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ROME TRANSFORMED

Non-Intrusive methodologies for large area urban research

Rome Transformed conference

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Conference Abstracts

This conference is part of the Rome Transformed project that has received funding from the European Research Council (ERC) under H2020-EU.1.1., the European Union's Horizon 2020 research and innovation programme (Grant agreement No.: 835271)

Azzari M., V. Bologna, C. Pappalardo, C. Berti. *A software for the Management and Analysis of Stratigraphic Data from Different Sources in a 3D Environment*

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The aim of this paper is to describe the design of an efficient, flexible, and scalable tool to generate Digital Terrain Models (DTM) related to the historical periods identified by the Rome Transformed project, starting from the stratigraphic data produced by various survey methods.

The design and development of an ad-hoc software solution for the creation of a tool able to manage stratigraphic data has been a crucial choice for the Rome Transformed project. After the evaluation of the available technologies, it emerged the need of a specific tool that would allow the storage and normalization of the data produced, their georeferencing and lemmatization, so as to flow in an orderly and usable way in a geodatabase of an ArcGIS project.

The solution adopted was the creation of a "tailor-made" software, as suitable as possible for the purposes of the research.

The main steps to build an ideal project workflow were obtained through continuous discussions with all the specialist teams, in order to identify the best import and conversion tool for each category of data to be implemented in the software: structural analysis, GPR, archival research and drilling.

The goal is to ensure the correct systematization of stratigraphies in the database, supported by lemmatizations and generation of 3D GIS geometries to be associated to each dataset: PointZ, MultiPointZ, PolygonZ. These 3D geometries are necessary data to generate a DTM in a GIS environment.

Once the analysis and comparison process is completed, the import scripts and input forms are created to populate the database. The database adopted to ensure these specifications is PostgreSQL with the PostGIS extension that will be fully compatible with the GIS platforms used: QGIS and ESRI ArcGIS.

This paper describes the main features of the software created and the database schema developed to ensure maximum compliance with each type of data needed for the generation of DTMs for each historical period.

Bianchi E.[1], A. Pansini[2]. *Roman buildings on the western slopes of the Capitol. Investigations and new approach technologies*.

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Following the demolition works carried out between 1929 and 1933 for the construction of Via del Mare, a large Roman district emerged from the western slopes of the Capitoline Hill, near the commercial area of the Forum Holitorium in Rome. The excavations, supervised by the archaeologist A.M. Colini, discovered the remains of several multi-storey residential buildings, dating to the Imperial age. Among them, only the Insula dell'Ara Coeli was preserved due to its exceptional state of conservation; all the other buildings, known as Taberna delle Tre Pile, the Caseggiato dei Molini, the Grande Insula, the Casa Cristiana and the Balneum, were instead razed to the level of the new Via del Teatro di Marcello and were forever covered by the new development of the area. Beside the short descriptions of the structures published by A. Muñoz in the volume Campidoglio (Rome, 1930), the finds have never been thoroughly examined: the excavation works were done in a hurry and only a synchronic plan, devoid of any interpretative element, was published.

In 2015 the Sovrintendenza Capitolina ai Beni Culturali launched a multidisciplinary project aimed at the recovery and analysis of the structures and the study of the urban and architectural characteristics of the district from the Republican age to the Middle Ages: it, also, provided for the collaboration of various professional figures. As part of this project, it has been possible, after more than 80 years, to access the surviving remains of the ancient buildings and to assess their current state of conservation.

The survey, conducted by the "Sapienza" University of Rome (Chair of Survey and Technical Analysis of Ancient Monuments - Department of Antiquity Sciences) in collaboration with the association Roma Sotterranea, was carried out with the most recent technologies, aimed at documenting the remains as accurately as possible for the study and the development of a 3D model of the buildings. A series of laser scanner surveys of the structures along Via del Teatro di Marcello and inside each underground area has allowed the development of a unified point cloud model, making it possible, for the first time ever, to view the buildings not only in their spatial relationship and in a two-dimensional and three-dimensional way, but also in relation to the modern urban context.

The documentation produced constitutes an important starting point for the reconstruction of the development of this ancient district of Rome.

Boschi F.[1], E. Giorgi[1], M. Silani[2]. *Combining past, present, and future. Non-invasive mapping for the urban archaeology of Ascoli Piceno (Italy)*.

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The Asculum Project started in 2012 as a collaboration between the University of Bologna, the Soprintendenza per i Beni Archeologici delle Marche and the Municipality of Ascoli Piceno, primarily as a project of urban and preventative archaeology in a long-lived city. Within this collaborative framework, the project benefits a wide range of interests, helping to reconcile the needs of preservation and research with a sustainable urban development.

The integration between new and old data from a variety of sources (geophysical and topographical survey, archaeological excavations, geological and geomorphological analysis) is at the basis of the research, towards the reconstruction of the ancient urban landscape and its transformations over the centuries.

At Ascoli we have adopted an integrated approach to the assessment of complex deposits from long-lasting contexts with non-destructive methodologies. The project has integrated the geophysical investigation of the underground deposits with the 3D documentation of the surviving historic buildings, using laser scanning and photogrammetry alongside the analysis of structural stratigraphy, the study of the building techniques and of the artefacts. Important key studies have focused on the main squares and open areas of the city, with their historical monuments (Piazza del Popolo, Piazza dell'Arengo, Piazza Viola, Piazza San Gregorio Magno), allowing to see beneath the paved surfaces and providing new insights to interpret the evolution of the buildings and the development of crucial sectors of the Roman and of the Medieval cityscape. The exploration and the assessment of the buried archaeological record is widely supported by the notable work of the archaeological units that are routinely involved in the local rescue archaeology, as a result of a consolidated relationship of mutual collaboration.

Beyond research, the project is also fostering knowledge outside the academic environment, focusing on the city and on its social and cultural development. Fulfilling the University's third mission, we have offered talks, site visits and interactive visits to archaeological excavations, to those living in Ascoli and those interested in the city's history. These activities confirm the role of public engagement in raising awareness on the contribution that modern methodologies and up-to-date technologies can make in the protection of archaeological landscapes threatened by urban development, with undeniable benefits and positive impacts on the daily life of the community now and in the future.

Campana S.[1], S. Camporeale[1], J. Tabolli[1], R. Pansini[1], S. Güzel[1], G. Morelli[3], F. Pericci[4], M. Sordini[4], L. Gentili[5], F. Gianni[5], F. Vitali[6], G. Carpentiero[7], D. Barbagli[8], *SOS project: a new challenge for a novel approach to the understanding of historical cities*.

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Recently a new research initiative has been launched under the title of SOS which is the international call for help by ships and sailors at sea – 'Save Our Souls' but in our case the acronym means, SOtto Siena (Beneath Siena). It is designed to undertake an innovative study of the urban archaeology of the city based on three principal lines of research.

The first entails the creation of a WEB-based 3D Archaeological Information System for the subsoil of the city. Alongside the development of this GIS a second line of research will entail the acquisition and refinement of STREAM X GPR data for all of the public spaces such as streets, squares, courtyards and gardens that are at least theoretically accessible within the city for the mapping of archaeological features down to a depth of about 3 m and over an estimated 25 hectares of surveyable area. The third element in the project will focus on identification of all existing archaeological, historical, and geological information about the city and its representation in the WEBGIS platform; this element of the project design will also be devoted to the development of interpretative frameworks for the radar data, permitting its integration and progressive combination with the documentation and future results from within the city.

Carboni F.[1], E. D'Ignazio[2], M. Serlorenzi[3]. *Conducting archival research in an interdisciplinary context for Rome Transformed.*

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Archival analysis is one of the tools exploited by the *Rome Transformed* project to carry out a comprehensive survey of the Eastern Caelian, being part of that multidisciplinary approach which, alongside scanning and architectural analysis, geophysical surveys and environmental analysis will bring data together to reconstruct the evolution dynamics of this urban sector from the first to the eight century CE.
The data obtained through this type of research contribute to assessing the archaeological and architectural remains still visible in the area and provide evidence of the vestiges that were destroyed or obliterated over the centuries. They play a crucial role in leading structural analysis to a better reconstruction of the ground exposed structures and in giving clues for the interpretation of the anomalies detected by geophysical prospections. Legacy data are also pivotal for defining the reshaping of the landscape throughout the key periods covered by the project.
This paper aims to discuss the challenges encountered during the first phase of data capture from Rome and Vatican historical archives and their comparison with the more recent records that populate the ArcheoSITAR platform. We will describe the methodology used in recording extremely fragmentary and heterogeneous documents, the preliminary interaction of these raw data with the results of other non-invasive research methods, the complexity of extracting from them 3D information.

Dabas M.[1], F. Blary[2], G. Catanzarit[3], *The challenge of archaeologists using geophysics in urban areas*.

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Geophysical prospecting, even if now used routinely for managing cultural heritage questions in open areas, suffers in currently urbanized environment from various difficulties which makes its use non-trivial. A certain number of constraints in the urban environment are generally well known: presence of mechanical vibrations, electromagnetic noise, presence of infrastructures, furniture, pedestrians, cars above the surface, presence of underground modern services (water, gas, electricity, fibers, etc.), and most obviously, presence of above ground structures which tend to fragment into small pieces the areas that can be measured. Others like the very high heterogeneity of the subsoil (rubble and a highly complex multi-phase stratigraphy) remains the biggest challenge for the geophysicists and ultimately for archaeologists during the interpretation process. The very good results obtained over abandoned roman towns for example are due to the conjunction of facts that are seldom encountered in today's city centres: low depth of structures (< 1 m); existence of some destruction phase that has cleared up the rubbles and made apparent walls or their negative counterpart; existence of a single phase of construction of the urban layout. The situation of today's cities is closer to the one of "tells" in middle-east countries. If the first archaeo-geophysical surveys in cities were very 'punctual' and were often limited to the study of religious buildings or parks, in recent years the appearance of new methods such as the electrostatic method (also called CCR – Capacitively Coupled Resistivity) or motorized ground radar (GPR) allow the investigation of very large areas. Two examples will be shown: the research conducted in Alexandria during the 2000s and the one, coupled with 3D survey, carried out more recently in Brussels. In both examples, several classes of geophysical methods are used simultaneously to solve the archaeological questions: presence of the Heptastadium in Alexandria, presence of medieval buildings in Brussels. The ancillary role of micro-topography will also be shown for both studies. For both experiences, the role of the electrostatic method will be discussed in comparison to other surveys. Processing of data and integration of all types of data is also a very important and challenging part of the work. Several types of data processing for GPR and for CCR acquisition will be shown and prove that our interpretation heavily relies on these processing workflows that can –and should evolve during the interpretation process. It will be shown also that without extra information like old plans and drawings, our geophysical interpretation may remain very poor. Finally, we can ask ourselves what exactly is the role of geophysical information obtained in such contexts. Is it only useful for archaeologists, or can we imagine a more integrated approach with geotechnical engineers, network managers, urban planners? Can it be used blindly as in the case of an archaeological diagnosis or does it have to answer a specific question?

Demetrescu E.[1], C. Gonzalez Esteban[2], S. Morretta[3], R. Rea[3]. *Methods and techniques for the interpretation and reconstruction of the ancient landscape outside the Aurelian Walls*.

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With this contribution the authors offer an overview of the methodologies for landscape reconstruction and interpretation applied in the past 15 years on the study of the area outside the Aurelian Walls in Rome, between Porta Metronia and the Felice Aqueduct. We discuss the use of information provided by core drilling, previous excavation documentation and cartography for the reconstruction of the urban stratigraphy and focus on a specific case study: the virtual reconstruction based on stratigraphic data of the Amba Aradam Metro station excavation.

The initial stage of the work focuses on reconstructing, sourcing, and visualising the remains of rooms 14 and 15 discovered during the excavation of the station. The narrow selection of contexts would work as a test for the method proposed, while the process is modified and adapted according to the nature of the site. Field data, such as the Harris matrix, plans, context sheets and photogrammetry, are used as a base to develop the hypothesis for a virtual model. The model includes a reference to the several sources (metadata) and processes (paradata) that led to its creation. This makes it possible to summarise and converge a range of different data to a reasonable and organised interpretation of the archaeological remains, by using the formal language of the Extended Matrix and by connecting different software, such as yEd and Blender EMtool plug in. The final stage of the project is to create a 4D model of the excavated layers that were found on top of the reconstructed archaeological remains. By doing this, we develop a full record of the site and of the processes that affected its development, from its initial development to the moment of discovery. Once completed, the source-based model (the virtual model and the source information integrated within) is added to the EMViq online service. This software is a great tool for scientific research, as it allows to query, visualise, and interact with the information on the screen and through Virtual Reality. This feature also makes it is a starting point for an attractive outcome for public engagement.

The Amba Aradam case study reaffirms the benefits of the Extended Matrix as a standard middle ground between archaeological excavation, virtual reconstruction and the sources involved in bridging the gap between the two. In addition, it allows an easy and simple data sharing at international level. This method represents a simple way of meeting and representing the links between archaeological records, virtual reconstruction, and online dissemination.

De Santis, A., Bottiglieri, L., Colli, D. , Rosa, C., Solvi, M. *The archaeological area of S. Croce in Jerusalem: new data for the reconstruction of the ancient landscape.*

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The archaeological area of S. Croce in Gerusalemme, an imperial residence during the Severan age and during the Constantinian period, has recently undergone several restoration works and archaeological investigations.

The evidence that emerged from these interventions, alongside a thorough data review from past research, have allowed the re-assessment of the buildings that originally belonged to the imperial complex, a new understanding of their building phases and of the residence's original extent and internal articulation.

The study of historical cartography and geognostic analyses have shown that in many cases the design choices have been conditioned by the geomorphological conformation of the land, marked by deep ditches and steep differences in height, that have constrained the positioning of the buildings in the area.

We are trying to reconstruct the historic evolution of this area and, also through three-dimensional graphic models, to suggest a new and in-depth reading of the complex, both from a structural and chronological point of view.

Haynes I.[1], T. Ravasi[1], I. Peverett[2], M. Grellert[3], M. Simpson[4]. *From interpretation to provocation and back again: Rome Transformed SCIEDOC and the Ospedale di San Giovanni in Laterano.*

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Integral to the interdisciplinary dialogue that drives the interpretation of the complex urban deposits encountered by the ROMETRANS project, is the notion of 'provocation'. A range of 3D visualisations are developed using architectural and landscape modelling software in order to make the team's interpretative work more tangible, accessible and contestable. This approach has the merit of forcing team members to address issues that might be omitted from basic plans and textual narratives. Conscious of the concerns addressed by the goals of the London Charter (2006) and Seville Principles (2011), these provocations are supported by ROMETRANS SCIEDOC, a user-friendly system that allows all interested parties to explore the source materials used to justify each element, thus creating an ongoing, open dialogue.

To illustrate the process, this paper takes the case study of the Late Antique domus discovered under Corsia Mazzoni in the Ospedale di San Giovanni in Laterano (Rome).

Portions of the Late Antique Domus were excavated at four different times between sometime before 1944 and 1972. A joint team of Newcastle University (UK) and the University of Florence (Italy) carried out 3D data capture and structural analysis of the structures as part of the San Giovanni in Laterano 2 project (Haynes *et al.* 2019; Ravasi *et al*. 2020), later incorporated into the ERC funded Rome Transformed project (Haynes *et al*. 2020). The domus belongs to a property dating to the imperial period that underwent successive transformations, to reach its current visible state during the 4th century C.E., when a large portico with a fountain at the centre and lavish floor and wall marble veneers were added to the residence. The interpretation of all the surviving structures together with the analysis of unpublished archival information have allowed the development of four 3D visualizations of the portico that have been made available to the wider community through a tailored version of SCIEDOC.

SCIEDOC (www.sciedoc.org) was developed in 2016 in recognition of the London Charter (2006) and of the Seville Principles (2011), with the aim of responding to the issues arising from the increasing body of research that deal with 3D virtual reconstructions in the heritage sector and as a simple, cost-effective and intuitive tool for researchers, to provide the evidence for and the argumentation supporting their decisions in the 3D visualization process (Pfarr-Harfst, Grellert 2016).

Rome Transformed has adopted and adapted the Reconstruction Argumentation Method developed by SCIEDOC, and over the course of 2020-2021 a team of archaeologists, architectural visualizers and software engineers based at Newcastle University has adapted it to the needs of the project, developing a research tool that will deal with natural and historical landscapes alongside large architectural complexes on an urban-scale research area. Our approach to 3D visualization in the heritage sector recognises the need to develop a tool that takes into consideration the possibility to create multiple variants of a single model and that addresses the issue of probability in the development of visualizations (Grellert *et al.* 2018). We approach this issue by following the principle that any visualization (our View/Variation) developed by our team and discussed through the Reconstruction Argumentation Method does not necessarily constitute a "finished" product but rather a "provocation", used as a visual tool to engage the research community in a specialist discussion. The visualization, searchable through specialist tags the argumentation, and the discussion, recorded on a thread, allow for the development of successive modifications called "Iterations". The creation of successive iterations provides a potential response to the issue of how to ensure a transparent discussion over the 3D visualization process, allowing the necessary space for an ongoing critical discussion.

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Kay S., E. Pomar, G. Morelli, *Rome Transformed: a multiple method geophysical approach for the urban investigations of the East Caelian.*

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The large-scale geophysical surveys of the Rome Transformed project have the objective of supporting the investigation of the Eastern Caelian from the first to the eight centuries CE. The methodology combines the use of a number of geophysical prospection techniques with archival research, structural analysis, 3D digital recording and sampling of deep sedimentary sequences. The study area covers 13.7km2 which includes deep stratigraphic contexts and a wide range of urban infrastructure including tramlines, service pipes, roads and buildings.

The British School at Rome, together with the Consiglio Nazionale delle Ricerche and GeoStudi Astier has used a combined approach of Ground-Penetrating Radar and Electrical Resistance Tomography. The Sessorian Palace, the gardens of Villa Wolkonsky, the Basilica of Saint John Lateran and the communal park alongside the Aurelian walls have been investigated with both techniques in order to maximise the understanding of the sub-surface. The combined approach, together with high precision geographical referencing, has allowed a detailed approach which will in turn inform the future deep sedimentary cores.

Kay S., E. Pomar, P. Campbell and K. Vukovic. *Integrated GPR and laser scanning of Piazza Sant'Anastasia, Rome*.

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The Basilica of Sant'Anastasia is one of the earliest churches in Rome, built around the time of Pope Damasus I in the 4th century AD. It lies at the southwest corner of the Palatine hill on the edge of the Circus Maximus and was built on a range of Roman structures which were used for the foundations. Between 1857-63 a series of excavations were conducted under the church, revealing a series of shops and warehouses dated to between the 1st and 4th centuries AD. The structures faced on to a paved road which runs under the present right aisle of the basilica, parallel to the modern Via dei Cerchi. The excavations indicate that the buildings continue to the northwest underneath the piazza in front of the basilica.

The British School at Rome, in collaboration with the Parco Archeologico del Colosseo, has conducted a non-invasive survey of Piazza Sant'Anastasia, with the aim of recording the continuation of the buildings. The survey was carried out using Ground-Penetrating Radar with two antennas of different frequencies (400MHz and 200MHz) in order to maximise the resolution of the survey at different depths. Furthermore, the piazza and façade of the church were also recorded with a laser scanner to generate a 3D point cloud, allowing in the first instance the creation of a Digital Surface Model (DSM) to topographically correct the GPR data.

The results of the geophysical prospection and laser scanning were integrated in a shared 3D environment, allowing the analysis of the GPR data together with the standing structures. This methodology, when applied in a complex urban situation, allows for a greater understanding of the subsurface features and their relationship with the local environment. The survey was successful in recording features at different depths and revealed the continuation of buildings underneath the piazza therefore challenging present assumptions about the urban nature of this area in the Imperial period.

Lagóstena L., J. A. Ruiz Gil, J. Pérez Marrero, P. Trapero, J. Catalán, I. Rondán, M. Ruiz Barroso. *Three coloniae and Three municipia: non-invasive exploration of urban contexts in Roman Hispania*.

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Since 2016 our team has been developing non-invasive research methodologies applied to the study of large archaeological areas corresponding to ancient cities in Roman Hispania.

In this paper we present the case studies represented by the Roman colonies of Hasta Regia (Mesas de Asta, Jerez de la Frontera), Ilici (La Alcudia, Elche) and Libisosa (Lezuza, Albacete), and the Latin municipalities of Balsa (Luz de Tavira, Tavira), Arva (Alcolea del Río) and Calduba (La Perdiz, Arcos de la Frontera) located in the Roman provinces of Betica, Tarraconensis and Lusitania. These cities are different from each other and offer a wide variety of examples in terms of topography, geography, current land use, state of preservation and archaeological intervention. Therefore, research on each site was approached by considering its peculiarities. We have always experimented with the most appropriate investigation methodologies, mainly consisting in the use of Unmanned Aerial Vehicles (UAVs), ground-penetrating radar (GPR), magnetometer and terrestrial Lidar.

The present paper discusses the different issues encountered during the entire research process and the strategies applied, as well as the most relevant results for each case study as part of the conclusions of this experience.

The large number of study sites, the length of the research period, the nature of the surfaces analysed and the diversity of situations make this research experience unique among the non-invasive investigations conducted so far in Spain.

Millett M.[1], F. Vermeulen[2], A. Launaro[1], L. Verdonck[2].*Ground-penetrating radar survey as the linchpin of a multidisciplinary approach to the study of two Roman cities in Lazio*.

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Our understanding of Roman urbanism relies on evidence from a few extensively investigated sites, such as Pompeii and Ostia, which are unrepresentative of typical Roman towns. Non-invasive survey approaches on a multitude of abandoned ancient urban sites in Italy and elsewhere are now rapidly changing our approach to the Roman city. This paper presents the outcome of the first high-resolution GPR surveys of complete Roman towns in Italy, *Falerii Novi* and *Interamna Lirenas*.

We review the methods deployed and provide an overview of the results, including discussion of some case-study areas within both towns. We demonstrate how this type of survey has the potential to revolutionise archaeological studies of urban sites, while also challenging current methods of analysing and interpreting large-scale GPR data sets.

Recent works have demonstrated the value of GPR survey on Roman urbanism, but these projects are predominantly small scale, covering no more than a few hectares. Since 2015, however, we have deployed GPR on a much larger scale to generate high-resolution images of these two complete greenfield Roman towns in Lazio. Although such rapid data collection allows entire Roman cities to be mapped at an unprecedented level of detail, interpretation of these large data sets still relies largely on visual analysis and the manual digitisation of anomalies.

These traditional, time-consuming interpretative methods are no longer able to exploit fully the potential of geophysical prospection, and here we propose possible ways forward. This includes first of all the fusion of the GPR data with the data obtained from full scale geomagnetic prospection of both towns, and the integration with traditional and more innovative topographic and archaeological methods, such as surface survey, drone based 3D modelling and aerial and satellite photography. Secondly, we propose computer-aided interpretation as a means of handling large data volumes in a more efficient and objective way.

Finally, the presentation will also, in continuation of geophysical surveys carried out in recent years by this Belgo-British team, discuss the current and future strategies for stratigraphic contextualisation, focused chronometry, 3D-visualisation of the physical landscape, creation of a DEM, erosion modelling and environmental reconstruction of both urban sites. A systematic coring program, targeted excavation and test-pitting are some of the operations under development.

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Multidisciplinary approach for characterizing the shallow subsoil of the Central Archaeological Area of Rome for geohazard assessment.

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In 2009, after declaring the state of emergency for the central archaeological area of Rome, following the adverse weather conditions of November and December 2008, the Government Commissioner and the Italian Department of Civil Protection (DPC) assigned the Institute of Environmental Geology and Geoengineering (IGAG) of the Italian National Research Council (CNR) to evaluate the geohazard level affecting the Central Archaeological Area of Rome (i.e., Palatine Hill, Roman Forum, and Colosseum). Research activities started up in February 2009 and were concluded in February 2011, with the valued contribution of the archaeological Superintendence.

The first two phases of the project (between February and December 2009) were carried out mainly using available information from public Institutions and private companies. Three new thematic maps - on a 1:1,000 scale - were produced at the end of the second phase: (i) a geological and hydrogeological map with seven geological cross-sections, (ii) a susceptibility to instability map, and (iii) a seismic amplification susceptibility map. The third and final phase allowed to perform new field surveys and involved three CNR research Institutes (apart from IGAG, scientific coordinator, the Institute for Technologies Applied to Cultural Heritage was involved) and University departments.

The new surveys were planned to achieve two main goals:

1) the characterisation of the archaeological layer, in order to (i) map the bottom surface of the anthropic covering, and (ii) typify the archaeological layer in terms of physical and mechanical properties.
2) the characterisation of the underlying geological bedrock, aimed to (i) map the geological units and typify the recognised lithotypes in terms of physical and mechanical properties, (ii) detect and monitor the water table position, and (iii) detect conditions potentially susceptible of instability (i.e., landslides, cavity or chamber collapse, seismically induced settlements).

The subsoil setting of the study area (less than 1 km^2) was preliminarily defined by means of already available 200 geotechnical boreholes. By the way, a new drilling campaign was performed to better investigate the geological and archaeological layers of Palatine hill and surrounding areas. Twenty-five continuous coring vertical boreholes (total depth between 20 and 60 m) were drilled.

All the boreholes crossed the anthropic layer, which ranges in thickness between 1 meter (at the hilltop) and 18 meters (along the slope and at the base of the rise). Several boreholes also crossed the network of tunnels dug in the tuff rocks underling the anthropic layer.

Lithological and stratigraphic logs of boreholes, integrated with information from local archaeological stratigraphy, allowed to strongly constrain (i) the bottom surface of the archaeological layer, and (ii) the boundaries between geological units.

Because almost no direct observation either of the geological bedrock or of the pre-anthropic/anthropic contact is possible due to the thousand-year-old anthropic covering, an extensive geophysical survey was than planned to extend correlations all along the study area, and to characterise internal variability of subsoil units.

Twenty-four ERT were performed at the Palatine hill and the Roman Forum. Resistivity field data were collected using different array configurations (Wenner-Schlumberger and Dipole-Dipole) and electrode spacing (from 1 to 10 m), obtaining different investigation depth (from about 8 to 80 m). In all cases, the resistivity values range from 10 to more than 1280 Ωm. As regards the archaeological layer, in general, relatively high resistivity values (>400 Ωm) are associated to voids and/or cemented conglomeratic walls, while low to moderate resistivity values (<400 Ωm) are related to anthropic silty sandy backfill material.

With GPR method a high-resolution data acquisition technique was adopted to reconstruct a global image of five areas. For the measurements, a 500 MHz bistatic antenna with constant offset, a 70 MHz monostatic antenna and a 35 MHz monostatic antenna, were employed. The horizontal spacing between parallel profiles at the site was 0.5 m, employing the 500 and 70 MHz antennas and 1 m, employing the 35 MHz antenna. Some signal processing and representation techniques were used for data elaboration and interpretation. With the aim of obtaining a planimetric image of all possible anomalous bodies detected in the ground, the time-slice representation technique was applied using all field profiles. Amplitude of reflections recorded in the time-slices is mainly referable to the distribution of archaeological structures. High amplitude reflections can be referred to archaeological remains and, locally, to voids located in the anthropic layer. Low amplitude reflections can be related to the anthropic backfill and, in few cases, to the geological bedrock.

All the previous and new geological, geotechnical, and geophysical data were stored in a geographic information system (GIS) carried out by IGAG for the Italian Civil Protection in the framework of the UrbiSIT project (www.urbisit.it).

Integration of the geophysical surveying methodologies with geotechnical boreholes allowed defining a detailed geological model of the study area, in terms of buried topography, geometries of geological and anthropic bodies, and lithotype distribution.

The geological and hydrogeological map, along with the geohazard susceptibility map were updated in the light of the new data. Geological and hydrogeological data allowed reconstructing a preliminary 3D model of the archeological area. This model helped to better understand the underground water circulation to establish flood risk mitigation strategies for the defense of the archaeological heritage.

Moreover, geotechnical in situ and laboratory tests, active (Down-Hole, Cross-Hole, and MASW) and passive (noise measurements) geophysical surveys allowed to define a subsoil model aimed at 1D and 2D numerical evaluation of the seismic response of the area. The main results of this study lie in a seismic micro zonation map on a 1:2,000 scale and site-specific response spectra to be used for seismic retrofitting of the monuments.

In conclusion, the main goals of the project were achieved at the end of the study. The application clearly demonstrates the potential for full integration of geological, geophysical, and archaeological methodologies to better characterise the geological and anthropic layers in archaeological areas. As a matter of fact, results show that: 1) both buried topography and internal complexity of the archaeological layer are detectable; 2) main boundary surfaces between geological units are laterally traceable; 3) presence of voids in the geological bedrock, locally crossed by boreholes and constrained by archaeological information, is presumable.

Piro S., D. Zamuner, T. Leti Messina, D. Verrecchia. *Acquisition, integration, and interpretation of multiple GPR data sets in urban area, as part of the ERC Rome Transformed project.*

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Important research and technical issues are related to the prospection in urban area to locate subsurface cavities and/or archaeological remains and to produce hazard mapping. In many cases, cavities, such as subsidence features, voids and collapses represent disruptions to the geometry of an originally near-horizontal layered system. Geophysical techniques can be employed to identify the feature geometries by contrasts in the physical properties but can be strongly conditioned by cultural features that interfere with instrument measurements (utilities, structures, surficial debris).
The critical phase of the geophysical survey in urban area is the interpretation of the collected data and the characterization of the degree of confidence in the interpretations.
The urban subsoil consists often of many layers documenting the history of a place, keeping records of alternating phases of construction and destruction. The shallow subsurface of modern cities contains reams of pipes, cellars, wells, cavities, tunnels, graves and foundation walls of former houses, churches and town fortifications.
The most promising non-destructive geophysical prospection method for use in urban area is GPR (ground penetrating radar). GPR measurements are less affected by the presence of metallic structures compared to magnetometer prospection and they result in the largest amount of data of all commonly employed near-surface geophysical methods, providing detailed three-dimensional information about the subsurface (Trinks *et al.* 2009, Piro *et al.* 2020).
In the present paper the surveys made with GPR method to investigate different sites in the area of S. Giovanni in Laterano, Scala Santa and Santa Croce in Gerusalemme, as part of the ERC funded Rome Transformed project (2019-2024) are presented and discussed.
The aim of the GPR survey is to identify Roman and high-medieval age remains which could enhance understanding of the ancient topography and the urban evolution of the study area.
For The measurements a GPR SIR3000 (GSSI), equipped with a 400 *MHz* (GSSI) bistatic antenna with constant offset, a 70 *MHz* (Subecho Radar) monostatic antenna and a SIR4000 system equipped with dual frequency antenna with 300/800 MHz were employed.
All the GPR profiles were processed with GPR-SLICE v7.0 Ground Penetrating Radar Imaging Software (Goodman 2020). The basic radargram signal processing steps included: (i) post processing pulse regaining; (ii) DC drift removal; (iii) data resampling; (iv) band pass filtering; (v) background filter and (vi) migration. With the aim of obtaining a planimetric vision of all possible anomalous bodies, the time-slice representation technique was applied using all processed profiles showing anomalous sources up to a depth of about 2.5 m (Goodman, Piro 2013; Piro, Goodman 2008).
With the aim of obtaining a planimetric vision of all possible anomalous bodies the time-slice representation technique was applied using all processed profiles (Goodman, Piro 2013; Piro, Goodman 2008).
Ground Penetrating Radar (GPR) survey at the selected areas has produced significant and fruitful results that will be discussed during the presentation.

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Ruiz Gil J.A., L. Lagóstena Barrios, J. Pérez Marrero, P. Trapero, J. Catalán, I. Rondán, M. Ruiz Barroso.

GPR survey in the Punic harbour of La Martela (El Puerto de Santa Maria, Spain) and the methodology used for the processing and archaeological visualisation of the data.

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The first example of city planning in Western Europe is located in Cádiz (Spain) where the Phoenician colony of Gadir was founded. The city was interested by a long urbanisation process until Roman times.

Several historical settlements, with industrial and commercial function, integrated the territory of Cádiz bay, as well as other life and burial places like the inland settlement of Castillo de Doña Blanca. This population process was adapted to the marine landscape of the Bay, while itself caused the urban transformation of the coastal environment of the medieval Cádiz Bay.

Since 2016 our research team has carried out a non-invasive study with the aim of safeguarding the historic environment and advancing the research on the urban development. In this paper we show the results of the GPR surveys conducted in La Martela, the Punic harbour of Castillo de Doña Blanca. This is a Phoenician settlement known thanks to excavations carried out between 1979 and 2001 and the non-invasive investigations conducted by our team, consisting of aerial and land photogrammetry and geophysics surveys (with single and multi-antenna GPR system).

La Martela is located on the floodplain, at the foot of the Phoenician settlement of Castillo de Doña Blanca, in a zone where there were no archaeological remains. A 6 hectares survey area was covered with the GPR multichannel Stream X system, thus leading to the discovery of an archaeological site of short-term phase. The orthogonal layout and the building types, with the elongated rooms of the Phoenician and Punic 'warehouse' type, are a clue to date its last construction phase to the 3rd century BC.

In this communication we present the proposed workflow for optimising the results of large area multi-channel GPR surveys to obtain accurate urban cartography, enhancing the value of this method as a research source.

Although geophysical techniques use interpolation as a mechanism to visualise data, these results provide enough quality to map underground structures of archaeological interest with precision. Ultimately, the floor plans obtained through geophysical techniques should be considered as valid as the ones derived from a traditional survey of excavated archaeological remains.

Schmidt A.[1,2], T. Sparrow[2], C. Gaffney[2], V. Gaffney[2], A.S. Wilson[2], R. A.E. Coningham[1]. *4D with Accuracy: why bother?*

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For the communication of archaeological and other Cultural Heritage results to the public, 3D representations have long been very effective tools. In recent years, advances in information technology even facilitated 3D time laps animations based on different phases of sites and monuments (e.g. for the ship burial site in Gjellstad, Norway; https://www.gjellestadstory.no/). Although most such representations are based on archaeological results, they do not require high fidelity as large parts of such reconstruction models are hypothetical in any case. Would a full and accurate 4D recording (i.e. 3D with additional time dimension) of archaeological data provide additional benefits, given that recording and data management would require more efforts and possibly even new work paradigms?

Inherently, all well-recorded archaeological data already contain 4D information, albeit in a disaggregated form, consisting of map and section drawings, context identifications, and sequencing, for example using the Harris matrix. During the post-excavation analysis these data are conceptually assembled into a 4D record. Several groups have demonstrated clearly how 3D recording of all excavation phases can be used to derive these conventional products (if desired), as well as forming the basis of a complete 4D data set (Aspoeck & Fera 2015; Larsson et al. 2015; Schneidhofer et al. 2017).

We present here the benefits of compiling a 4D data set of all the physical evidence from a heritage site. This is based on the combination of work from two projects: 'Curious Travellers: Visualising Heritage' (http://www.visualisingheritage.org/CT.php) (Wilson et al. 2019) and 'Reducing Disaster Risk by Evaluating the seismic Safety of Kathmandu's Historic Urban Infrastructure' (Davis et al. 2019). One of the heritage sites that was investigated in this joint effort is the historic centre of the city of Bhaktapur in the Kathmandu valley, Nepal. Many of its temples were destroyed by the Gorkha earthquake in 2015 and some of them were rebuilt in subsequent years. Our data consist of photogrammetric reconstructions of the centre before its destruction, using photographs taken by tourists and submitted to the project; photogrammetric and scanning data collected after the rebuilding of some of the temples; and of geophysical data from a detailed ground penetrating radar (GPR) survey of the subsurface. Combining and manipulating these data sources proved to be challenging and new approaches had to be developed, for example by using automated extraction algorithms for delineating the GPR anomalies (Schmidt & Tsetskhladze 2013).

The reconstructed historic 3D data are important for conservators, architects and engineers during their reconstruction and conservation activities and the 4D data set can be used for detailed documentation and comparison of the historic monuments in their different architectural incarnations. It also allows accurate measurements of individual monuments and of the relationships between upstanding and subsurface remains, and as a source for derived visualisations for presentations to the general public. The efforts of combining the heterogeneous data into one accurate 4D representation are hence offset by the detailed analysis that is now possible.

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SITAR project. New approaches and methods for an open data archeology of Rome

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SITAR (*Sistema Informativo Territoriale Archeologico di Roma - Archaeological Territorial Information System of Rome*) has been launched in 2008 by the Soprintendenza Speciale per i Beni Archeologici di Roma in order to digitize and gather all the scientific data coming from the archaeological excavations and the geological research surveys carried out within the territory of Rome and Fiumicino. Its goal is to ensure the visibility, transparency, and dissemination of the scientific data on archaeological excavations in the city of Rome: a digital registry dedicated to Rome's heritage, free for all to access and consult.

Turner, A. *Marvellous metadata: Managing metadata for the Rome Transformed Project*.

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This paper explores the use of an integrated approach to the use of an Access database and ArcGIS Pro to manage the complex and varied metadata produced by Rome Transformed. It is often a failure of many projects to properly record the full range of metadata available. This is largely due to the perceived tedious nature of the metadata recording process and sometimes reinforced by the impression that the data being recorded has no immediate clear and obvious benefit to the overarching aims of that project. Often detailed metadata is only recorded to satisfy the requirement of repositories like the Archaeological Data Service. Contrary to this notion, this paper will explore the concept that by recording metadata in an easily accessible format and integrating it within the visual spatial data generated by a GIS, it is possible to not only produce something that provides immediately tangible results but also produces the means by which a thorough exploration of data integrity can be easily achieved. The grading of data between that which can be deemed empirically precise and that which could at best be described as 'fuzzy' plays an important role in the successful integration of data from a wide-ranging set of disciplines. It is hoped that this paper will show that by making the process of accessing and cross-referencing the metadata from these disparate sources for specialist and non-specialist alike it is possible to holistically substantiate arguments regarding the relative validity and value of data sources within the project.

Ullrich B., R. Freibothe, R. Kniess, H. Zoellner. *Challenges and solutions of GPR-surveys in urban areas of Rome, Jeddah and Athens*.

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Impressive results from recent Ground Penetrating Radar (GPR) surveys show the great potential of this geophysical survey method to detect subsurface remains of human activities in the past. Newly available multi-channel and array technologies push the boundaries of spherical resolution and efficiency of GPR surveys. They also produce huge datasets, which can be used for vivid virtual reconstructions of detected buried remains. However, these sensational results are mostly achieved under ideal circumstances in easy accessible, minimally disturbed, and golf course-like (or archaeological park) environments. In contrast, GPR surveys of urban research areas pose great challenges to the entire workflow from the geophysical and topographical survey and data processing to the archaeological interpretation of data. This paper discusses these challenges and their specific solutions, highlighting three recent GPR surveys carried out by Eastern Atlas in densely built modern metropolitan areas in the Mediterranean and the Near East.

The Campidoglio project in Rome, directed by Prof. C. Parisi Presicce (Musei Capitolini) und Prof. Dr. O. Dally (DAI, Rome) in cooperation with the Sovrintendenza Capitolina ai Beni Culturali started in 2018. The GPR surveys aim to map the architectural remains of the sanctuary of Iuppiter Optimus Maximus as well as the medieval use of the Capitoline hill after the sanctuary was abandoned. As everywhere in the eternal city of Rome, these surveys examine an extremely heterogeneous underground. Various phases of human impact altered the subsoil and with it the local physical properties – as is the case in all here presented case studies. Furthermore, the varying surface conditions at the Campidoglio, including asphalt roads, compacted gravel paths, and post-medieval parks affect ground coupling. The wave propagation in the ground is influenced by recent pipes and supplies of variable depth, size and materials as well as levelled topography of different parts of the natural hill.

The recent research project in Historic Jeddah, the Gateway to Makkah, is directed by Eng. S. Nawar (MOC-Ministry of Culture, Kingdom of Saudi-Arabia) and focuses on the old town of Al Balad. The very lively, densely built historic centre spreads out over 70ha and is characterized by more than 350 historic buildings. The possibilities for large GPR-survey are severely limited by the irregular alleyways between the high historic buildings. One of the greatest technical challenges is the positioning of the GPR-data, as GNSS reception is not possible in the narrow streets. Therefore, alternative positioning systems using robotic total station and survey wheel data have to be adopted to obtain cm-accuracy.

The new research project in Kontopigado, south of Athens (Greece), conducted by Dr. R. Jung and Dr. E. Kardamaki (OREA-Institute for Oriental and European Archaeology, Vienna, Austria) in cooperation with K. Kaza-Papageorgiouis focuses on a Mycenaean industrial area which was partly excavated before the Athens metro station Alimos was built. GPR surveys were executed to gain information on the surroundings of the known workshop area in sloping terrain. Here, too, the above-mentioned challenges of variable surface materials were encountered on roads, unpaved areas and sportsgrounds. Moreover, the reconstruction of the exact elevation levels of the detected remains is essential for a precise interpretation of the workshop elements. The recognition of very shallow pits in 3d-datasets incorporating several meters of topography requires a detailed reconstruction of ancient and modern surface levels, combining all available data of the former excavations, new topographical surveys, and the depth of processed GPR-data.

Wilson A. S.[1], A. Walker[2], C. Gaffney[1], T. Sparrow[1], J. Moore[1], S. Simpson[2], J. Ritchings[2]. *Virtual Bradford*.

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'Virtual Bradford' will be an open BIM LOD3.0 textured 3D model/ digital twin/ digital clone of the historic inner city of Bradford, West Yorkshire.

It will provide accurate levels of detail for the built environment for use in various strategic priorities for the Council, including urban/ civic planning; improve traffic management; support the modelling of air quality, flood risk and noise pollution; contribute to disaster management planning; and to highlight the heritage of the City and its benefit to enhancing education, tourism and in fostering civic pride. The datasets will be captured using an inhouse multi capture backpack and trike system which uses a combination of mobile laser scanning, GNSS, Structure from motion (SfM) and 360 video. These will be integrated with existing datasets such as aerial lidar to produce a rich and accurate set of 3D geospatial datasets.

These datasets will provide the framework and foundation for further digital documentation of important historical sites, buildings, and artefacts, to open Bradford's Heritage to the world (Bradford 2025 - City of Culture bid; linkage to Bradford UNESCO City of Film) through development and promotion of virtual-tourism that explores our cultural value and allows us to connect the past with future generations. This will create resilience around tourism in the district, including COVID recovery, but also to irreparable damage such as fire (e.g., Notre-Dame, Glasgow School of Art). This is led by Adrian Walker, Sydney Simpson and Joe Ritchings from Bradford Metropolitan District Council, as a piece of collaborative research with Professor Andrew S. Wilson, Professor Chris Gaffney and Tom Sparrow at the University of Bradford, using expertise in geospatial research, imaging and visualisation developed within 'Visualising Heritage'. The work is linked to extant funded activity between the University and Bradford Council through the EU SCORE project.