A GIScloud system for knowledge, data sharing and management: urban archaeology and smart city solutions for culture and tourism in Lecce (Apulia, Italy)

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Abstract: The paper concerns an experimental system for the management of data related to the archaeological heritage of the urban area of Lecce. The system, based on the cloud technology (SaaS), includes a dashboard accessible from the web, some applications for the consultation of the new digital archaeological map of Lecce and for the management of an heterogeneous dataset of ancient features of the Messapian, Roman and Medieval times, many of which are now “invisible” because of the obliteration by modern structures. In fact, the historical center of Lecce is a multi-layered context with a continuity of life from Iron age until now, across the Messapian, Roman, Medieval, Renaissance, Baroque and Modern times. The system manages also raster time-slices from GPR and ERT prospecting carried out in various contexts, offering the ability to read 3D subsurface anomalies at depths between 3 and 8 m.
The system is based on a suite of open source software modified according to the project purposes. The result is a web portal that offers an area for consultation/inserting/modifying alphanumeric and geospatial data and an area for consultation only, depending on the credentials of the users during login. This portal allows researchers and Public Administrations technicians to manage and share data, while other users (citizens, scholars, tourists) are able to query the data only.

Keywords: GIS, cloud, archaeological map, urban archaeology, data sharing and management, Lecce.

Introduction

A smart city should always have appropriate tools for urban planning. When modern towns have a long continuity of life from ancient periods until now, these tools need to include also archaeological maps integrated in GIS platforms, which allow to document and clarify the different phases of transformation of multi-layers settlements. In fact, archaeological maps are very important instruments for the reconstruction of the evolutionary dynamics of population pattern in different contexts and for understanding the historical development of ancient settlements that have a complex and multi-stratified archaeology, requiring the analyses and studies of a large number of heterogeneous data.
Among GIS platforms dedicated to cultural heritage, the web-oriented systems are surely the best solution for the problems of data dissemination and sharing, even aimed at an urban planning that takes account the preservation of ancient remains and their enhancement of value. In the cases of a research project that involves many Institutions needing the sharing of a virtual workspace, not only for databases consultation and query, but also for databases implementation, a GIScloud platform can constitute a good solution. For

these reasons, as part of the project DiCeT (*LivingLab Di Cultura e Tecnologia* - Smart Cities and Communities Social Innovation), the Institute for Archaeological and Monumental Heritage of the National Research Council of Italy (CNR-IBAM), and in particular the Laboratory of Ancient Topography, Archaeology and Remote Sensing (AnTARes Lab) is developing a GIScloud system dedicated to the case study of Lecce (Apulia, southern Italy). The system integrates a vector archaeological map and is a remote shared environment aimed at store, manage and analyse heterogeneous archaeological data regarding in particular the Messapian (about 7th - 3rd centuries BC) and Roman (3rd century BC - 5th century AD) periods of Lecce. The GIScloud platform is fundamental within the research project, which involves different Institutions that are working on the same study area. In fact, in addition to the AnTARes Lab., the research involves also the Laboratory of Informatics for Archaeology and the Laboratory of Archaeology of the Salento University (Department of Cultural Heritage) and it is developed in cooperation with the Superintendence for the Archaeological Heritage of Apulia Region. Thanks to the GIScloud, the different Institutions can easily and at the same time implement on-line both geo-spatial and alphanumeric data and share the results of the investigations.

Moreover, the end user of the system is the Municipality of Lecce (in particular, the Office for Informative Systems), which can have a continuously up-to-date instrument (i.e., the archaeological map integrated in the GIScloud) for the knowledge of the “invisible” archaeological heritage of Lecce. In fact, only a very few remains of the Messapian and Roman periods are nowadays visible, while most ancient features are re-buried under modern roads, squares and buildings after the archaeological excavations of the last 115 years. Therefore, the GIScloud platform can constitute an essential tool for an urban planning that should take in account preservation and value enhancement of the cultural heritage.

Lastly, the GIScloud can also represent a basic instrument for dissemination to a large public (scholars, citizens, tourists, etc.) of data regarding the oldest periods of Lecce and the development and transformation of the city during centuries. About dissemination, the disciplinary approach applied in Lecce allows a complete and always available on-line dataset regarding archaeological information, which provides a powerful and highly innovative tool for the knowledge of the cultural heritage of this town, easily accessible by stakeholders and end users through internet or their mobile devices.

G.S.

Study Area

The historical centre of Lecce lies on a Messapian and Roman settlement. The oldest archaeological remains in this area date back to the Iron age (9th-8th cent. BC) and constitute of small groups of huts discovered in various sites of the city, as Idomeneo road, Panzera square, Duomo square, Lo Re avenue, and Epulione square (in general about Lecce in the Messapian and Roman periods see: D’ANDRIA 1995, 1999 and 2004; GIARDINO 1994 and 2008; GIARDINO, ARTHUR, CIONGOLI 2000; GIARDINO, LONOCE 2011). In the Messapian age (7th-3th cent. BC), Lecce is characterized by a scattered settlement, with inhabited areas alternating with open spaces, public areas, necropolises and places of worship. During the 4th century BC, Lecce is transformed into an urban-type settlement, even with the construction of city walls at the end of the same century. In the 3rd century BC, it was conquered by Romans and after the Social War Lecce-Lupiae became a municipium ascribed to the Camilia tribe (SILVESTRINI 2005, 152-155; DE MITRI

2010, 84-87). Between the end of the Republican age and the beginning of the Imperial period, Lupiae exceeded in importance the nearby city of Rudiae, located about 2 km to the south-west. The city was monumentalized in the Augustan age (when it was equipped with a theatre and an amphitheatre) and in the subsequent centuries it became the main Roman city in Salento (southern Apulia). In Late Antiquity, Lupiae is still a rather important city, which maintains an unchanged economic capacity and preserves much of the previous urban layout, with some transformations in the roads network.
A deep crisis and a radical change of settlement struck the city in the mid-sixth cent. AD, when it was sacked by the Ostrogoths and the Episcopal seat was vacant probably until 9th century. The Byzantine period (half of the 6th - half of the 12th cent.) is one of the least known age of the history of the city (about transformations of Lecce during the Medieval and Modern ages, see: GÜLL 2011; CAZZATO, FAGIOLO 2013; about archaeological excavations regarding the Medieval and post-Medieval periods, see in particular: RESCIO, TAGLIENTE 1994; QUERCIA 2003; GÜLL 2004; ARTHUR, TINELLI, VETERE 2008; DE SANTIS, CONGEDO 2010; CAPRINO, GHIO, SASSO 2013). From the second half of the 12th century, in the Norman age, Lecce is affected by an intense building development. In this period the city walls retraced in many sectors the Messapian fortifications and the first structures of the castle (nowadays called Castle of Charles V) was built immediately to the east of the town, linked to the city walls and aimed at the fortification of the eastern side of Lecce, facing the Adriatic coast, about 12 km far (about the Castle of Lecce, see: ARTHUR ET AL. 2003; ARTHUR, TINELLI, VETERE 2008; CANESTRINI, CACUDI 2014). In the Swabian age, the castle was renovated and expanded. Later, the city came under various dominations (Counts of Brienne, Maria d'Enghien, Aragonese, Venetians) and continued to develop.
At the half of the 16th cent., Lecce was one of the main cities of the Kingdom of Two Sicilies. Between 1537 and 1545, new powerful city walls, designed by Gian Giacomo dell'Acaja, were built; they retrace the previous ones in many sectors and are still preserved in particular along the south-western and western sides of the historical centre of Lecce. In the same years, even the castle has been profoundly transformed and expanded (again according to the design of G.G. dell'Acaja), including part of the oldest structures and assuming the appearance that it still preserves. Between the half of the 16th and the 18th cent., most of the churches, monasteries, and public and private buildings of the historical centre of Lecce were built.

Important transformations of the city occurred in the second half of 19th and in the first of 20th cent., when numerous demolitions and rectifications of streets were made. In particular, the main works concerned the eastern sector of the city, in the area of the present Sant'Oronzo square (Fig. 1), where in 1900 the demolition of the so-called Isola del Governatore (the block including the Palace of Governor) allowed the discovering of the amphitheatre, which was partially unearthed, and of a sector of a Messapian necropolis (Figs. 2-3), on which was built the Banca d'Italia Palace (GIARDINO, ARTHUR, CIONGOLI 2000).
The plans of *Isola del Governatore* (Fig. 3, A) and of the buildings immediately to the north were strongly influenced by the underlying structures of the amphitheatre (CAZZATO 2000). The western sector of the ancient monument was completely excavated in 1930s, after the demolition of other old buildings, which allowed the discovering of further Messapian tombs that were covered by the construction of the INA Palace.

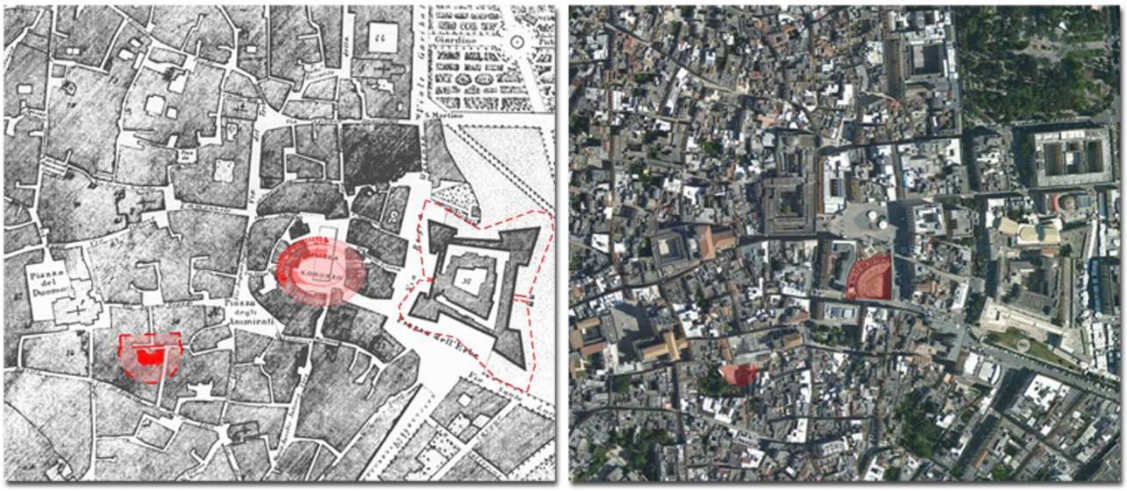

Fig. 1 – Comparison between the historical plan of Lecce drawn in 1882 by Michele Astuti (on the left), and a present aerial photo (on the right): the areas of theatre and amphitheatre were highlighted. In the map are traced also the ditches of the castle, filled between 1860 and 1872.

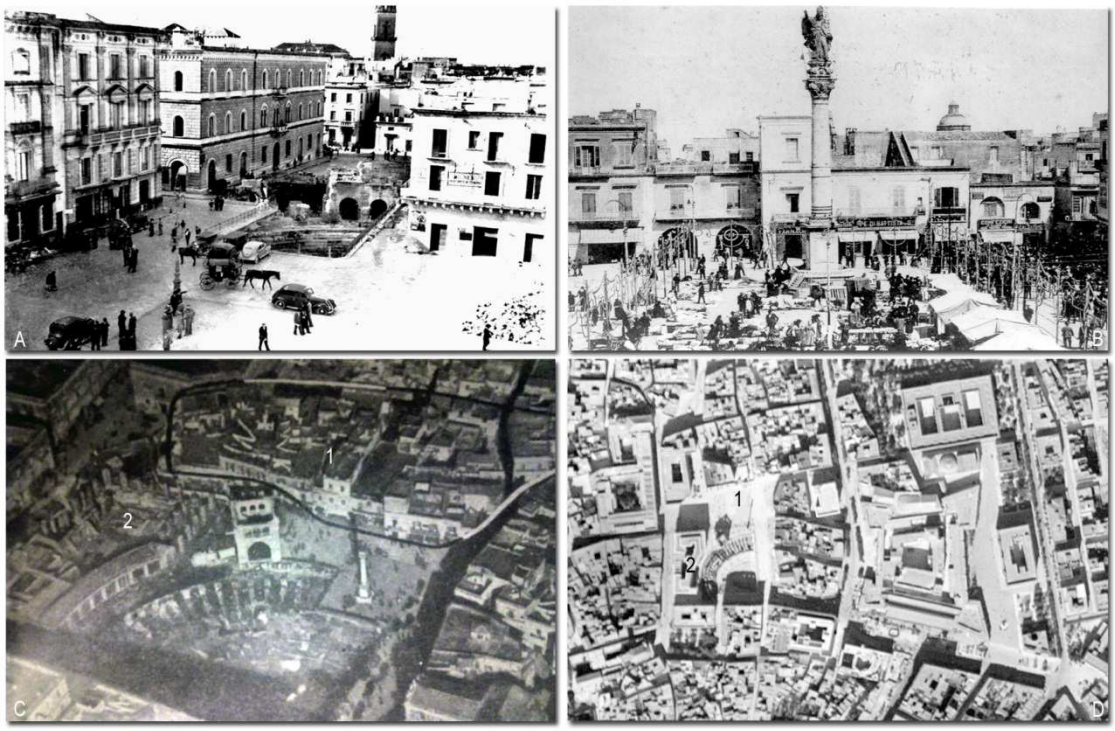

Fig. 2 – Ancient photographs of the area of Sant'Oronzo square: A) the sector of the amphitheatre excavated in 1900; B) the block called Isola delle Capande, demolished in 1930s; C) aerial photo of the 1930s, in which the Isola delle Capande (1) and the INA Palace (2) under construction are visible (the western sector of the amphitheatre was already excavated); D) the Isola delle Capande (1) is not present in the new Sant'Oronzo square and the INA Palace (2) is completely built in an aerial photo taken in 1947.

The current appearance of Sant'Oronzo square was obtained thanks to the demolition (in the same 1930s) of the *Isola delle Capande*, the block located immediately to the north of the amphitheatre (Fig. 3, B).
Lastly, among the other main monument of the Early Imperial age, the theatre was discovered in 1929 during the excavation of the foundations of a house located between the gardens of the Romano Palace and the

D'Arpe Palace, which are in the south-eastern sector of the historical centre of Lecce; the remains of the monument were partially unearthed in 1938.

Fig. 3 – The area of Sant'Oronzo square: on the left, a cadastral map drawn before 1900 where the demolished or transformed buildings are highlighted in red; on the right, the same buildings and the amphitheatre (in red) are overlapped on the present aerophotogrammetric map (in grey), which shows a more regular layout.

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Research project methodology

It is necessary a multidisciplinary research approach to study the development of a city with a long continuity of settlement. In the case of Lecce, the reconstruction of the Messapian city and its transformations during the Roman period needs to be still completed. In fact, it is necessary the integration of the fragmentary information acquired in the last 115 years in many sites of the historical centre and in the surrounding areas. For this reason, the AnTAReS Laboratory of CNR-IBAM and the Department of Cultural Heritage of the Salento University (Laboratory of Archaeology and Laboratory of Informatics for Archaeology) are performing (within the general tasks of the DiCeT project) a project of integrated research based on the production of a digital archaeological map where the ancient remains (both preserved or re-buried after excavations) are positioned together with the new data acquired thanks to geophysical prospecting carried out in numerous areas of the city. The map is integrated in a GIScloud platform that, as a collaborative environment, not only allows the management of multi-layers archaeological data, but it is an important tool for sharing data between the Institutions involved in the research activities (AnTAReS Lab. and Archaeology and Informatics Labs.) and in the management and preservation of the ancient remains (Archaeological Superintendence and Municipality of Lecce). In fact, in a city in continuity of life of about 3,000 years, the urban expansion and the development of the city must be integrated with the needs of preservation of ancient monuments and their enhancement of value.

In the archaeological map, the data of old excavations and discoveries made in particular between 1900s

and 1930s (DE GIORGI 1907), also included in previous general studies and schematic maps (BERNARDINI 1959; DELLI PONTI 1968; D'ANDRIA, PAGLIARA, SICILIANO 1980; D'ANDRIA 1999), are georeferenced on a large-scale and up-to-date cartography. These data are integrated with the discoveries of the last 30 years, made during small-scale excavations connected with restoration, infrastructure and building works (CIONGOLI 1987, 1988, 1990, 1991, 1992, 1994, 1996, 1998, 1999; QUERCIA 2002; DE MITRI 2002-2003 and 2012; FONTANA ET AL. 2003; POLITO 2003; AA.VV. 2011). Moreover, it was decided to acquire new information about the buried archaeological remains through geophysical prospecting performed by the Laboratory of Geophysics of CNR-IBAM in cooperation with the AnTARes Laboratory. Therefore, many public areas (roads and squares: Fig. 4) were investigated using mainly Ground Penetrating Radar (GPR) and, in a few cases, the Electrical Resistivity Tomography (ERT). By these instruments was possible to acquire new data about buried ancient features (as, for example, the structures and the tombs along Palmieri road, or the walls in Santa Chiara square or, even, the ditches of the north-western fortifications and of the Castle of Charles V), which were georeferenced in the archaeological map. Very important for interpretation of buried structures documented by geophysical anomalies was also the study of the urban transformations that occurred in the second half of 19th and in the first half of 20th cent., which involved many public areas of the historical centre of Lecce and surroundings. Therefore, the archaeological map constitutes the base on which all archaeological data were integrated and contextualized, with particular attention to the Messapian and Roman periods, but not omitting the subsequent transformations during the Medieval age. The map represents the palimpsest of the archaeological information and the base on which are set up the subsequent and important stages of data processing and interpretation, and reconstruction of the ancient settlement plan and necropolises organization.

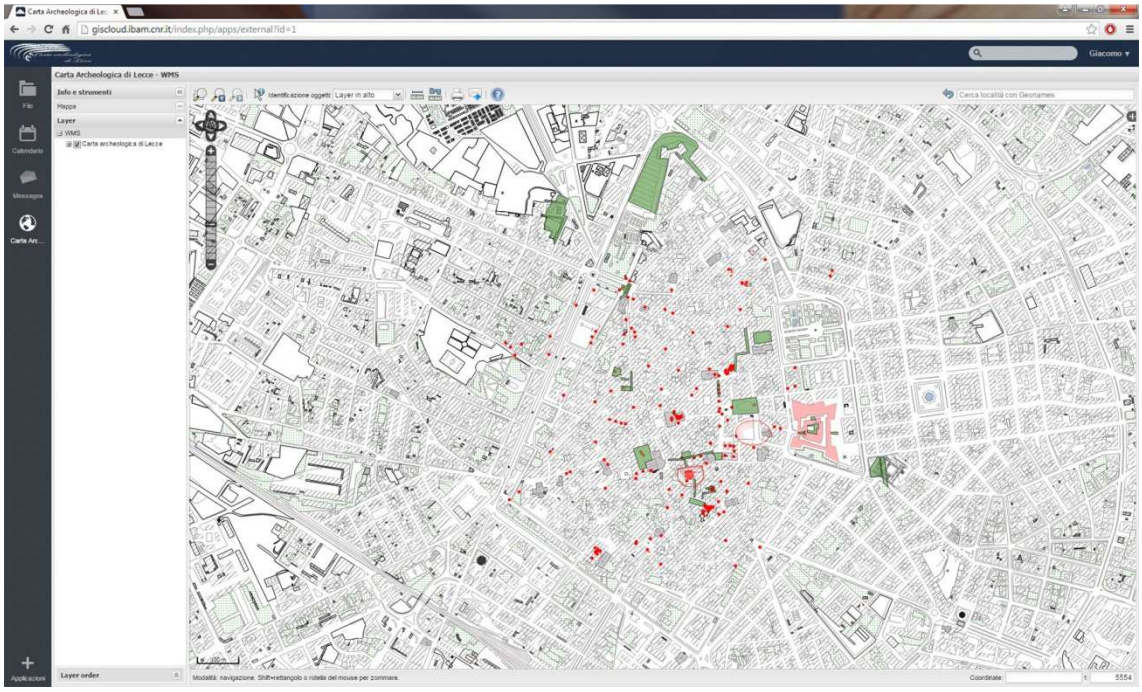

Fig. 4 – The areas investigated using geophysical prospecting are highlighted (in green) in the archaeological map of Lecce.

Moreover, the data stored in the archaeological map integrated in the GIScloud are the “base of knowledge” also for the dissemination of data regarding the oldest and less known periods of Lecce, which is one of the main task of the DiCeT project. It will allow giving archaeological information to tourists through internet using their mobile devices. This dissemination will include even the production of 3D reconstructions and applications of virtual reality and augmented reality performed by the Laboratory of Information Technology of CNR-IBAM and based on the knowledge documented in the archaeological map. The task is to enlarge the touristic offering of Lecce, nowadays limited to the Baroque period, and to document monuments that are not accessible or visible (as the Messapian chamber tomb named Hypogeum Palmieri, which is within a private property, or the remains of the Temple of Isis, built in the Augustan age and nowadays below Vernazza Palace, or even the other archaeological remains re-buried after the discovery and the archaeological explorations), or even ancient buildings that are difficult to understand in their entire plans due to the partial excavation (as the theatre and amphitheatre, which are the only Roman monuments nowadays visible, but of which only the ima cavea and the western half respectively are unearthed).

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Giscloud: the structure

The National Institute of Standards and Technology (NIST) defines cloud computing as a system that facilitates smart and on-demand access to shared resources, hardware and software (MELL, GRANCE 2011). It implements three basic types of services: IaaS (Infrastructure as a Service), PaaS (Platform as a Service) and SaaS (Software as a Service) (FEHLING et al. 2014).

The IaaS services, probably the most complex and expensive, are useful to create virtual machines, where the user can define the number of processors, hard disk size, the amount of internet bandwidth, and so on.

The PaaS services, can be considered as development platforms where the user can install and uninstall applications which himself created, in order to verify the actual functionality.

Finally the most popular SaaS services are virtual spaces in which there are a series of applications ready-to-use , often collected in a dashboard; the end-user can only use these application and cannot access in any way to the cloud infrastructure. These app cannot be modified by the end user of the service, but he can use them without any restriction: usually, these are applications for sending and receiving emails, software for storing and sharing files quickly, applications for the control of workflows within a community of researchers and developers.

The Giscloud project is a SaaS-type cloud that appears as a shared virtual space where some users, if authorised, can remotely exchange heterogeneous data and information related, for example, for the implementation and development of thematic maps (Fig. 5).

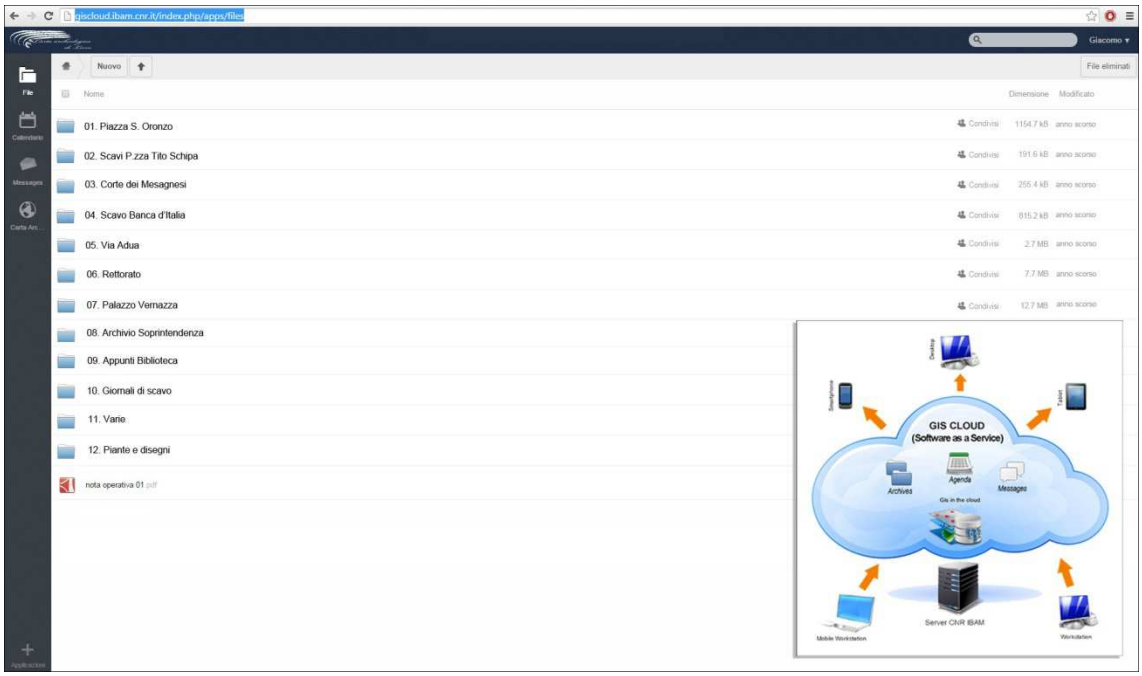

Fig. 5 –The control panel of the GisCloud. On the left is visible a vertical toolbar with links to storage archive, the calendair app, the internal message service and the GisCloud service. On the right a schematic representation of the internal functionality of GisCloud system: a shared space contains all applications always available through the web.

Proprietary solutions already exist on market, for this type of web application made by large software house: if on the one hand it allows sharing data quickly and easily, on the other it does not guarantee total control over these data, which are frequently migrated on remote servers owned by the same companies that produce the software.

During the development of research projects carried out by the Laboratory of Ancient Topography, Archaeology and Remote Sensing of the CNR-IBAM, it was decided to start experimenting a GIScloud platform self-made, based entirely on open source software resources, and anchored to the hardware of the research institute: the possibility of using the lab's server farm, in fact, has greatly facilitated the work, allowing to restrict the development of the abstract layer only.

The physical layer of GIScloud is composed of a database server that hosts both a MySQL database for the regulation of access to the cloud, both a postgre/postGIS database (DOUGLAS 2003) for managing cartographic data and associated metadata and a storage server with capacity of 8 Tb of storage for documents. There is also a server exposed on the internet that implements Apache webserver (LISKA ET AL. 2002) and that answers all incoming calls from the web. Conceptually, the operation is quite simple: the http service provided by Apache webserver, recognizes the requests coming from the network and destined to GIScloud and then redirects them to the MySQL database for managing cloud users (KOFLER 2006, and the online MySQL 5.6 Reference Manual: *http://dev.mysql.com/doc/refman/5.6/en/*). This database verifies the identity of anyone who attempts to connect and grants access to the cloud by user level (Administration, inserting/editing data, consultation only); then it displays the customized control panel (Fig. 5) that articulates, at this stage of the development of the system, in four main applications designed especially for users authorized to the data manipulation. These applications consist in a remote hard drive (to store the

files), a project planning system (agenda), an internal messaging system and, obviously, an open source GIS system.

The app for storage and file sharing, can be considered as a real remote hard disk to place any type of file which can be shared with a remote user or with a group of users through a few clicks of the mouse: this solution, for example, allows to scan the pages of a book directly through the camera of a mobile device, making them quickly available to the research team; in fact, as soon as the files are sent to the cloud and shared, these can be immediately viewed by all authorized users which can access to these resources through the use of other mobile devices connected to the network, such as, for example, the modern smartphone and tablet PCs. The system is capable of storing files of any extension and incorporates an online visualization system for image files, pdf files, and MS Office and OpenOffice file.

The second application, with functions of electronic agenda that appears on the dashboard, was developed as a useful tool in the work group because not only allows programming the work and deadlines, but also allows requesting a videoconference meeting among group members: it sends a mail to entire staff, notifying the day and the hour of the meeting. This solution greatly simplifies the exchange of information within the team and, at the same time, helps system administrators (who are also responsible for research) to keep under control the workflow of the group. At this stage of development it wasn't integrated a platform for audio and video streaming for videoconference meeting: if necessary it will be implemented in future versions of GIScloud.

The third application, closely linked to the previous one, is a system for sending messages between members of the Group: it is particularly useful to facilitate rapid personal comparisons especially on research themes that do not require the attention of the whole team.

Finally, there is the cartographic services area, which is the core of the project and the hardest part, which has required most of the developing time and is still being tested. Also this one is based on open source architecture, and takes advantage from cartographic engines such as GeoServer (RUAS 2011), to offer services like Web Map Service (WMS), useful to share the data stored in a database PostgreSQL/postGIS (HALL, LEAHY 2008). In other words, the vectors that describe the mapping of areas of study have been converted into alphanumeric strings that, in turn, were stored in a PostgreSQL/postGIS database and linked to tables that contain metadata about the archaeological evidences. GeoServer accesses this database and, on the basis of the request received by the remote user through a web interface, generates an interactive map and displays it in the browser window of the remote user. The map is queryable and new entities can be inserted or modified directly through the web , as also the metadata. On the other hand, the graphical interface of the map and the toolset must be improved. Data can still be entered into the system through a desktop software such as, for example, Quantum Gis (CASAGRANDE ET AL. 2012), or through a C.R.U.D. (Create, Read, Update, Delete) system (about CRUD see: *http://portofino.manydesigns.com/en/docs/reference/introduction*).

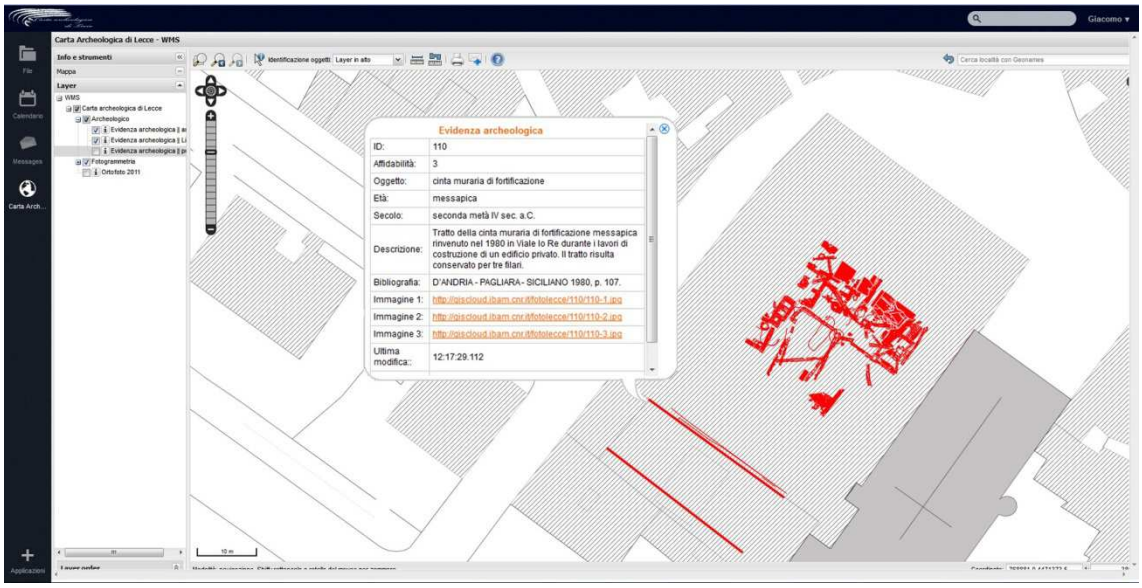

Fig. 6 – An example of a query of the data stored in PostgreSQL/PostGIS through the GIScloud interface.

G.D.G.

Giscloud: data management for geophysical prospecting

During the works of the DiCeT project for the archaeological map of Lecce, it was decided to make some non-destructive analysis of the subsoil, in different areas of the city, through the use of a dual antenna Ground Penetrating Radar at frequency of 200/600 Mhz and, in a few cases, of Electrical Resistivity Tomography. In particular the GPR highlights the subsurface anomalies at different depths, generating vertical slices by emitting electromagnetic waves and measuring their propagation time. These vertical slices are stored in the instrument and undergo further processing that, through the algorithms implemented in a dedicated software, merges all vertical slices to create a three-dimensional model of the subsurface anomalies. This three-dimensional model therefore allows to obtain two-dimensional horizontal slices of the subsoil at certain depths that consist of a series of image files that can be geo-referenced and analyzed on a thematic cartography.

During implementation of the GIScloud of the city of Lecce, it was decided to also integrate this type of data, thus expanding the dataset of the available information. Specifically, the image files of prospecting have been transformed into georaster that can be used on giscloud platform. These georasters were then transferred to the storage server and then the connection paths to visualize them in map space were created; the georasters have been then rearranged for the visualization and indexed by intervention area and depth. The result can be enjoyed directly in the GIS app of the cloud: in the legend on the left side of the monitor there is a folder containing all the prospections, which in turn contains all investigated areas into sub-folders (Fig. 7). Within each sub-folder there is the dataset of the scans, organized according to the frequency (200 or 600 MHz) and then, according to the depth, from the shallowest to the deepest. The same approach was applied to the few time slides acquired using ERT in not-standard L-shape configuration. Once georeferenced and integrated into the map of the city, such scans allow to analyze a range of spatial data before starting the stratigraphic excavation, putting into practice those activities typical of preventive archeology.

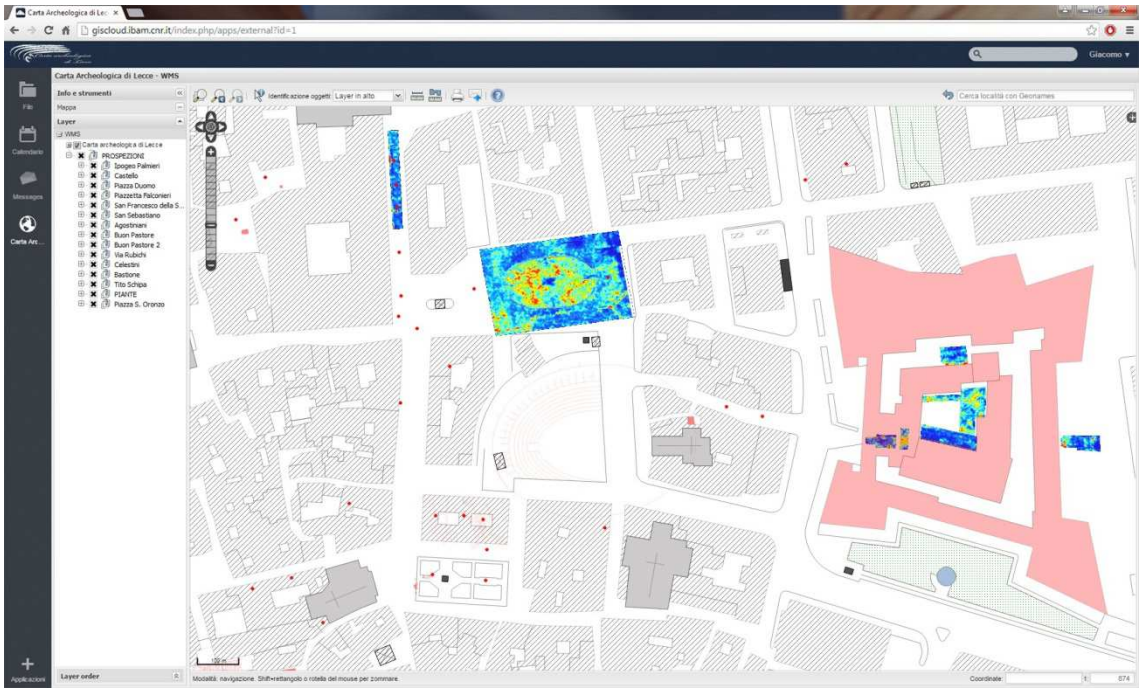

Fig. 7 – GPR slices are integrated in the map and shared through the GIScloud. On the left, the tree structure for the data consulting.

Once stored in GisCloud, these data are available through the web and can be useful both to archaeologists that, before embarking on the excavation, can have an idea of what lies beneath the road surface, both the responsible authority for urban planning that can have a more complete idea of the activities to be performed in a specific area of the city when planning to open yards in areas with high archaeological “risk”.

G.D.G.

Archaeological remarks

The research activities on the archaeological map of Lecce, still in progress, are allowing to upgrade of information and further detailing the reconstruction of the historical evolution of the city, especially between the Messapian and Roman periods. One of the main results of the research project is the integration, for the first time, of all archaeological data on a large-scale and up-to-date cartography, which allows, for example, the production of thematic maps regarding specific stages of development and transformation of the settlement, or specific phenomena. In this way, it is possible to reconstruct and integrate together the scattered fragments of archaeological information about Lecce. Moreover, the GIScloud allows a rapid and easy data management and integration, which facilitates the study and reconstruction of the oldest historical phases.

A very important theme of the archaeology at Lecce is the transformation of the settlement from the Messapian period to the Roman age. In the small-scale archaeological excavations performed in various sites within the historical centre (as Lo Re avenue, Epulione square, Castromediano square and Vernazza Palace), numerous materials and structures dated to the 7th-5th century BC were found. During the 4th century BC Lecce was transformed in an urban-type settlement (D’ANDRIA 2004; GIARDINO 2008, with previous bibliography) and in the last decades of the same century a city walls was built in large square

calcareous blocks (in the outer part) and smaller irregular stones (in the inner part). It had a total width of 7 m and was about 3 km long, enclosing a surface of about 60 hectares, which corresponds largely to the historic centre of Lecce (Fig. 8). Stretches of city walls, partially overlapping on oldest necropolises and on which the fortifications of the sixteenth century AD are directly superimposed (GIARDINO 1995), have been identified in several points of their route, as Napoli gate, Adua road, Lo Re avenue, Manifattura Tabacchi, cloister of the Carmelite Convent. In this period (4th-3rd century BC), Lecce was characterized by a scattered settlement, alternating inhabited areas with open spaces, public areas, necropolises and places of worship, as the rectangular cultic enclosures discovered in Giravolte road, in the south-western area of the city (DE MITRI 2002-2003 and 2012; FONTANA ET AL. 2003), and in the area of Vernazza Palace, in the south-eastern sector (AA.VV. 2011). About the irregular road network of the settlement, it is possible to remember the Messapic street (flanked by a necropolis) that was unearthed in the cloister of the Carmelite Convent (with remakes between 1st century BC and 2nd century AD), or the street dated to the 3rd century BC discovered in Castromediano square, characterized by numerous remakes between the Augustan age and the 5th century AD (FONTANA ET AL. 2003).

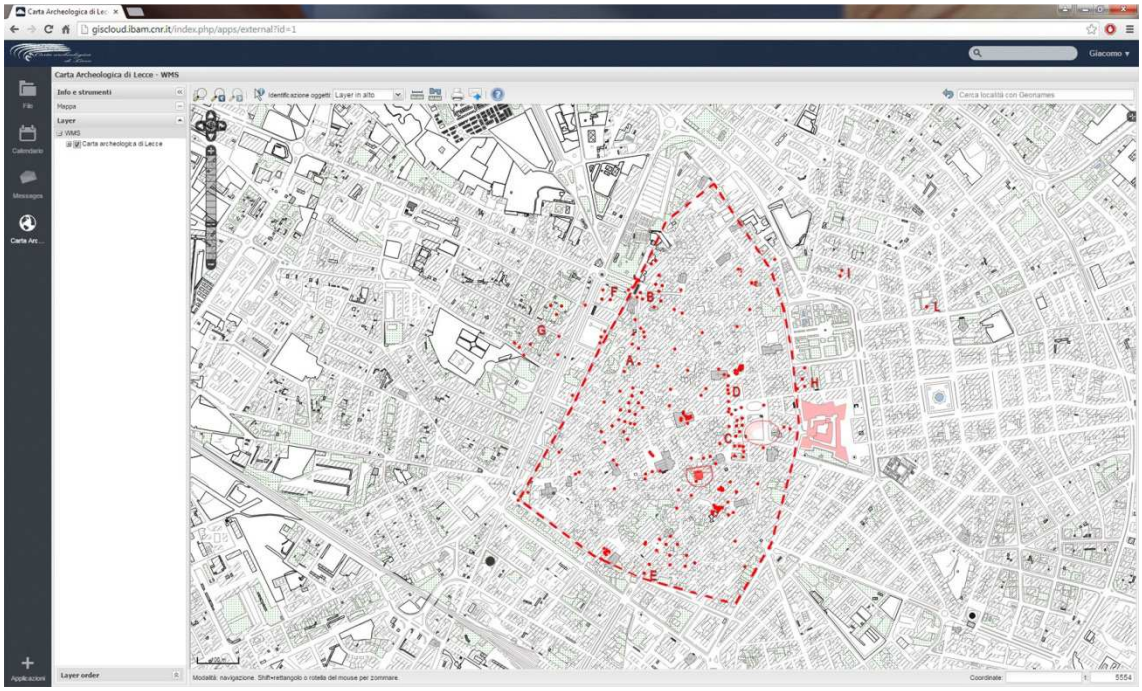

Fig. 8 – Archaeological map of Lecce in which the dashed line indicates the hypothetic route of the Messapian city walls.

In the 4th-3rd centuries BC, the necropolises, which are often reused after a few centuries, are located both outside (as in University avenue and Trinchese road, along ancient routes: Fig. 8, F and H) and within the city walls, where more than 100 tombs are known (GIARDINO 1994); they are above all grave piths and sarcophagi, but a few aristocratic hypogea were also discovered. Many tombs are in the westernmost sector of the city, in the area of Palmieri road and Napoli gate (Fig. 8, A-B), where two hypogea are known. Among them is the so-called Palmieri hypogeum, characterized by a cross-shaped plan, with open chambers on the three sides of a central vestibule; it was used between the end of 4th and the 2nd century BC (L'ARAB 1991-1992). Another large necropolis is in the easternmost sector of the city (Fig. 8, C-D), including the area of

Banca d'Italia Palace (where there is another hypogeum), Augusto Imperatore road and INA Palace (Fig. 9), Rubichi road and Castromediano square. Other tombs were discovered along Cairoli road, in the southernmost sector of the city.

Fig. 9 – Messapian tombs discovered below INA Palace in 1930s (Carluccio Archive, Lecce).

After the Roman conquest, the urban plan of Lecce-Lupiae was reorganized. From the Late Republic period all tombs (where there is the transition from the interment ritual to the incineration) were outside the city walls; in fact, the necropolises were located immediately to the west and east of the city, along the roads that arrived at Lupiae (GIARDINO, LONOCE 2011). In the first area, there are tombs in Pozzuolo, Vaste and Valesio roads, and in University avenue (Fig. 8, F-G). To the east of the city are the necropolises unearthed in Porcigliano and Casanello roads, in the block to the north-west of the crossing between Gobetti road and Saints Giacomo and Filippo road, and in the block delimited by XXV Luglio avenue, De Santis square, and A. Costa and S. Trinchese roads.

Between the Late Republic and the Early Imperial age occurred significant changes in the previous urban plan. In particular, the easternmost sector of the city, previously occupied by a Messapian necropolis, was monumentalized. In this area, during the Early Imperial age, a short distance from each other, are built the amphitheatre, a thermal building located in Santa Chiara square, the theatre, and a temple dedicated to Isis, recently identified below Vernazza Palace (Fig. 10, A-D). Therefore, the two large buildings for shows are built on the eastern periphery of the city, also to welcome spectators from the countryside without that they invaded the city centre during the spectacles.

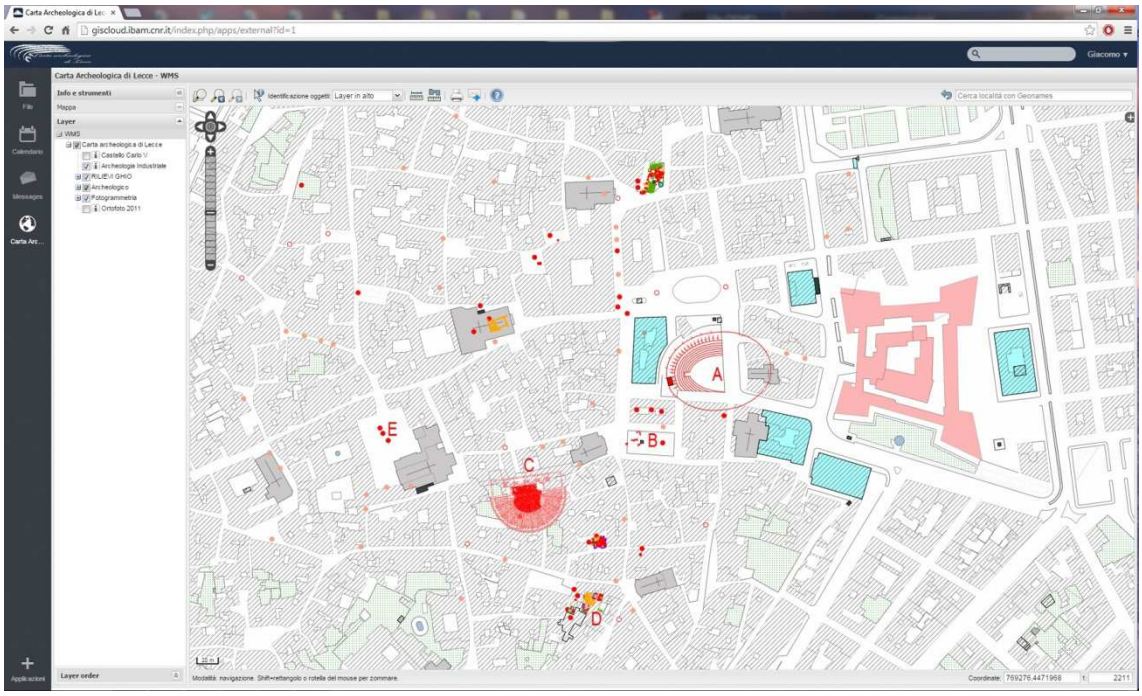

Fig. 10 – A detail of the archaeological map of Lecce regarding the eastern sector of the historical centre.

The amphitheatre (Fig. 11, A-B) was unearthed only in the western sector and originally it measured about 102 x 85 m (AMICI 1996 and 1999). It was in part obtained by digging the bedrock and partly rests on sturdy arches in *opus reticulatum*. The *cavea* was divided in three floors and could accommodate up to 14,000 spectators. The elliptical shape *arena* (about 53 x 35 m) is nowadays about 8 m deep from the current level of Sant'Oronzo square. About the theatre (Fig. 11, C-D), partly dug into the bedrock (D'ANDRIA 1999), archaeological investigations have identified *orchestra* (diameter of about 13 m), *pulpitum* (m 6 x 31) and *ima cavea*, which was divided by five radial staircases into six wedge-shapes (cunei). Moreover, in the same south-eastern sector of the city, even a second temple (maybe the Capitolium or a building dedicated to Apollo) had probably to be. The capitals discovered in the court of D'Arpe Palace (not far from the theatre), very similar to other two reused in the Cathedral of Otranto, hat to belong to this temple. According to tradition, the *forum* may have been in the area of Duomo square (Fig. 10, E). During Roman period, the road network is more regular than in the Messapian age, but the city do not seems characterized by an orthogonal plan. Among the streets of the Roman period discovered in small-scale excavations, one is in Rubichi road, paved with slabs (*basoli*), while another is in Epulione road, which was 4.5 m large and had two stages (end of the 2nd - first half of the 3rd cent. AD, and half of the 3rd - beginning of the 4th cent. AD); a blacksmith shop of the 2nd - first half of 3rd cent. AD was unearthed near the second street (QUERCIA 2002; FONTANA ET AL. 2003). Lastly, among the structures of the Roman period, it is important to remember the large *trapetum* with *lacus olearius* (2nd - 1st cent. BC) discovered in Castromediano square (FONTANA ET AL. 2003), at the eastern periphery of the city, not far from the road directed to the harbour of *Lupiae* in the site of San Cataldo, along the Adriatic coast. The structure was obliterated in the Late Imperial age (4th - 5th cent. AD), when the city still did not show obvious signs of decay. Belong to this phase also a rich *domus* with mosaic floors found in Sotterranei road (GIARDINO 2005) and some walls and a road unearthed in Longobardi square (POLITO 2003).

Fig. 11 – The unearthed sectors of the amphitheatre (A-B) and the theatre (C-D).

G.S.

Conclusions

The GIScloud of the archaeological heritage of Lecce is an user friendly platform, suitable to manage complex data across standardized and optimized procedures to share data over the web in a fast and efficient way. This “smart tool” contains all the features for study and management of ancient evidence, as a typical GIS system and offers all the opportunities of the Clouds to share data between research agencies, the authority for protection and management of cultural heritage and the authority for the urban planning. So, the purpose of GIScloud is to improve the functionality of the most complex and advanced geographic information systems on desktop computers by extending and enriching these systems: in fact the GisCloud provides a support for the data share through the Internet network. The fundamental difference between the GisCloud and the earlier webGIS systems is that the first have a shared space always available to store and manage archaeological and bibliographic documents. In a classic webGIS system, there are not tools to manage the working group, to share data, to view and comment these documents through an internal messaging system: a webGIS, in essence, it is very useful for one-way communication of information (who implements the system shares information). Through GisCloud, instead, communication is two-way: the information, in fact, can be inserted from anywhere and immediately it became available to all authorized users through a few simple operations. The experience in Lecce highlighted the usefulness of this system: the archaeologists who conducted the excavations in the city, for example, were able to integrate the data collected in the field with the that experts have recovered from libraries and superintendence data archive. These informations were immediately available to the community through the GisCloud. In some cases archaeologists have even asked their colleagues to find the documentation about previous excavations at

the superintendence and put it in GisCloud, in order to have these data available on the tablet pc: it was a guide to decide where excave. In the specific field of the archaeological research and of the studies of ancient topography, the ability to access this shared space (in which users can compare ideas and projects or can consult documents and can plan the works), it is a really important resource, especially for international project. Moreover, the choice of opensource as a development platform of the system is a successful solution: apart from the very low cost of deployment and management (just some programming experience is needed to put online all of the package), this tool could be easily replicated in other projects of archaeological research in ancient topography, without any cost to purchase software licenses. Experts in the management of the system could be trained, and the GisCloud could be replicated in any research facility. Moreover, among the results in the medium term, if the GisCloud will be adopted for the storage and management of data from systematic archaeological surveys, it could become an easy and fast way to exchange data and information with the public administration and all entities responsible for monitoring, management and enhancement of cultural heritage. Lastly, the case study of Lecce confirme that digital archaeological maps constitute a fundamental tool in order to study and reconstruct an ancient settlement in continuity of life and also in the supporting the preservation policies of ancient remains and the urban planning activities.

G.D.G.

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