42% of the interventions are topographically located with accuracy.

Although the Etruscan, Roman and Late Antiquity ages are among the most attested, they are strongly represented by occasional recoveries, which often provide exclusively decontextualised data (26.5% belong to the Etruscan age, 28% to the Roman period and 18.9% to the Late Antiquity). Since 193 A.D. is the date established in the project for the start of Late Antiquity (ANICHINI *et alii* 2012: 14), it is no surprise that this period is attested quite significantly and almost continuously from the start of the century to today: some of the centuries that we consider as part of Late Antiquity have always been traditionally considered as belonging to the Roman period and, therefore, worthy of greater attention. Both Roman and Late Antiquity finds are already recalled in information dating far back in time and continue to be reported during the entire century, with a peak at the start of 2000, given the threefold increase in the number of investigations during this period. Etruscan evidence, instead, started from the 1950s. The most important interventions, composed of preventive and rescue excavations were mainly carried out in areas external to the city's medieval walls[30]; in these areas, located almost exclusively north of the historical centre, since the deposits did not increase during post-classical periods due to the development of the medieval city towards south, it was possible to trace the most ancient deposits at quite superficial heights.

The Etruscan finds spread along the northern and north-western borders of the area under study, in agricultural areas, where surface surveys reveal traces of this period; finds are more sporadic in the city centre and often consist of finds recovered from the bottom of occasional deep trenches, residual material in the lowest levels of excavations, and artefacts found in core sequences. In the southern and eastern areas, the traces are very few and almost all refer to recoveries[31]. Roman and Late Antiquity finds are distributed in the northern and western areas in the historical centre north to the Arno; only six are

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[29] Assistance in Piazza Vittorio Emanuele II. In this case, the development of an underground multi-storey car park allowed significant depths to be reached through suitable construction site management which monitored and isolated groundwater surfacing

[30] With the exception of the excavations in Piazza dei Miracoli, via Sant'Apollonia, via Consoli del Mare, via dell'Arcivescovado and other minor interventions.

[31] 27% occasional recovery, 16% preventive excavations, 14% cores, 13% rescue excavations, 11% planned excavations, 10% assistance, 3% surveys, 5% unspecified.

positioned south of the river[32]. Overall, the accuracy of the topographical positioning of the intervention areas is around 40%. Information reliability for these periods is quite alarming: for the Etruscan age only 16% is between 9 and 12, for the Roman period and Late Antiquity the figure amounts to 26%; over 50% of finds have a value between 1 and 4, of which 35% are between 1 and 2. This means that a large amount of these data lack minimum documentation, despite around a third are planned or preventive excavations[33] and that the huge amount of registered data only partially corresponds to an actual information basis allowing the reconstruction of the settlement and development dynamics of the city during these centuries.

Evidence for the Early Middle ages is poor, although data began to be sporadically recorded from the 1940s. Owing to the problems related to the groundwater level, the most significant finds related to this phase are achieved with planned excavations (therefore, with more or less planned research) and preventive excavations (where permitted by the depths associated with the works to be performed) and through cores[34]. The finds are mainly located in the north-western[35] and western part of the historical centre; evidence in the eastern part of the city is sporadic as well as to the south of the Arno, exclusively near the church of Santa Cristina in Kinzica.

The Late Middle Ages, instead, is one of the most highly represented periods[36] and apart from a few occasional recoveries (mainly pottery), this period is investigated with greater attention from the end of the 1970s. Together with most ancient data, which rarely take into account Late Medieval finds (unless related to small or large "treasures" – money, jewellery, partly decorated tableware, etc… – or to epigraphs), we may observe that throughout the Eighties, the portion of the stratigraphic sequence of the 'Dark Ages' is still not documented, not even in planned excavations. Following the adoption of preventive excavations and archaeological assistance (systematically from 2001), an ever-increasing amount of information started to be collected and the deposit began to be fully documented; this includes the medieval phases which were often preserved at relatively superficial depths and were usually removed before the arrival of the archaeologist. The finds are distributed mainly in the historical centre within the walls, both to the north and south of the Arno, and in immediately neighbouring areas, with the exclusion of the southern sector and nearly all the eastern area.

As seen, medieval finds overall represent a quarter of total finds, however, although a high number of interventions have been performed recently, documentation reliability has levels between 46 and 58% (Early Middle ages and Late Middle ages, respectively) for values between 1 and 4 and do not exceed 23% for values between 9 and 12[37]. The positioning of the investigated areas is highly more accurate, reaching 62%.

The same considerations can be made for the modern and contemporary ages which are further associated with preventive procedures; attention appears to have been given to these periods exclusively over the last fifteen years. Regarding the spatial distribution of the finds,

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[32] 25% occasional recovery, 19% preventive excavations, 16% planned excavations, 15% rescue excavations, 11% assistance, 6% cores, 3% surveys, 5% unspecified

[33] For the Etruscan age the values are the following: 1-2 = 35%, 3-4 = 15%, 5-6 = 32%, 7-8 = 2%, 9-10 = 4%, 11-12 = 12%. For the Roman period and Late Antiquity the values are as follows: 1-2 = 35%, 3-4 = 20%, 5-6 = 19%, 7-8 = 2%, 9-10 = 10%, 11-12 = 14%.

[34] 30% from preventive excavations, 22% from planned excavations, 17% from assistance, 13% from cores, 12% from rescue excavations, 3% form occasional recoveries and unspecified interventions

[35] Santa Maria district

[36] 35% from preventive excavations, 20% from assistance, 14% from occasional recoveries, 13% from rescue excavations, 11% from planned excavations, 6% from cores, 1% from survey

[37] Early Middle age values are the following: 1-2 = 24%, 3-4 = 24%, 5-6 = 23%, 7-8 = 6%, 9-10 = 17%, 11-12 = 6%. Late Middle age values are the following: 1-2 = 31%, 3-4 = 25%, 5-6 = 16%, 7-8 = 6%, 9-10 = 8%, 11-12 = 14%.

which report an accuracy ranging between 70% and 75%, the areas are similar to those of the Late Middle ages, spreading (especially for the Modern Age) to northern and western peri-urban areas. Regarding the Modern age, 36.4% of finds are the result of preventive excavations and 28.4% of assistance activities. Planned and rescue excavations both amount to around 11%, unlike the Contemporary age in which these values drop by a half, 5.6% and 6.1%, respectively, and rise to 46.4% in the case of preventive excavations. Information reliability only partially improves: 1-4 values amount to 49% for the Modern Age and drop to 42% for the Contemporary Age; 9-12 levels reach 26%[38].

The data reveal how the type of intervention influences sample representativeness and, partially, information reliability. That preventive excavations allow almost complete diachrony is an obvious fact; less obvious is the little attention paid by planned research interventions – even in recent times – to post-classical traces, especially post-medieval traces. The fact that depth is an influential item in the documentation of an entire multi-layered sequence cannot be ignored to such an extent that the detailed knowledge of all the preserved deposit is worth taking into account. Can the planning of a sample exceeding the depths required for executing a work which will seal a part of the city area for a long time, be considered feasible? Is it possible to plan, in terms of timing and costs, the most suitable forms of intervention in order to obtain a cross-section that allows us to imagine (also through the interpolation of small samples) the spatial distribution of the settlement and its altimetric trend throughout the different historical periods? Wouldn't an activity such as this allow us to take more preventive measures and optimise future research?

8.7 Categories of finds

A forthcoming contribution will provide a detailed description of the various categories of finds for each period; however, some general considerations will be presented in this paragraph, bearing in mind that in the presence of a large amount of data, casual factors – not dictated by strategic or methodological choices – may partially influence the transversal reading of certain trends.

The data confirm that up to the 1970s the only categories[39] represented were those in which the object had a significant value or monumental importance. Places of worship, houses – where associated with high-quality masonry structures or floors – health/hygiene buildings (especially spas) and on rare occasions clay manufacturing facilities (classical age) are the most attested. Road infrastructures are also recorded and, more sporadically, hydraulic infrastructures[40], cemeterial areas and single tombs. It is only from the 1980s, with the establishment of stratigraphic procedures and, subsequently, of medieval and post-medieval archaeology, that the data increased. Although some categories are specific to certain historical periods, others cut across many periods. The variety of excavation procedures, associated with new intervention approaches, are able to document categories that, although not providing valuable items, are able to outline a broad profile of the city's activities. Consequently, production plants emerge, ranging from metal manufacturing to glass manufacturing fabric manufacturing and industrial structures;

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[38] Modern age values are the following: 1-2 = 27%, 3-4 = 22%, 5-6 = 21%, 7-8 = 4%, 9-10 = 8%, 11-12 = 18%. Contemporary age values are the following: 1-2 = 20%, 3-4 = 22%, 5-6 = 29%, 7-8 = 5%, 9-10 = 8%, 11-12 = 16%.

[39] See §6.4 for the list of categories

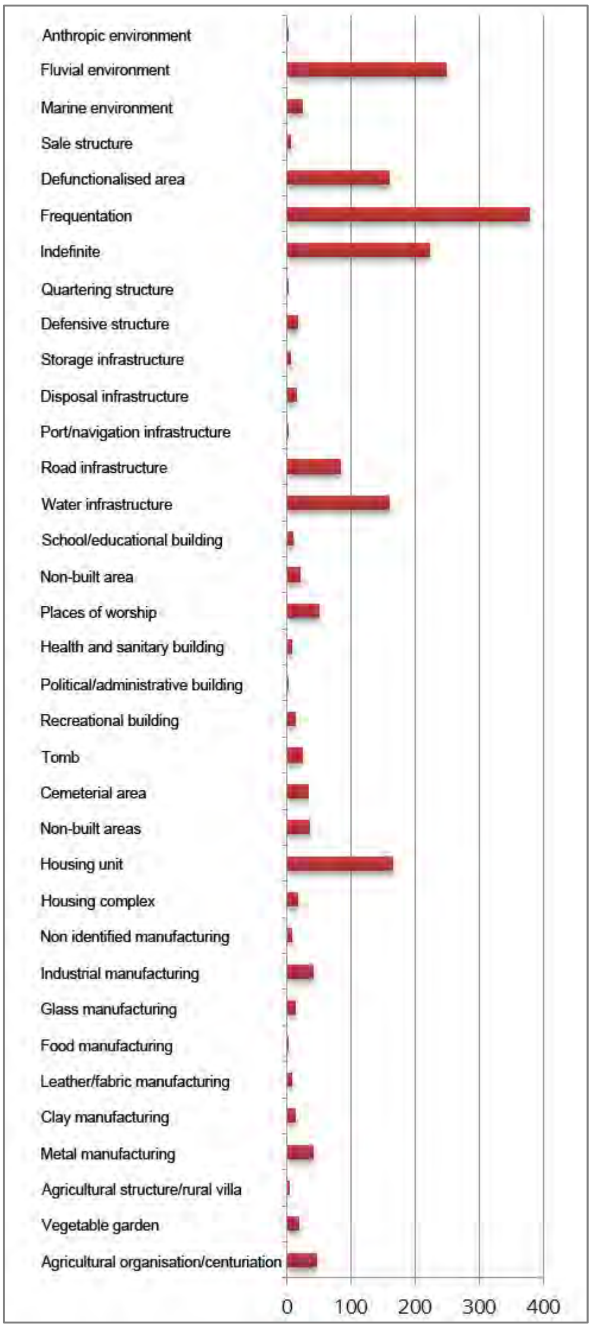
[40] Before 1981, only 15 finds are ascribable to the hydraulic infrastructures category (fresh water system, sewage water system, well, wash-house, aqueduct and embankment); the other 147 are recorded from 1981 to 2011. Although they are mainly structured elements associated with classical, medieval and modern ages, information about them is only obtained in the event of planned excavations and following the gradual adoption of preventive excavations and assistance activities at the end of the 1990s. The documented structures are mainly post-classical. Data reliability is averagely low (over 70% between 1 and 5).

storage and disposal infrastructures also appear as well as manufacturing traces, agricultural layout and, lastly, the defunctionalisation and abandonment of areas.

The most represented category (20%), which is common to all periods and chronologies, is the generic term "frequentation/presence" (Figure 10.14). This is associated with the majority of occasional finds (with the item "mobile artefacts"), but also with phases that cannot be better characterised within a large number of stratigraphic sequences (also referable to "mobile artefacts" or "traces of use")[41].

The indefinite nature of certain finds is continuous throughout the decades, thus falling into the "indefinite" category; a change of direction has been registered over the last decade thanks to extensive research which has increased the knowledge of the artefacts and deposits characteristic of the city and has made interpretation easier, thus reducing the percentage of this category to 5%[42].

A special analysis must be carried out for "natural contexts". Among the initial information produced is a survey carried out by Nello Toscanelli (an expert interested in the city's historical aspects) in 1924 at a site located along the River Arno[43]. Toscanelli recorded "a heap of pebbles from the River Serchio" at a depth of 4 metres, giving him "confirmation of the place where the Arno and Serchio merged in ancient times". Toscanelli's observations already contain all the elements that guide modern geoarchaeological research: observation of geological data, height recording and, above all, dialogue with experts of the Geology Museum (Toscanelli 1933: 187).



8.14 Representativeness of the different categories of finds.

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[41] Mobile artefacts represent 86% of finds of the "frequentation/presence" category, against 13% of traces of use and 1% indefinite. It is interesting to notice how only 3 finds can be catalogued as "traces of use" before 1981 (2.6% of the finds in this category up to this period), whilst in the following decades, the association of the artefact with the activity and so with the context, reveals a more balanced proportion between the two items (30% traces and 70% finds between 1981 and 2011). In general, data reliability is low, with values between 1 and 5 amounting to 74% for traces of use and 81% for artefacts.

[42] After peaks of over 22% during the 1940s and 1950s, the "indefinite" value dropped to 12% between 1961 and 1970 and to 7.3% during the following decade. The percentage rose again above 8.3% between 1981 and 1990, and then dropped to 6.6% during the 1990s.

[43] Between piazza Garibaldi and current Lungarno Pacinotti.

This episode and the mentality that guided him, however, were of an occasional nature; it was necessary to wait until the 1980s to see more frequent geological recordings. During the 2001-2010 decade, the figures improved and geological recordings were regularly carried out during interventions, also due to the increase in coring activities aimed at jointly analysing both natural and man-made stratifications. Different behaviour, however, is registered: in the best performing cases an objective and accurate description of the natural sediment is provided, with references to grain size, consistency and colour, accompanied by interpretation of the natural facies. More often, however, the objective data are described very superficially without any interpretation or, if an interpretation is given, there is no reference to the aspect of the natural sediment. In all cases, when reading the stratification, there is no integration between the archaeologist's and geologist's competences, with a view to enhancing the information potential of the layers created by man, nature or by the combined action of both[44].

Lastly, the "no data" recordings need to be mentioned. The sample at our disposal reveals a positive trend towards the gradual recognition of the importance of this type of information; although now part of common archaeological awareness, it does not appear to be equally acquired in the documentary transfer of information. We do not know how many interventions really did not find archaeological traces because there is no documentation for many of them. Indeed it is only towards the end of the 1990s that "negative" reports started to briefly appear at the end of the excavation reports. During the 2001-2010 decade, alongside traditional information, data about the natural data were for the majority reported, although briefly.

8.8 The 'time' for nouns

We do not expect the picture that has been provided to be complete and to have fully covered all possible aspects; it emphasises the fundamental importance of raw data as a primary factor for every more detailed study. Italian methodological research too often only considers interpreted archaeological information and does not feel the need for a direct approach with archaeographic data. Choices of this kind have effects on the entire discipline of archaeology and on the different ways it is presented and managed. From university training to professional work, from research to protection… in every sector, the inability to recognise the real and essential importance of raw data has led to a paralysis, which prevents the study of new solutions and the production of further information. The confidence placed in univocal interpretations (awaited for years until publication of the archaeological data) and the failure to make critical and public dialogue an opportunity for growth for the entire scientific community have produced a system too often sheltered behind small individual worlds claiming inexistent information ownership. The Code of Cultural Heritage firmly establishes that cultural heritage belongs to the State and associates the related documents with that heritage. It is so obvious that it almost seems innovative to assert that the State is composed of its citizens and that cultural heritage belongs to everyone.

Although it is regretful that when collecting and registering archaeological information, many data available cannot be used because produced in an age when importance was not given to documenting the unrepeatable phases of a destructive process, such as archaeological excavations, it is instead serious and unacceptable to

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[44] This awareness has guided the investigation strategies during the MAPPA project. In order to acquire new subsurface data useful for reconstructing the transformation of the human and natural landscape of the area of study, twenty cores were carried out in the areas that presented less archaeological and geological information. A group of archaeologists, sedimentologists and geomorphologists was set up for this purpose which performed a combined (not parallel) reading of the stratifications and jointly shared knowledge, observations and problems, in a virtuous circle which produced a new methodological proposal. The results of this work will be presented in a forthcoming MapPaper.

find this same behaviour in recent and very recent years. How is it possible to invest and work to optimise prevention, planning, management and valorisation activities within a system that has no rules, where what is openly stigmatised is still accepted?

It is no longer possible to wait; there is no longer room for inconsistent rules in Italy and in Europe, where the smartest remove what should be guaranteed to everyone. Creating a documentation standard and making sure it is respected, means giving space to the deserving, to professionalism and to information quality, thanks to which the pieces of history can be put together. The effort we must make is to change a deep-rooted and outdated mentality; to use technology to broaden the field of exchange and sharing; to leave room so that the investment made by the State and which it continues to make to train highly specialised professionals may finally have an impact on the country and on its economy and culture. Our request is to take a few steps forwards and quickly, and maybe ask someone to take a few backwards.

History is made of data, nouns, and it is exactly these data that will never allow interpretative adjectives to change its meaning. Everyone should have the opportunity to propose the adjectives they think best and should do this by using information that is correctly produced and recorded.

9. Aerial archaeology: new and old data

Monica Bini, Marco Capitani, Marta Pappalardo, Giorgio Franco Pocobelli *(DOI: 10.4458/8219-12)*

This chapter will illustrate the methodological applications used during the MAPPA project for analysing aerial photographs. This work was carried out by archaeological and geological photo interpretation experts.

Two separate mapping representations have been produced so far; they will be integrated and analysed with other data during a second phase, thus allowing, at the end of the study, the reconstruction of the landscape of Pisa during the city's different historical phases.

9.1. Aerial archaeology and cartographic rendering of traces

9.1.1 Methodological introduction

The area of study spreads across over 11,500 hectares[1] including the city of Pisa, part of the surrounding municipal territory and also portions of the neighbouring areas of San Giuliano Terme and Cascina (Figure 9.1).

The first archaeological studies of Pisa systematically supported by aerial photographs date back to the 1960s when Giulio Schmiedt, former director of the Istituto Geografico Militare - IGM (Military Geographical Institute) and subsequently professor of "Aerial archaeology" at Pisa University, reconstructed the ancient topography of the *ager Pisanus* thanks to the material preserved at the IGM and attempted to define its port system (SCHMIEDT 1964: 74-78). Over the following years, Marcello Cosci conducted research throughout the territory using the same techniques as Schmeidt. Cosci – who attended Schmeidt's university courses – was among the first in Italy to test new survey tools for archaeological purposes, such as satellite and infrared imagery, and to systematically apply digital image processing techniques; these activities enhanced knowledge of the local areas and contributed to reconstructing the ancient landscape[2]. Nevertheless, an analytical map of aerial archaeological evidences, as a whole, is still missing.

The research activities – upon which the preliminary data in this chapter are based – were carried out starting from the aerial photographs held at the Centro di Documentazione Aerofotografico Marcello Cosci (Marcello Cosci Aerial Photography Documentation Centre), donated by the scholar's heirs to the Department of Archaeological Science of Pisa University. The archive, which is currently being catalogued, is composed of over 100 folders relating to the flight commissioned by Regione Toscana to EIRA in 1975, and of many other strips acquired by the scholar in the course of his research activities in other companies and institutions. The archive includes flights that cover Tuscany for the most part[3].

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[1] Initially, the study was meant to include the municipalities of Pisa, Vecchiano, San Giuliano Terme, Cascina and Calci. Due to the short time and huge amount of data, we focused our research on a smaller area included in a rectangle measuring km. 13,250 x 8,700, extending astride of tablets IGM F. 104 II SE (Pisa), F. 105 III SO (Cascina), F. 111 I NE (Guasticce) and F. 112 IV NO (Colle Salvetti), and of the following sections of the Regional Technical Map: 273050 (Pisa), 273060 (Ghezzano), 273090 (San Piero a Grado) and 273100 (Riglione).

[2] Among the most interesting results achieved by Cosci, the reconstruction of the paleo-river beds of the rivers Auser and Arno must undoubtedly be remembered; various methods and different professional skills were employed in the areas of Pisa and Lucca (COSCI 2005 with bibliography).

[3] The archive may be indicatively estimated in over 6000 positive images, both black and white and coloured, and a large amount of slides.

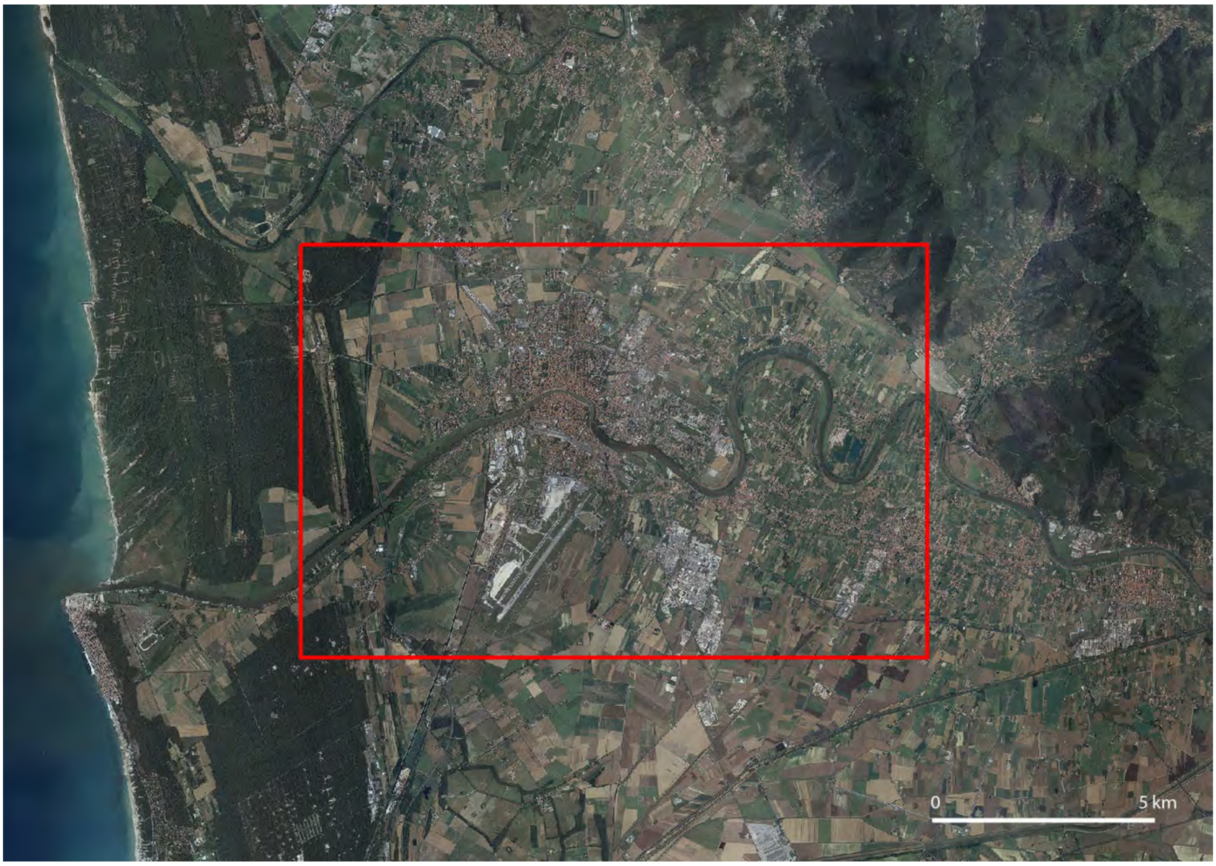

Fig. 9.1 View of the area of study.

The study was carried out with the aim to analyse the aerial images by integrating traditional aerial photography methods and modern GIS technologies (GUAITOLI 1997: 10-12; GUAITOLI 2003: 101-102) and thus to manage an information layer within the MAPPA project with traces found in the aerial photographs[4]. Geological anomalies, especially traces related to the paleoriver beds of the Auser and Arno which, during ancient times, strongly characterised and influenced land occupation patterns, will instead be studied by the geologists of the project team. In the second part of the work, the two maps obtained (archaeological and geological) will be overlapped, allowing the landscape to be reconstructed during different historical periods thanks to the integration of data from geological investigations and bibliographical/archival study.

The research activities were developed according to a work programme divided into four different phases:

- Collection, preliminary analysis and selection of the flights useful for the study;
- Digital acquisition and georeferencing of the images;
- Stereoscopic analysis and archaeological photo interpretation; rendering and filing of anomalies; preparation of a map for each single flight with the identified traces;
- Data integration and final representation of the "map of anomalies".

Our work started, therefore, by systematically collecting the aerial photo documentation of the area; we gave preference to the zenith flights for the geometric characteristics of the images. In addition to the Cosci material, which includes many strips

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[4] The archaeological analysis of LiDAR data, acquired by the MAPPA project during an advanced research phase, is not considered in this chapter and will be the subject of a subsequent study.

acquired from the IGM, the flights preserved in the Archivio Cartografico della Regione Toscana (Cartographic Archive of Regione Toscana) were examined and the RAF flights preserved in the Aerofototeca Nazionale (National Aerial Photo Library) of the ICCD (Central Institute for Cataloguing and Documentation) were consulted[5].
This research phase, which led to analysing a total amount of 118 vertical strips related to flights between 1943 and 2010, allowed us to choose the flights which best responded to the project's requirements, both in terms of scale and amount of anomalies found[6]. The large amount of aerial photo documentation available, which covers a chronological period of almost sixty years, besides evidencing the territory's urban development, contributed to correctly interpreting the anomalies, which in some case (at times frequent) are defined by old country roads or abandoned agricultural divisions.

Regarding GIS environment management, the images selected were acquired in digital format at medium resolution[7]; before cartographically rendering the images, only the areas for which greater detail was needed were scanned at high definition (1200 dpi). As a result, the system was not weighed down by heavy files and, at the same time, the traces were digitised with a very high mapping accuracy since it was possible to enlarge details without losing clarity.

The photos were processed using techniques for the radiometric improvement of photo quality (contrast and light) whereas the use of directional filters for highlighting linear elements (x-edge filters, y-edge filters and diagonal edge Detection), although tested, did not lead to important contributions for the purpose of our research[8].

The raster images selected were subsequently georeferenced on the basis of the 1:10,000-scale digital CTR provided by Regione Toscana (Gauss-Boaga reference system), used as project mapping support[9]. A minimum of twelve to twenty correlation points were entered for each photo (a greater number in the case of the RAF photos) in order to limit image distortion to a strict minimum and contain the Root Mean Square Error under one metre deviation.

The few perspective photographs used were processed with a professional digital image rectification programme[10] before the georeferencing phase. Since these are highly detailed photographs, taken at low altitude and showing small parts of flat terrain, the Root Mean Square Error of the images is lower than the tolerances accepted for the vertical aerial photos.

Regarding the photos of the RAF flights performed for war purposes between 1943 and 1945 – in which the images reveal a completely different landscape than now – georeferencing was carried out using the orthophoto map made with the frames of the 1954 Base Flight (in which changes due to massive urban expansion and different land use can still not be seen), in order to more precisely identify the points required for optimal correlation with modern cartography.

Trace digitisation was carried out together with the

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[5] I take the opportunity to thank A. Fiaschi, E. Masson, R. Montaini, M. Pugi and G. Tagliaferri, of the Cartographic Archive of Regione Toscana for their kindness and help. Special thanks to the director of the National Aerial Photo Library - E.J. Shepherd, and to all the staff, for the advice and digital support provided when filing the material of the Marcello Cosci Aerial Photography Documentation Centre.

[6] The frames of the following flights were rendered: 1943, 1945, 1951, 1953, 1954, 1978, 1980, 1986, 1988, 1996, 1999, 2008, 2009 and 2010.

[7] Acquisition with a professional level scanner from 300 to 600 dpi, in relation to the flight scale, was necessary only for the flights preserved at the Marcello Cosci Aerial Photography Documentation Centre, whereas the aerial images of Regione Toscana, as well as the cartography and orthophoto maps, and a number of RAF photos from the National Aerial Photo Library were provided in digital format.

[8] For the use of these image processing techniques applied to archaeological contexts, see the results of the tests carried out on a number of frames of the O area of Pisa (DEL SEPPIA 2005).

[9] The ArcGIS 10 module of ESRI s.r.l. was used for georeferencing the photos.

[10] Rectification was carried out with the *Photometric 2010* programme of GEOTOP s.r.l.

stereoscopic analysis of the frames[11] and directly at the computer with the ArcGIS 10 graphic module; this resulted in the creation of polygonal shapefiles and of a "Map of anomalies" for each flight, containing the rendering of the traces identified (Figure 9.2). A different approach was taken with the traces of the *ager Pisanus* centuriation which, since consisting of roads or canals still in use today, are visible in all the flights. In order to speed up rendering and avoid weighing down the database with heavy records, we decided to digitise these traces using only the orthophoto map created with the 1978 images (an excellent flight in terms of clarity and aerial shots) which represents a good compromise in terms of quality and mapping accuracy with respect to the RAF photos, which do not cover all the area under examination, and the Base Flight[12].

Each shapefile is associated with a database containing key information about every single mapped anomaly. In the absence of coded documents for the specific handling of aerial photography anomalies[13], a table was developed in the wake of the experience gained in other research projects, both at university and ministerial level[14].

Fig. 9.2. Scheibler Area. Detail of the "Map of anomalies", with graphic rendering of the traces visible in the following flights: RAF 1943 (strip 15, frame 3043), RAF 1945 (strip 262, frame 3230), Base Flight 1954 (strip 7, frame 2052), Prospective Flight 2009.

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[11] Anaglyphs were necessary to appreciate the stereoscopic vision of the land only for the 2010 flight provided by the Municipality of Pisa, with high-definition digital images (1200 dpi).

[12] It should be considered that the 1978 flight allowed the rendering of 77 traces of centuriation axes, both *cardines* and *decumani*, as well no less than 367 agricultural divisions with the same orientation of the centuriation. The forthcoming study of the *limitatio* will be further examined, based on integration of the traces identified in previous flights.

[13] Regarding the interpretation of aerial images, the indications provided in the format for drawing up the "preventive archaeological evaluation document" – currently the only attempt to provide an official codification for the sector – are highly unsatisfactory. For observations on the document, see CERAUDO 2011: 7-8.

[14] POCOBELLI 1997: 20-21; POCOBELLI 2009: 54; POCOBELLI 2011: 117-118.

In the "archaeological trace record", in addition to the flight information items (executor, year, strip, frame, etc.), location (province, municipality), anomaly features (type of trace, definition, description and interpretation) and a number of fields necessary for acquiring data in the ICCD's Information System, a "photo-interpretation code" was also included; the code is an alpha-numerical code developed by the Laboratorio di Topografia Antica e Fotogrammetria dell'Università del Salento (Laboratory of Ancient Topography and Photogrammetry of Salento University) run by Marcello Guaitoli and is used for the development of targeted archaeological mapping and trace rendering[15].

Every single anomaly is identified by a trace number, i.e. a field composed of a progressive numerical code followed by the year of the flight: consequently, trace 002/43 univocally indicates anomaly number 2 of flight 1943. The record fields regarding the typology and definition of the trace were set with closed dictionaries which, since using approved aerial archaeology terminology, allow the system to be queried according to standardised parameters.

At the end of the rendering activities, around 1500 anomalies were identified, mapped and entered in the database regardless of their chronology. The anomalies included disused horse racing hippodromes, channelling and drains related to abandoned agricultural settings or abandoned railway lines which form an integrated part of Pisa's recent history. The final product of our work is the "Map of aerial photography anomalies" which is not only a working tool for experts but also a container of information in which all the traces identified throughout the research have been recorded, regardless of their interpretation or dating. The map leads to a further value: it progresses from a simple thematic mapping product to a tool that, since lacking pre-defined cultural superstructures, provides overall and wide-ranging evaluations and can be used for different purposes by a variety of professionals, both for territorial management/knowledge and for future research, such as historical-urban studies and excavation surveys. The map becomes a true container that may be enhanced and implemented through the addition of further information layers on the basis of new images and specific thematic queries. In this perspective, a layer can be developed containing accurate indications of the craters caused by the bombing of the Allied Forces during World War II; this is of interest both to scholars dealing with local history and, more realistically, to delimit areas at risk of demining when planning public or private works, or to provide further indications when scheduling excavation and protection work.

By overlapping the layers of the various flights, by combining the bibliographical and archival data, and by comparing historical cartography – especially with the Leopoldino Land Registry maps provided by Regione Toscana in georeferenced raster format – and the 1930 IGM tablets used as

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[15] I would like to thank Prof. M. Guaitoli for authorising use within the MAPPA project. With regard to scientific value, technical characteristics and the utility of targeted mapping see PICCARRETA 1997: 51-65; PICCARRETA, CERAUDO 2000: 133-142.

The codes used for rendering the anomalies are the following:

11220000	Abandoned railway
13510000	Sports facilities / Hippodrome
70100000	Generic trace from humidity or vegetation
70110000	Trace from micro-relief
71107A1A	Trace of defensive bulwark (Level I)
74010A1A	Road trace (Level I)
74011000	Road survival
76000A1B	Trace of survival (Level II)
76025A1A	Building trace (Level I)
76025A1B	Building trace (Level II)
7C640A1A	Trace from tumulus (Level I)

historical reference base during the rendering phase, it was possible to correctly classify and interpret the anomalies recorded.

At the end of these activities, after the traces were cleaned and graphically simplified (through hierarchisation so as to distinguish different degrees of reliability), the "Map of aerial photography anomalies" was definitely drawn up (Figure 9.3).

9.1.2 Preliminary data

The study carried out on the aerial photographs allowed many traces to be identified, the majority of which, given their orientation, should presumably be related to works associated with Roman centuriation and agricultural division inside individual lots. As previously mentioned, it is important to point out that the data briefly presented represent the final outcome of the aerial photo interpretation and photo rendering phase, that is, the first step of the MAPPA project and the starting point of the subsequent activities. Indeed, as usually happens in scientific research, these first activities allowed a series of questions and historical-topographical problems to be focused; we will attempt to answer these issues as the project continues. An in-depth study will determine the need for corrections and explanations which, in any case, should not ultimately alter the general picture provided.

Piazza dei Miracoli and the suburban area

The 1951 zenith aerial photograph of Piazza dei Miracoli preserved at the Marcello Cosci Aerial Photography Documentation Centre and recently published (ALBERTI, PARIBENI 2011: 28), clearly shows a large number of vegetation traces determined by the masonry structures related to Roman-age *domus* and to the first phase of the basilica and baptistery, the latter visible in the Camposanto court (Figure 9.4).

Fig. 9.3. The aerial photography anomalies identified during the research. Simplified cartographic base drawn from the 1:10,000-scale CTR map.

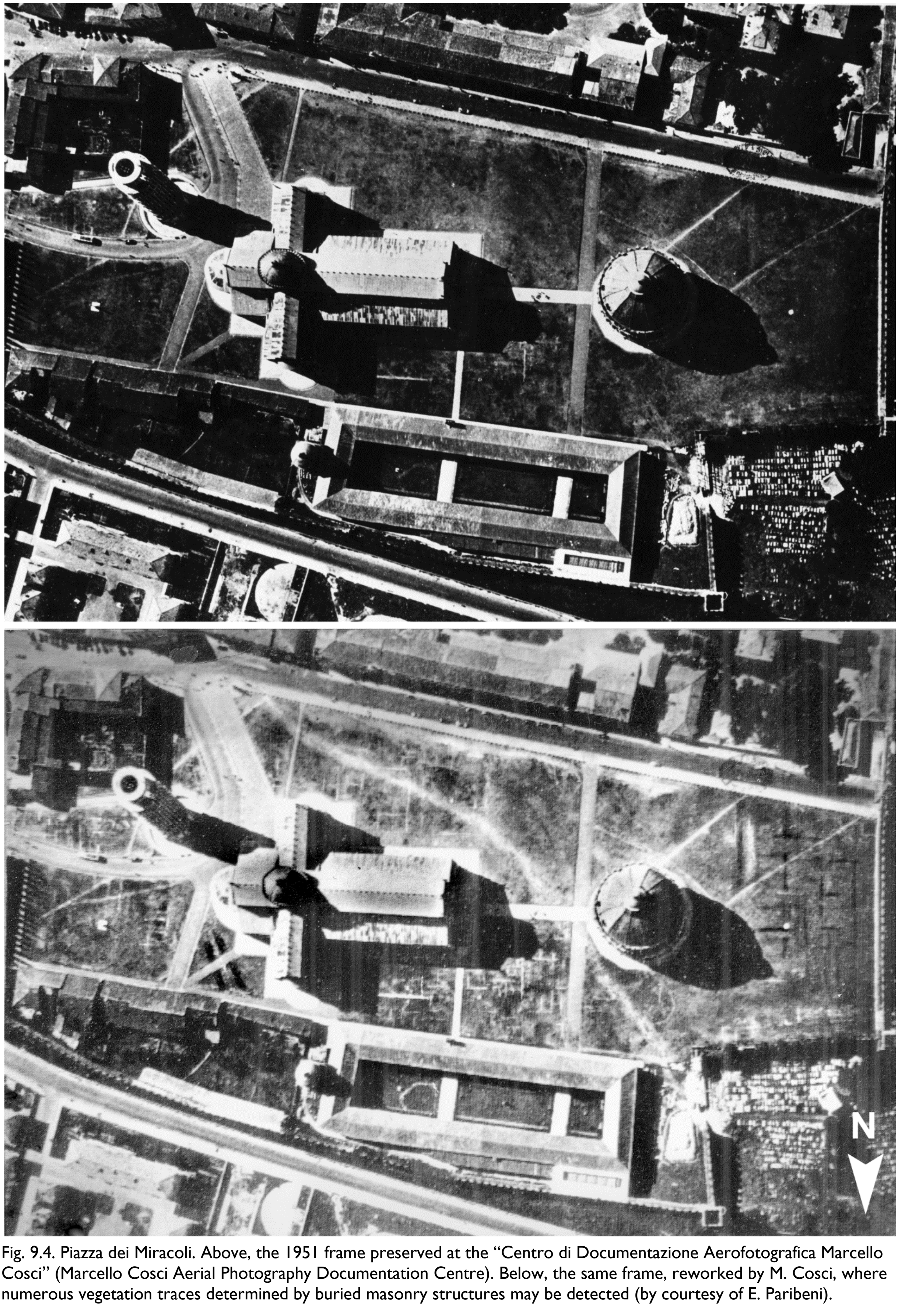

Fig. 9.4. Piazza dei Miracoli. Above, the 1951 frame preserved at the "Centro di Documentazione Aerofotografica Marcello Cosci" (Marcello Cosci Aerial Photography Documentation Centre). Below, the same frame, reworked by M. Cosci, where numerous vegetation traces determined by buried masonry structures may be detected (by courtesy of E. Paribeni).

The structures, investigated in various excavation campaigns (Fedi 1991: 59-77; Alberti, Paribeni 2011: 18), reveal a substantially constant orientation along the cardinal points, with the sole exception of a number of anomalies S and SW of the Baptistery with a NW-SE orientation. Given the current state of knowledge (no archaeological excavations have been conducted in the area)[16] it is not possible to make any suggestions on the reasons for this difference, which may be related to an intermediate building phase between the abandonment of the Roman *domus* and the medieval monumentalisation of the square.

In the area immediately N of the municipal walls, instead, the aerial photos taken by the Royal Air Force during the Second World War reveal the traces of fortifications that started to be built in 1626 to defend the city. The remains of the *Canto a Lione* bulwark and the trench are particularly evident; they are located between Via Contessa Matilde and Via Leonardo da Vinci, in the NW corner of the city in front of the Israelite Cemetery, and of the bulwark called *della Forcha* positioned between Porta a Lucca and Largo S. Zeno[17], in the stretch between the latter and Via Marche (Figure 9.5). Subsequent urban expansion led to disappearance of the evidences: in the 1953 flight, the north-western bulwark appears to have been built and the *della Forca* bulwark has been occupied with houses. Nonetheless, the latter influenced the development of the buildings in this area which still maintain the triangular layout of the original structure (Figure 9.6).

At around 300 metres NE of Porta a Lucca, the RAF photos show the mid-XIX century railway and part of the railway route (subsequently dismantled) which connected Pisa to Lucca before construction of the Pisa S. Rossore station. The route, which is visible for an overall length of around 850 metres, practically disappears in the following 1953 and 1954 flights (Figure 9.5).

The anomalous pattern of the suburban road network in the area to the E of the walls, which is clearly visible in the RAF and Base Flight aerial photographs, reveals the construction of the defensive bulwarks called *San Francesco*, *Santa Marta* and *Barbagianni*, indicated in XVIII century cartography (Tolaini 1992: 99, fig. 89) but which cannot be identified on the basis of other elements (Figure 9.7).

The northern sector

In Podere dei Passi, S of the Fosso del Maltraversino, in an extensively built area today between Via delle Prata and Via di Gello, the aerial images taken on 20 August and 6 September 1943 clearly show traces of vegetation which, arranged along parallel and orthogonal lines, present the same orientation of the *ager Pisanus* centuriation (Figure 9.8).

The same situation, although less evident, can be found in lands further E, in Podere di Mezzo-La Rete, between via di Gello and SS n. 12 del Brennero, where parallel vegetation anomalies, with NW-SE patterns, reveal the same orientation of the *limitatio*. The vegetation traces recorded in the 1954 Base Flight, although less numerous and not as clear, confirm and integrate the RAF flight data. Obviously, the anomalies refer to canals or field boundaries within the centuria[18].

In Gagno, in a field between the Pisa-Lucca railway line and SP n. 9 of San Jacopo, a good number of flights clearly reveal traces of a horse-racing hippodrome, with major axis E-W, which

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[16] Sample number 1300 can be located further N than the described traces (Alberti, Paribeni 2011: 19; Alberti 2011: 295-299).

[17] The names of the bulwarks are reported in a XVIII map, in which the XVII century fortification works are indicated (Tolaini 1992: 99, fig. 89).

[18] In the light of this study, the 1954 flight does not reveal traces near the Fosso del Maltraversino of the *castrum* that the Ligurians built, according to Livy, at the entrance of Pisa in 193 B.C. (Cosci, Spataro 2002: 15-18, fig. 3). Regarding the Roman *castrum*, the SW corner of the presumed embankment, which is visible only in the 1954 aerial photograph (Cosci, Spataro 2002: 17, fig. 2b), would seem to be an intersection of centurial axes, whereas the RAF images do not reveal anomalies (see Figure 2a of the article mentioned).

Fig. 9.5. The northern suburban area in an image taken by the RAF on 20 August 1943 (strip 3645, frame 4122). The traces of the XVII century defensive bulwarks *Canto al Lione* (1) and *della Forcha* (2) may be seen, as also the abandoned Pisa-Lucca railway line (3).

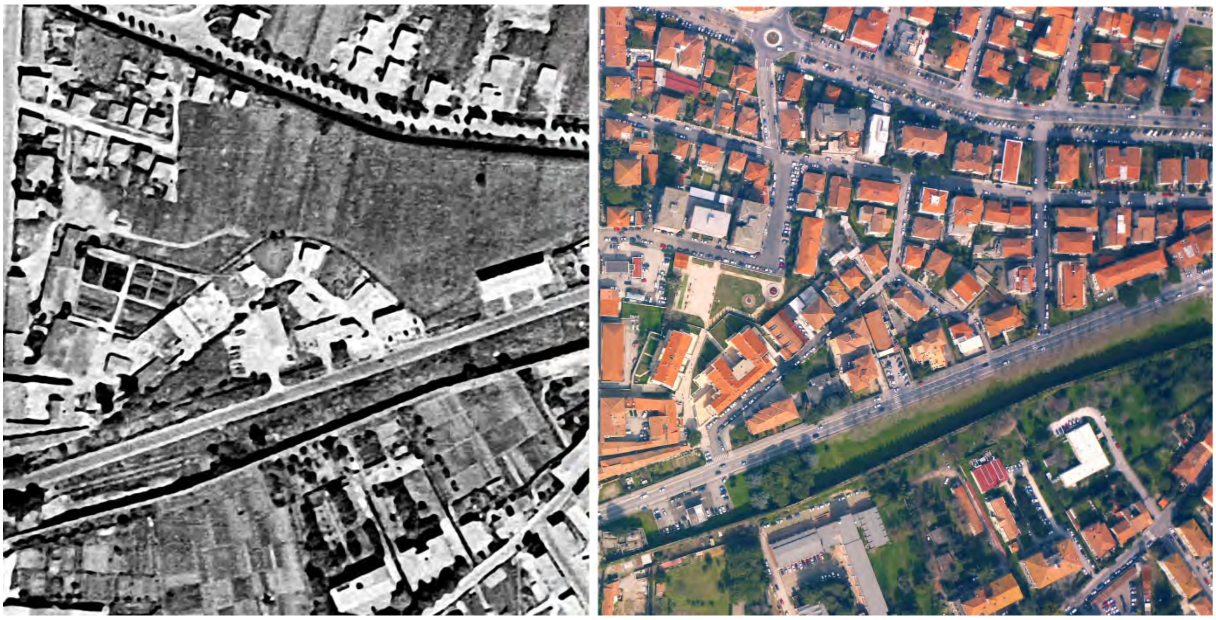

Fig. 9.6. Detail of the *della Forca* bulwark in the 1954 (left) and 2010 (right) traces.

Fig. 9.7. The eastern suburban area in an RAF frame of 20 August 1943 (strip 3645, frame 4122). The defensive bulwarks of *San Francesco* (1), *Santa Marta* (2) and *Barbagianni* (3) may be seen.

Fig. 9.8. Località i Passi. In the photo taken by the RAF on 20 August 1943 (strip 3645, frame 4122), the traces of the Roman agricultural division may easily be seen.

appears to have been abandoned in 1953 (width m. 160; length m. 360). It is interesting to notice that the hippodrome does not appear in the 1945 RAF photograph (Figure 9.9).

The traces of another abandoned hippodrome may be seen at 900 metres W of Porta Nuova, near the goods yard of S. Rossore. The hippodrome, with major axis N-S (m. 350x190) already appeared to be abandoned in the RAF aerial images (Figure 9.10).

At the suburban cemetery in Via Pietrasantina, the aerial photos of 1943, 1945, 1953 and 1954 reveal a circular trace of vegetation and micro-relief which corresponds to the so-called Tumulus of the Etruscan prince brought to light in 1998. Other smaller circular vegetation traces are visible close to the tumulus but have been prudently recorded in the database as "undefined traces", given the lack of objective confirmation (the presence of the tumulus is not sufficient to assume the presence of a "monumental" necropolis) and due to the fact that the traces are not repeated in several aerial images.

The eastern and north-eastern sector of the Municipality of Pisa and Cascina area

As known (PASQUINUCCI 1986: 33), this area provides the greatest number of traces of the *ager Pisanus* centuriation, whose *limites* still exist in current topography in the form of roads and canals or field divisions. The strong building development recorded in the eastern part of Pisa, up to Cisanello - S. Biagio in proximity of the right bank of the River Arno, as also along the large communication roads in the area of Cascina, deeply modified the territorial structure documented in 1960 and 1970 photographs, thus making it more difficult to recognise evidences of Roman agricultural division.

For the above reasons, the study of centuriation traces was carried out by analysing the 1978 orthophoto map of Regione Toscana. Aerial imagery has the inherent capacity to faithfully reproduce the territorial environment, compared to mapping representations which are the result of logical-cultural processes and of graphical simplification; hence, it was possible to render with greater detail and accuracy the traces of the Roman *limitation*, which still exist in the non-recorded field divisions of Military Geographical Institute maps[19]. These are for the majority *limites intercisivi* and agricultural divisions inside single centuria, identifiable in canalisations and field boundaries, but also *cardines* and *decumani* which are not indicated in published archaeological mapping and appear to define a wider centuriation area than that indicated in specialised bibliography (PASQUINUCCI 1986: 34, figures 4-6; PASQUINUCCI 1994: 191-192, plates; PASQUINUCCI 1995: plate XXXVIII).

Agricultural division, with NW-SE oriented *decumani*, is composed of axes at a distance of 20 *actus* (around 710 metres) although slightly different *centuria* are recorded, albeit rarely; this is probably due to the fact that centuriation was adapted to the different hydrographic features of the area during the Roman period. As already mentioned (PASQUINUCCI 1986: 33), modern topography reveals greater conservation of the *cardines*, with NE-SW orientation of the axes.

The southern sector

The urban development of this area, the presence of the Central railway station and airport, with their related infrastructures, and the complex paleo-environmental events, evidenced by medieval sources and toponymy, did not allow a large number of traces to be identified in this area.

RAF, 1953 IGM and Base Flight aerial images reveal a few centuriation *limites* only in the area of S. Giusto in Cannicci, between the railway station and airport.

Further S of the airport, in Mortellini, the presence of canals and agricultural parcels with similar orientation could represent expansion of the centuriation in this area also, although this idea needs to verified.

The western sector

This is the area that produced the greatest number of traces, among the most interesting of the entire

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[19] A detailed analysis of centuriation is not addressed in this chapter; it will be the subject of further work.

Fig. 9.9. Traces of a hippodrome for horse racing in Località Gagno (Base Flight, strip 7, frame 2051 of 1 August 1954).

Fig. 9.10. Traces of a hippodrome for horse racing to the west of the Pisa-San Rossore station (Base Flight, strip 7, frame 2052 of 1 August 1954).

Fig. 9.11. The so-called “Scheibler Area” in a prospective frame of 2009 and detail of the “Map of archaeological traces”, final representation of the anomalies detected in all the flights.

research, as well as important archaeological finds.

The so-called “Scheibler Area” is located in Sardine, between Via delle Cascine, Via Aurelia and the railway line; thanks to the anomalies detected by M. Cosci in a number of 1980 aerial photographs, the area underwent two excavation campaigns in 1983-1984 leading to the identification of Roman age trenches and, at a lower height, archaeological layers related to an archaic Etruscan settlement as also material dating back to the Bronze Age (Bonamici 1987). In 1998, on the eastern borders of this area, the works for expanding the S. Rossore railway station led to the discovery of three sunken ships in an ancient port area (Camilli 2004, with previous bibliography). The photos reveal traces of vegetation in 60% of selected flights, with an orientation similar to the centuriation grid; they can be interpreted as the boundaries of agricultural plots which the excavations confirmed as being drainage canals. By merging the data obtained from the rendering of all the traces (Figures 9.3, 9.11), it was possible to outline a more detailed picture than the one known so far (most recently Ciampoltrini, Cosci, Spataro 2011: 107-108).

The interpretation of the large vegetation anomaly (around 9 metres, i.e. 30 feet), which covers the entire area with the same orientation of the centuriation, is problematic. Given the inherent features of the trace (type, dimensions and orientation) it is most probably a road, more precisely a *decumanus*; however, it appears to be shifted by 40 metres with respect to the theoretical centuriation grid which, instead, perfectly coincides with the trace of the foundation (around 6-metre width, i.e. 20 feet). Furthermore, the archaeological excavation, located exactly at the intersection of the two axes mentioned above, only revealed the presence of drainage canals. This issue needs to be further examined, also in relation to the hydro-geological research results.

Very evident traces were revealed in the 1986 aerial photographs in Campaldo, N of Via delle Cascine in correspondence with the new stables, and related to Roman agricultural division (*Cosci* 1990: 181-183). However, even these anomalies must be analysed in further detail (Figure 9.12); in fact, although the traces are quite regular and clear, they reveal alignments that are not suited to the orientation of the centuriation grid, especially if compared with the picture that seems to emerge of the surrounding territory.

Anomalous traces of canals and field divisions in the adjacent field, along the northern side (Figure 9.13), may be seen in the 2010 aerial photos; they follow a different orientation with respect to the centuriation and appear to be related to a different land occupation and exploitation phase.

Further anomalies ascribable to Roman-age land measurement may be seen in the 1986 and 2010 photos at

Fiume Morto, in the fields E and W of the Campaldo draining pump and between the Pisa-Genoa railway line and SS n. 1 Aurelia; instead,

Fig. 9.12. Traces of the Roman agricultural division in a frame of Regione Toscana (strip 21, frame 211 of 22 September 1986).

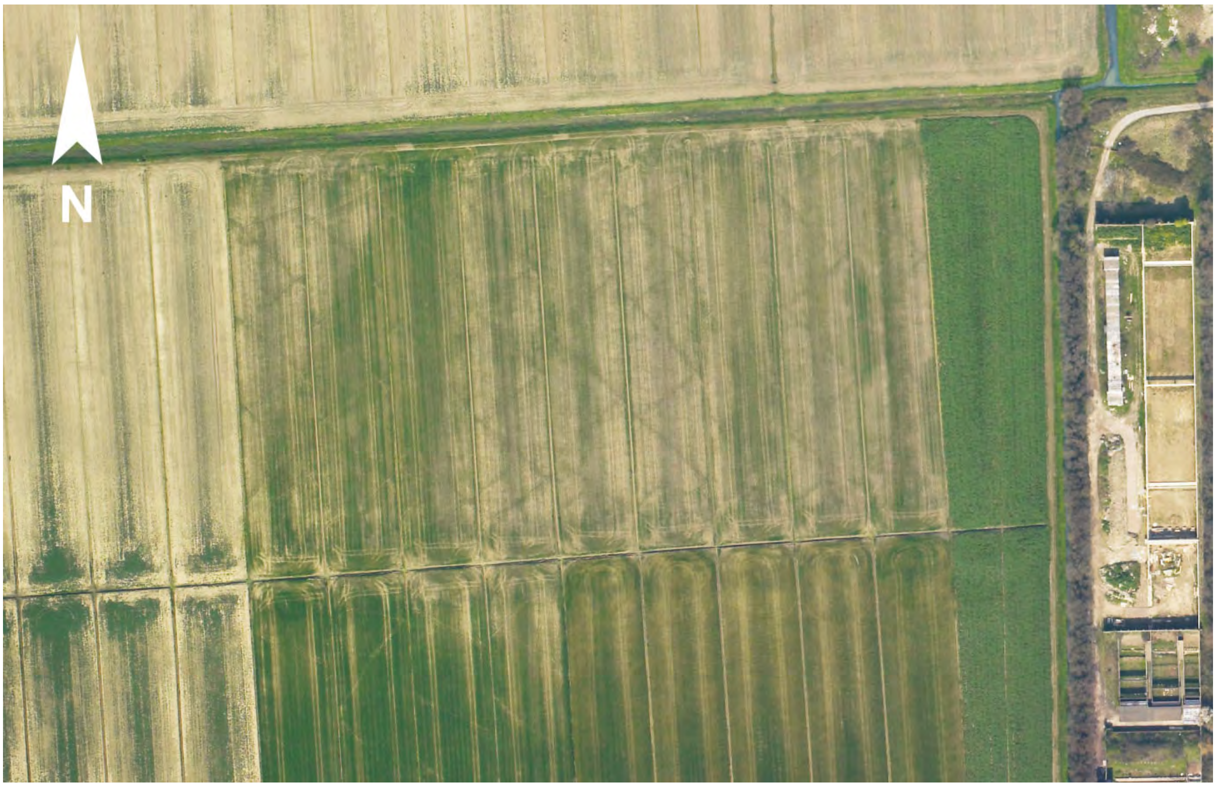

Fig. 9.13. Traces of agricultural divisions in a photograph of the Province of Pisa of 2010 (strip 8, frame 25213).

in the area close to the motorway, many traces refer to Modern age canalisation and water regulation works, some of which are still indicated in the 1930 IGM maps.

9.1.3 Conclusions

The description of the most interesting anomalies encountered during the research activities reveals that, in general, the traces are located mostly in the western area and less in the northern area (Figure 9.3). The southern area appears to be devoid of traces, most probably due to the marshy nature of the land documented in the Medieval age. The western area, instead, reveals a large amount of survival traces related to Roman age centuriation; this could be due to the fact that the land has been subject to fewer modifications compared to other areas, maybe as a result of less variation in the hydro-geological conditions.

The integrated analysis of several flights revealed a large number of traces which, when mapped, provide overall information about Roman-age agricultural land division. Elements also emerged that suggest the presence of a centuriation wider than that imagined so far.

Further study will focus on field inspecting the centuriation traces and other detected anomalies, and comparing geological research data in order to reconstruct the ancient landscape throughout the various historical phases.

[G.F. P.]

9.2 Geological photo-interpretation

9.2.1 Introduction

One of the most difficult applications of geomorphology is the study of plains (BONDESAN MENEGHEL 2004, FEDERICI 2005) due to their flat shapes and frequent cancellation following land use by man. The plain of Pisa is no exception: urbanisation and a large amount of reclamation, with which man has modelled the landscape over time, have contributed to cancelling the original morphologies and making interpretation quite difficult.

The plain of Pisa is physiographically divided into two separate areas:

1) the coast area, separated from the sea by a 4-7 km strip and mainly composed of a typical alternation of beach ridges and depressed areas, resulting from the interaction between coast, wind and river dynamics.
2) the floodplain, composed of a thick layer of deposited sediments, starting from the late Tertiary, inside a tectonic depression formed by the two main rivers: Arno and Serchio.

Although the first area preserves the original nature of the landscape reasonably well, making geomorphological interpretation easy, the second area, on which this study focuses, has always been difficult to interpret. The aim of this work – which was aided by the 1.10,000-scale Geomorphological Map of the Province of Pisa (FEDERICI 2005) and pre-announces a new and more detailed geomorphological map – is to identify all the traces of sunken river-beds only through aerial photo interpretation. The hydrographic network of the River Arno undoubtedly links the landscape of the plain of Pisa and of the entire provincial area (FEDERICI 2003). It is important, therefore, to clarify one of the most debated and at the same time forceful topics regarding development of this area. Defining the evolution of the Arno and Serchio over time and investigating their mutual interactions is certainly a complex task, as confirmed not only by the fact that the watershed between the low tracts, embanked and suspended, of the Arno and Serchio is still uncertain (FEDERICI 2003), but also by the huge amount of studies that have addressed the topic of the paleo-hydrography of Pisa from different viewpoints. Many studies that have addressed this topic are based mainly on historical mapping (PASQUINUCCI 1988, 2003, REDI 1988), others on subsurface data (ROSSI *et alii*, 2011) and further others on geomorphological data (FEDERICI *et alii* 2005, DELLA ROCCA *et alii* 2011) or data resulting exclusively from aerial photo interpretation (COSCI 2005). Ambitious attempts at integrating historical and geological data have also been attempted (CECCARELLI LEMUT *et alii* 1994); however, we are still far from reaching a reliable definition of the paleo-hydrographic network and of its evolution over time. These studies have often produced important results, but it is difficult to compare or integrate them. Those based on Historical Mapping have often theorized the watercourse traces, yet without any geological confirmation of their actual presence; those based on subsurface data have often accurately identified the presence of river beds at well-defined heights and have at times extrapolated cross-section data, yet they have not been able to reconstruct the paleo-hydrographic network. Studies based on geomorphological data have often produced shreds of traces dispersed across the plain, whose location and meaning within the paleo-hydrographic network is at times clear but at other times far less so. Studies based on aerial photo interpretation have the same limitations as geomorphological studies and often lack hierarchisation of the degree of reliability of the traces, thus making it difficult for third parties to use the data. There are often discrepancies among the results of individual works, whereas there is overall agreement on the reconstruction of the most well-known paleomeanders, whose shape is still evident and historical information still quite known. Specifically, the traces related to the most important adjustments carried out for flood control purposes, including 2 meander cuts dating back to 1338 in the Cascine Nuove area, the cut carried out in 1191-71 in Barbaricina, the Ferdinandeo cut in 1606 to reduce the effects of the SW side wind on the mouth of the River Arno. Lastly, the Metato cut on the River Serchio in 1579 (Figure 9.14).

In these and other cases, the landscape still preserves the elegant spirals of dead meanders (at times partially cancelled by cultivated fields or marshy vegetation traces in certain areas), however, in many other cases, this morphology has been completely cancelled. This study, which is the starting point of a much broader work, does not intend to provide an exhaustive and accurate picture of the hydrography of the plain of Pisa and its evolution over time; it intends to identify a methodology based on a multi-disciplinary approach. The data presented are the result of aerial photo interpretation and are based on the comparative analysis of a large number of selected flights. These results will be integrated with remote sensing and micro-relief data and will be checked with specific geophysical surveys, as well as with the detailed stratigraphy available for the area under study, in order to achieve their validation. This work will not only clarify the development of the paleo-hydrographic network of the terminal courses of the Arno and Serchio, but will also propose a methodology applicable to other areas.

9.2.2 Methods

The study of aerial photographs (stereoscopic and on screen) is the first essential step for an accurate geomorphological characterisation of the landscape. Compared to the campaign scale, stereoscopic analysis of the territory gives a general view of landscape shapes, defines respective spatial relations and allows perception of small steep areas which, in a floodplain, may refer to traces of paleo-river beds. This work is based on a rapid stereoscopic survey associated with a detailed study of the digital images on screen.

The level of evidence of every single paleo-river bed trace may vary depending on a large number of factors, such as: the different composition of sediments deposited by the river in the river-bed and the surrounding lands; the size of the watercourse; the depth at which the trace is located; possible intervention by man, which may have modified the original shape; climate and environmental factors at the time of the shot; and, lastly, technical factors when taking the shot. In order to achieve the best possible result, multitemporal aerial photo interpretation was carried out on aerial images taken between 1943 and 2010 (Table 9.1)

Table 9. 1. Aerial images used, divided by year of flight and institution of reference.

ACQUISITION	AUTHORITY OWNER
2010	Provincia Pisa
2009	I.G.M.
2007	I.G.M.
2005	I.G.M.
2003	I.G.M.
1999	I.G.M.
1996	I.G.M.
1988	I.G.M.
1986	Regione Toscana
1983	M. Cosci
1978	Regione Toscana
1954	I.G.M.
1953	I.G.M.
1943	R.A.F

The majority of the material was provided by Regione Toscana in georeferenced digital format. The other (paper) frames were scanned, georeferenced and corrected using the GIS functions of ArcGIS 10 software (ESRI). Correction was neces-

Fig. 9.14. Anthropic interventions on the main watercourses. Location of old traces that are easily legible on the ground.

sary to reduce the effects related to distortion, which a prospective representation of the landscape entails with respect to the representation resulting from an orthogonal projection. The correction of photographic representations, which is necessary for constructing the morphological information layers of the floodplain, was carried out according to the directives issued by Regione Toscana regarding digitisation of CARG products, for which at least 16 control points are requested during georeferencing. The reference maps used when acquiring (in GIS environment) the various aerial images were the 1:10,000-scale topographic maps of Regione Toscana, georeferenced to the Gauss-Boaga system, West zone.

The presence of aerial photographs related to different flights, i.e., acquired at different flight altitudes and using lenses with different focal lengths, implies the introduction of a distortion that varies according to the different years of acquisition. Furthermore, for photographic representations belonging to the same flight, the effects connected to the possible side movement of the aircraft (crab), due mainly to atmospheric disturbance when taking the photographic strips, may have produced stereoscopic models with different scale distortion for various frames. In order to limit these effects during georeferencing, a third order polygonal correction function was used. It should be pointed out that the distortion in the aerial photos did not allow the RMS value to drop below 3 for each processed image. With regard to the most distorted photographic images, the use of a high number of control points (> 20) kept the overall RMS error no higher than 8.

When viewing the frames, the paleo-river beds appear as winding, ribbon-like shapes; they are either single or interwoven and can be light or dark coloured. At times a border can be seen made of two lighter strips corresponding to the paleo-embankments (Figure 9.15).

The latter are made of coarser, usually sandy or sandy-silty sediments whose origin is linked to deposit phases resulting from overbank and overflooding. The darker trace, instead, identifies the area of the actual river-bed, featuring the accumulation of fine material during the extinction of the watercourse (FERRI CALZOLARI 1989). Among the films used for creating the photographic formats, the infrared film used for the 1983 night flight offered the best results in recognising the river-beds, especially in highly anthropised areas and in correspondence of urban centres. In these aerial photographs, the landscape is displayed with grey tones, which depend on the environment's ability to reflect the infrared light. The more humid areas, which have a high absorbent capacity with respect to the infrared light, are displayed on the photo with grey to black tones and are thus highly discriminated by the anthropic environment which, conversely, generally reveals a high reflecting power. This type of film is commonly used for the hydrographic study of wood-covered areas.

At times, however, anthropic structures may allow traces to be recognised. The division of cultivations, for instance, may reveal winding patterns in correspondence with ancient fluvial courses (Figure 9.16).

In order to develop the map of paleo-river beds, a polygonal feature class was constructed in ArcGIS, in which the single elements detected were digitised according to the limits (paleo-embankments) defining their geometry. In general, the definition of paleo-river beds based on aerial photography is a rather subjective activity. In order to prevent this and objectively define the degree of reliability of the morphotypes observed, the traces identified during the various flights were hierarchised in order to distinguish the more reliable traces from the less reliable and, consequently, less universally recognisable ones. The paleo-river beds were hierarchised by arranging the dataset of the respective polygonal feature class, i.e., through the definition of a field of attributes for each single year of flight (with value zero for a non-detected trace, and value 1 for a detected trace). This allowed us to distinguish between paleo-riverbeds observable in all the frames of the period considered and paleo-river beds observable only in frames of certain years. Lastly, a final field of attributes was constructed, called "degree of reliability", in which the values regarding the presence or absence of

Fig. 9.15. Traces detected near Lake Massaciuccoli. The winding pattern and the different colour between internal paleochannel areas and floodplain are evident.

Fig. 9.16. Plan division of cultivations and their layout with curved patterns, representative of ancient fluvial routes.

the trace for the different years of aerial photography were summed. Thanks to a query procedure, the degree of reliability of the single paleo-river beds identified can be viewed in the final representation. The degree of reliability observed in this study varies from a maximum of 8 to a minimum of 1.

9.2.3 Results

The analysis of the aerial photographs led to the identification of 287 fluvial traces which cover an overall surface of around 81 Km^2 and show how strongly the hydrographic network contributed to the geomorphological development of the area.

31.5% of the traces detected have high reliability, whereas over 50% present a degree of reliability between 1 and 2 (Figure 9.17). The intermediate classes present a percentage of the number of detected morphotypes that varies from 0.7% (reliability equal to 6) to a maximum of 6.6% (class with reliability equal to 3).

The width of the traces ranges from a maximum of around 500 m (probably due to the overlapping and shifting of traces over time) to a minimum of 25 m; regarding the length of traces, the values are between 8.8 Km and 320 m.

Smaller traces were identified inside the city centre of Pisa and south of Lake Massaciuccoli, whereas larger paleo-river beds are characteristic of the areas between the Serchio and Arno, and in areas south of the latter.

It is important to notice how certain traces identified, although spatially discontinuous, could be coeval and representative of the action of a single hydrographic element; however, in order to restrict interpretative errors, we preferred postponing the actual linking of the traces to a subsequent working phase after integration with other data.

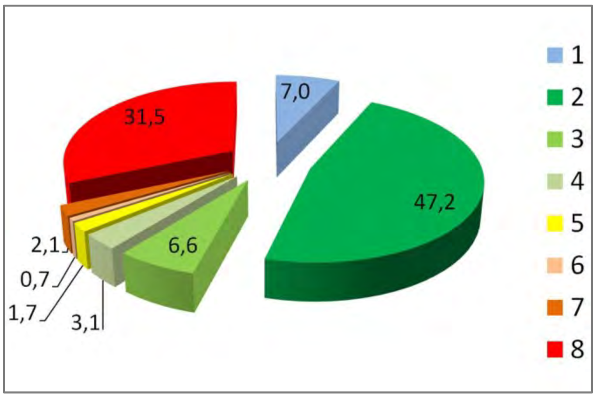

Fig. 9.17. Percentage of occurrences of traces in relation to their degree of reliability.

Regarding the density of the traces, it should be pointed out that a higher amount of paleo-river beds was found in the areas close to the current Arno and Serchio courses (Figure 9.18).

Even the degree of reliability of these traces is higher than that defined in the other sectors considered. This is probably due to the fact that the traces at issue may be more recent (and, therefore, more superficial) compared to the overall traces detected in the area of study, but also due to the presence of coarser, sandy-silty and silt-sandy overflow deposits in these areas, which allow greater contrast with the finer lithologies that are generally characteristic of the closing facies of the paleo-river beds. In addition to these areas, interesting fluvial paleo-traces were observed in correspondence of the south-eastern sector of the area investigated. Instead, in the areas immediately behind the more internal beach ridges (both north and south of the Arno), as also in the area around Coltano, only sporadic traces of paleo-river beds were detected, probably due to the nature of the land or its use by man.

9.2.4 Discussion

9.2.4.1 Traces north of the Serchio

The area between the Basin of Massaciuccoli and the current course of the River Serchio is characterised by marshy deposits which make it difficult to read the fluvial paleotraces via aerial photo interpretation. Nevertheless, a series of narrow and elongated traces with N-S direction may be seen, some of which have a high degree of reliability (Figure 9.18). These traces, considering the decreasing topographic heights towards the lake and the winding pattern of the morphotypes, are related to natural genesis. They may probably be interpreted as Serchio overbank channels, upon which man then intervened by building artificial canals, at times navigable. Many of these canals still exist and were already

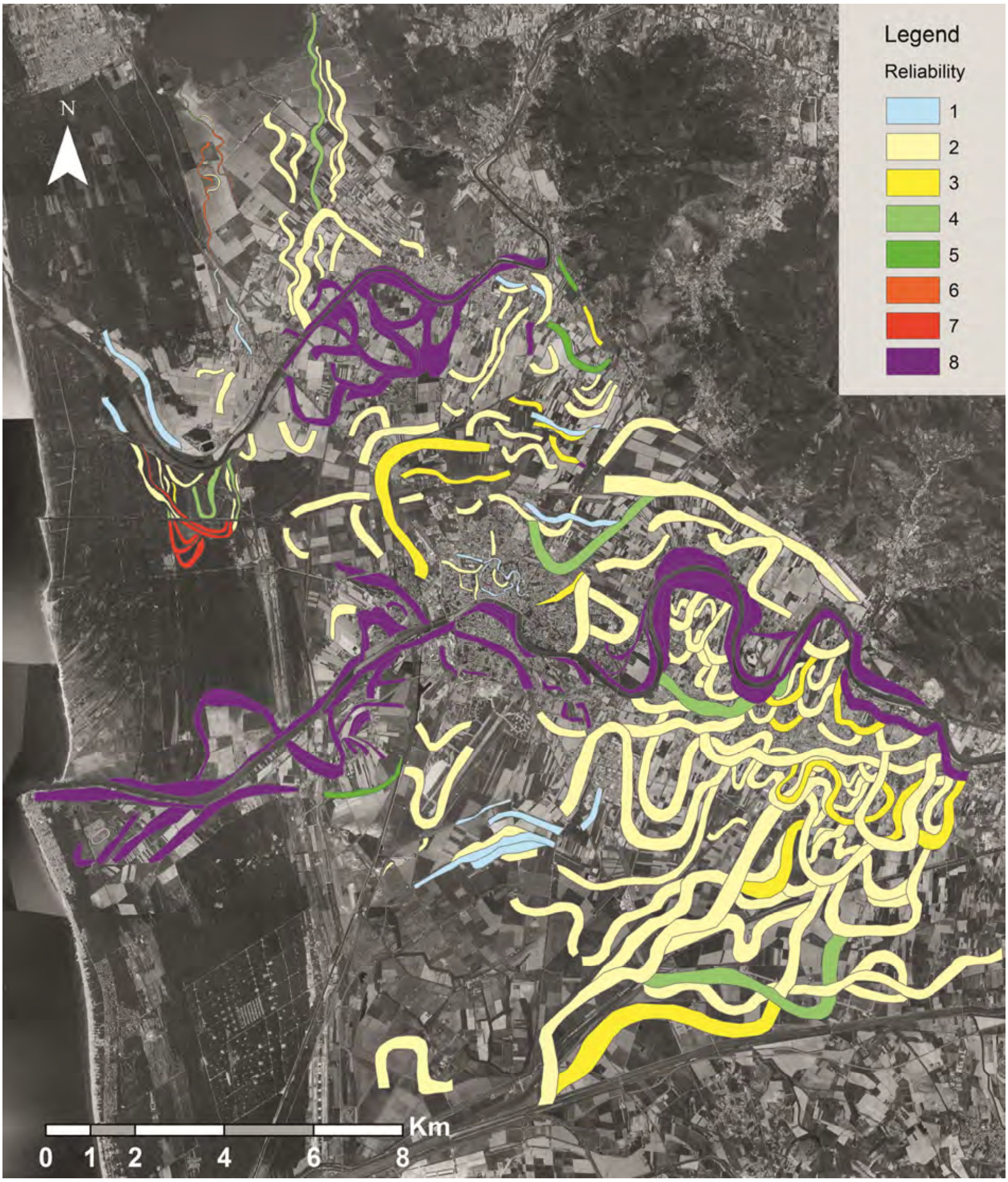

Fig. 9.18. Overall view of traces detected in the area of study and their hierarchisation depending on the respective degree of reliability.

known at least from the Middle Ages. The following canals are documented in this area: the channel or trench of Navariccia – located east of the Malaventre marsh and described at the start of XIV century as a trench for *quam itur cum navibus* (CECCARELLI LEMUT *et alii* 1994) – Fossa Magna, Fossa di Montione and Fossa Nuova. Further west, the Barra di Vecchiano that used to drain the waters of Vecchiano into Lake Massaciuccoli and the Fossa di Bovario, mentioned from 1190 (CECCARELLI LEMUT *et alii* 1994, REDI 1988).

9.2.4.2 Traces between the Serchio and Arno

Numerous paleo-river beds of different size and degree of reliability may be seen in the stretch of plain between the current courses of the Arno and Serchio. The geometrical arrangement of many of these traces does not allow us to distinguish whether they belong to the Serchio or Arno. The study, however, reveals interaction between these two important rivers: the extent and mode of interaction cannot be defined solely through aerial photo interpretation and will be the subject of future research developments.

The possibility cannot be excluded that the Arno interested sectors placed more to the north of its current course, as suggested by the paleo-river beds on the slopes of the Pisan Mountains, whose genesis is difficult to attribute to the Serchio. The lower amount of traces in proximity of the more internal beach ridges may be related to the presence of the marshy area called *Silva Tumulus* and attested in this area from the Late Middle Ages (GATTIGLIA 2011).

9.2.4.3 Traces south of the Arno

The area south of the Arno may be divided into two sectors: eastern, with a good number of traces, and western, close to the more internal beach ridges, containing the lowest concentration of traces.

The paleo-river beds identified in the eastern sector are representative of the gradual migration of the Arno from south to north (FEDERICI MAZZANTI 1988, DELLA ROCCA *et alii* 1987): from the area currently occupied by the Canale Scolmatore to the current Arno course.

In the western sector, the traces tend to become illegible as they gradually reach Coltano. The very few traces in this area may be related to the presence of persistent marshy areas documented from the Early Middle ages (BERTI RIZZO 2004, GATTIGLIA 2011) and continuing at least until the Late Middle ages (*Tumulus*). Extension of this marshy area into the Early Middle ages may have influenced the poor legibility of the traces in the eastern sector, where paleo-river beds are indeed recorded but with a prevailingly low degree of reliability. Furthermore, the action caused by the morphological high corresponding to the sands of Coltano, whose genesis is still strongly debated, makes the interpretation regarding its possible influence on the hydrographic development south of the Arno quite difficult and will be the subject of further research.

9.2.5 Conclusions

This work represents the starting point for the study of the paleo-river beds of the plain of Pisa.

It allowed us to identify a large number of traces, divided by degree of reliability, according to their recurrence over the various years of aerial photography, thus demonstrating the strict link between aerial photo-interpretation and multi-temporal analysis for purposes such as these. If this study had solely been based on the observation of images related to a limited number of flights, the majority of the traces would not have been identified and all the traces would have been equally reliable.

The aim of this work is not to provide an exhaustive picture of the paleo-hydrography of the plain of Pisa but to define an integrated method applicable to other areas and to identify various open issues in key areas of the territory. The overall picture particularly suggests some preliminary considerations that must be kept in mind during continuation of the research. First of all, the traces identified may be divided into three groups: two belonging, respectively, to the hydrographic basins of the Arno and Serchio, the third of uncertain attribution (Figure 9.19).

Attribution of each trace to the first two groups was based upon the geometry of the fluvial traces. Each family of traces appears to represent, in one or more sequences, the different traces that the respective watercourse has naturally acquired over time, in a relatively constant morpho-climatic context. Indeed, the meander form of the watercourses has remained constant and the most linear stretches are evidence of one of the phases of the natural evolution of a meander or of anthropic intervention. The less winding patterns of the Arno and Serchio river-beds today, compared to the detailed structure of some traces, is probably attributable to the reduction in

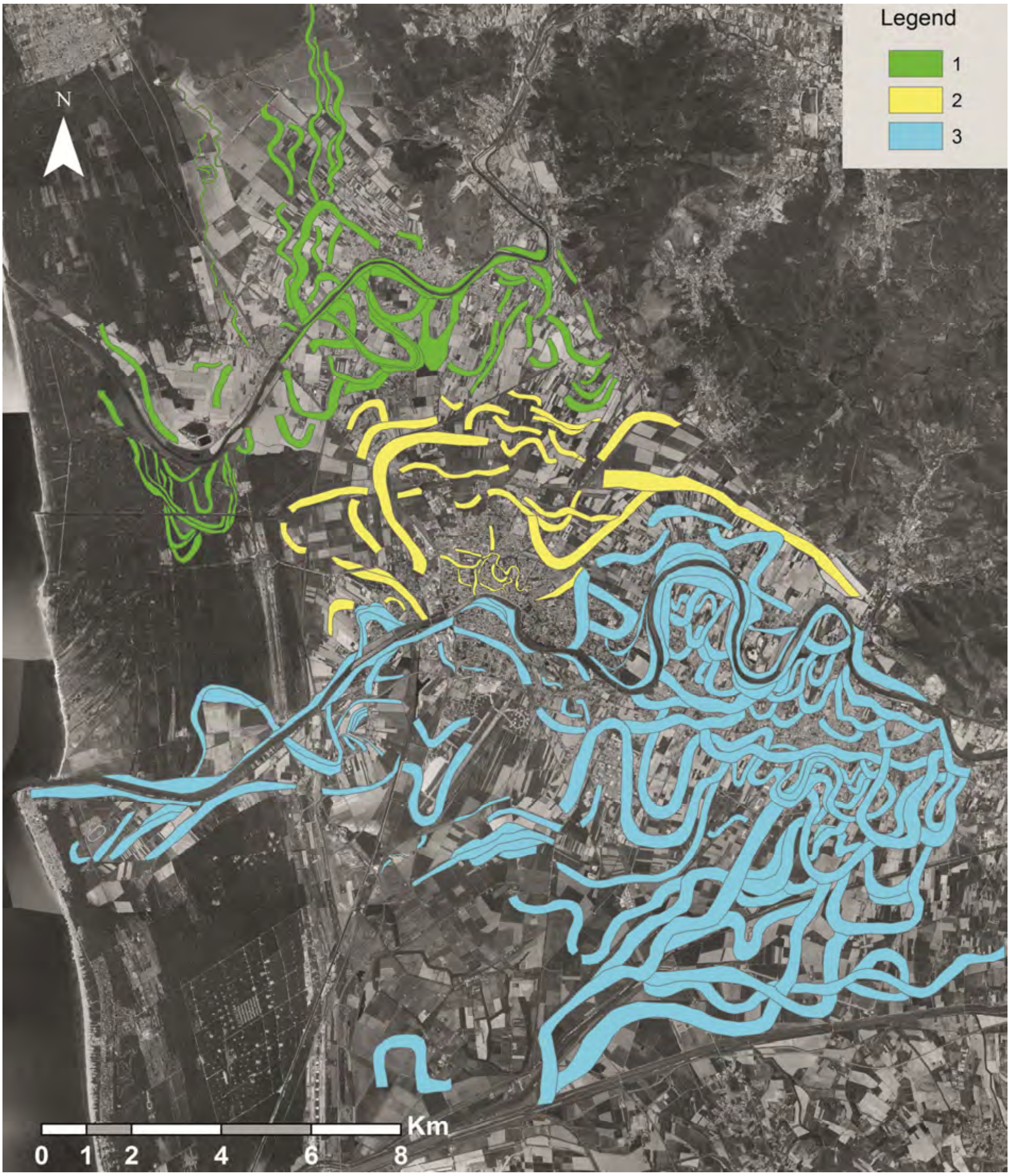

Fig. 9.19. Division of the traces identified in three groups: 1) those probably associated with the River Serchio, 2) those of uncertain attribution, 3) those probably associated with the River Arno.

flow and solid load of the watercourses, but also to constraints preventing their free development set in place by man over the centuries. From a geomorphological viewpoint, typological developments of the watercourses have not been evidenced.

The traces belonging to the third group must be attentively checked by cross-checking them with subsurface data. The integration of these observations with remote sensing data, subsurface (especially geochemical) surveys and geophysical surveys will allow us to validate or refute the assumptions and reconstruct the hydrographic paleo-network and its evolution through time.

[M.B., M.C., M.P.]

Appendix

The entries used in the various categorisation levels follow. Level I, II and III terms are reported in Table I.

Table no. I

Level I	Level II	Level III
Agricultural/vegetable gardening area	Agricultural organisation/centuriation	Agricultural land
		Boundary
		Canal
		Crevasse splay
		Reclamation
		Terracing
		Trench
	Vegetable garden	Enclosure
		Vegetable gardening land
	Agricultural structures/rural villa	Barn
		Construction yard
		Farmhouse
		Henhouse
		Oil mill
		Sheepfold
		Pars fructuaria
		Pars rustica
		Pars urbana
		Pigsty
		Stable
		Units/rooms
		Winemaking cellar
Production area	Metal manufacturing	Construction yard
		Goldsmiths
		Mint
		Structures indeterminated
		Structures for copper manufacturing
		Structures for iron production
		Structures for lead production
		Structures for the production of copper/bells
	Clay manufacturing	Clay quarry/cultivation
		Construction yard
		Structures for the production of bricks
		Structures for the production of pottery
		Structures for the production of pottery and bricks

Level I	Level II	Level III
	Leather/fabric manufactoring	Dyeworks
		Fullonica/gualchiera (fulling mill)
		Furriery
		Shoe factory
		Tailor’s shop
		Tannery
		Weaving mill
		Woollens factory
	Stone manufacturing	Lime klin
		Lithic artefact production
		Lithic industry
		Stone quarry/cultivation
	Food manufacturing	Bakery
		Butcher
		Construction yard
		Dairy
		Mill
		Oil mill
		Wine cellar
	Glass manufacturing	Glassworks
	Wood manufacturing	Joinery
	Industrial manufacturing	Chemical industry
		Mechanical industry
		Pharmaceutical industry
	Non identified manufacturing	Construction yard
		Structures related to non-identified manufacturing
Area for private use	Housing complex	Camp
		Construction yard
		District
		Insula
		Settlement
	Housing unit	Construction yard
		Courtyard
		Domus
		Hearth
		House
		Palace
		Pile dwelling
		Rural house
		Shed
		Tower-house
		Urban villa
	Non-built area	Clearing
		Private garden
Funerary area	Cemeterial area	Burial
		Cremation
	Tomb(s)	Burial
		Cremation
		Non identified
Area for public use	Recreational building	Amphitheatre
		Cinema

Level I	Level II	Level III
		Circus
		Construction yard
		Gymnasium
		Race track
		Sports field
		Stadium
		Theatre
	Political/administrative building	Basilica
		Comitium
		Construction yard
		Curia
		Curtis
		Forum
		Guild hall
		Palace
		Prison
	Health and sanitary building	Baths
		Construction yard
		Hospital
		Lavatory
		Thermae
	Place of worship	Baptistery
		Bell tower
		Chapel
		Church
		Construction yard
		Monastery
		Oratory
		Sacred area
		Sanctuary
		Synagogue
		Temple
		Votive shrine
	Non-built area	Garden/public park
		Clearing for public use
	School/educational building	Library/archive
		Museum
		Nursery
		School
		University
	Celebrative structure	Arch
		Monument
Infrastructures	Water infrastructures	Aqueducts
		Embankments
		Construction yard
		Fountain
		Wash-house
		Well
		Fresh water system
		Sewage water system
		Collection tanks

Level I	Level II	Level III
	Road infrastructures	Alley
		Avenue
		Bridge
		Centuriation road
		Construction yard
		Hospital
		Mansio
		Post stage
		Railway
		Railway station
		Road
		Square
	Port/navigation infrastructures	Dockyard
		Construction yard
		Ship yard
		River port
		Maritime port
		Dock/landing place
		Waterway
	Storage infrastructures	Construction yard
		Horreum
		Underground storerooms
		Warehouses
	Service infrastructures	Horse stables
		Petrol station
		Stables
		Workshop
	Disposal infrastructures	Organised waste dump
	Distribution infrastructures	Electricity network
		Gas network
		Telecommunications network
Area with military function	Defensive structures	Construction yard
		Fortress
		Tower
		Walls
	Quartering structures	Military camp
		Construction yard
		Barracks
Indefinite structures	Indefinite structures	Construction yard
		Structures
Frequentation	Frequentation	Indefinite
		Mobile artefacts
		Traces of use
Non place	Defunctionalised area	Abandonment
		Destruction
		Cancelling
		Spoliation
Commercial area	Sale structure	Bar
		Brothel
		Construction yard

Level I	Level II	Level III
		Macellum
		Market
		Shop/taberna
		Tavern
		Termopolium/caupona
	Accomodation structure	Construction yard
		Hotel
		Inn
Natural context	Marine-coastal environments	Bay
		Distributary channel
		Beach ridge
		Inter-ridge
		Coastal lake and swamp
		Lagoon
		Surfaced beach
		Submerged beach
		Subdelta
		Marine terrace
	Aeolian environment	Deflation surface
		Dune
		Retroduna
	Fluvial environment	Overflow area
		Marsh
		Canal
		Alluvial cone
		Coastal lake
		Floodplain
		River terrace
	Lacustrine environment	Swamp
	Anthropic environment	Quarry
		Reclamation
		Coastal defenses
		Mine
		Filling material

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