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Rome: NE slopes of the Palatine hill. Analysis and quantification of ancient architectures

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***Abstract* – The NE slopes of the Palatine and the Colosseum valley area have been the place of a long archaeological research; here the continuous urban development produced an overlap of architectural complexes distributed over time. The huge amount of archeological documentation elaborated by the research is managed by a data management system. For ancient walls analysis we have introduced the use of image-based-modeling photogrammetry in order to create a very detailed 3D documentation linked to a DBMS dedicated to ancient structural features. Through this methodology we can evaluate specific aspects of the ancient construction yards for each period; we can also refine the chronological sequences of the architectures and verify the contextual relationships of the surrounding buildings in order to formulate wide-ranging reconstructive hypotheses.**

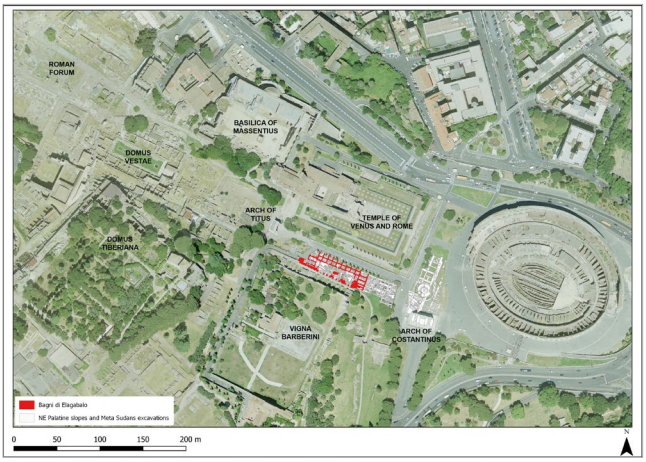

Fig. 1. The research area in the centre of Rome: general map of excavations in a rectified aerial photo.

I. INTRODUCTION AND ARCHAEOLOGICAL FRAMEWORK

The area of the north east slopes of the Palatine hill that faces the Colosseum valley has been the subject of a long archaeological research since 1986, carried out by the Department of *Scienze dell'Antichità* of "*La Sapienza"*, University of Rome. During more than 30 years of excavations, the material remains of major building and monumental interventions have been unearthed, testifying an environmental and topographical *continuum* where the development of diversified urban systems has involved a complex physical overlap of structures and architectural complexes distributed over time [1].

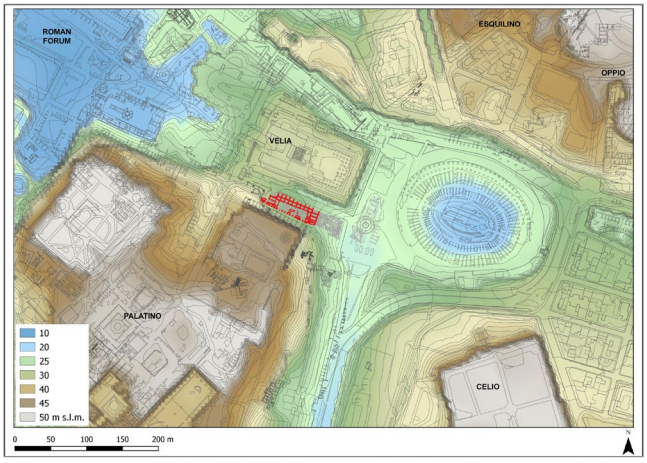

Fig. 2. DEM of the research area

Starting from the remains of Iron Age huts, found along the slope, we move on to an early urban planning witnessed by the presence of two sanctuaries dating to the Roman Kingdom (8th-7th century BCE) located along both sides of the ancient road leading to the Forum: one of them can be identified with the *Curiae Veteres* and has been frequented until the affirmation of Christianity.

The installation of a residential district, along the road, is documented already during the archaic period: subsequently this area has been periodically rebuilt in the following centuries, until Augustus age. In this period, at the meeting point of five of the new 14 city zones planned by the emperor, the first *Meta Sudans* fountain was built, in front of the *Curiae Veteres* which were also reconstructed in monumental shape during the years of the emperor Claudius. The real break-up here happened

in conjunction with the great Nero's fire: after this disaster Nero decided to carry out in this area a deep urban transformation that would end with the realization of his majestic palace, the *Domus Aurea.* In the years between 64 and 68 CE a total reorganization of the road system was made, with a regular and orthogonal shape according to the guidelines dictated by the palace project. In the Colosseum valley the new architectural complex was characterized by columned porticoes around an artificial pond over which the flavian dynasty later will build the amphitheater; the Palatine hill slopes were regularized by artificial terraces on arcades while the new climbing way to the *Forum* was flanked by arched porticoes. The urban planning of flavian emperors, focused on restoring a public dimension to the urban spaces occupied by *the Domus Aurea,* can be emblematically summarized in the reconstruction of the *Curiae* and of the *Meta Sudans* fountain, both burned in the fire. The area will be modified again by Hadrian with the construction of the Venus and Rome Temple and, on the other side, a of a long building flanking the porticoed street going to the Forum. After another catastrophic fire, at the end of the 2nd century CE the area was rebuilt again by the severian dynasty: in close connection with the new monumental project for the plateau of Vigna Barberini, the whole front of north east Palatine's substructures was heavily transformed while the constructions at its feet were completely dismantled and replaced by a new building with courtyard, commonly called "*Bagni di Elagabalo"*. Inside this monument, in the 4th century CE, a large banquet hall was obtained, with gardens and fountains and a small bath in the backyard. Finally, with the construction of the Constantine's Arch and the restorations at the Venus and Rome Temple the ancient urban history of the area was completed [2].

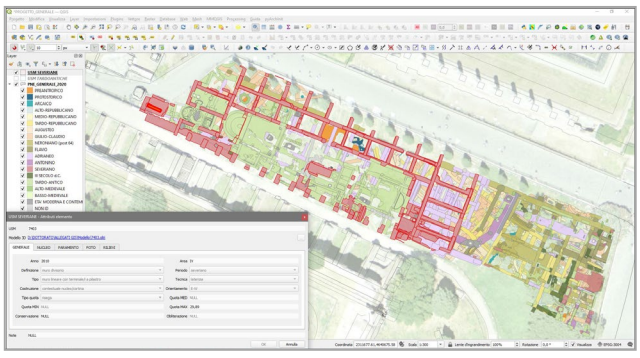

Fig. 3. Intra site GIS: written data management

The huge amount of documentation produced in front of such a complex stratigraphic sequence required the development of a data storage and management system, dedicated to contextualize information and capable of proposing new elements useful for research. The entire archive is therefore managed by an *intra-site* GIS (designed since 2001), used for data-retrieving, spatial analysis and for the elaboration of archaeological themes and/or reconstructive models. Over the years this system has been implemented in software, for the advent of new IT products, and in the stored contents: in our spatial database, today, digital and analogical documentation (in particular handmade archeological detailed drawings and on-paper archaeological forms) are managed together, in order to maintain the integrity of the research archive and its history [3]. To have the best results in this operation a memorandum of agreement has been approved by the *Sapienza*, University of Roma, the *Kore* University of Enna and the *I.S.P.C.-C.N.R.* (Institute of Sciences for Cultural Heritage of National Council of Research), institution that since 2007 has collaborated with the archeological research carried out at the Palatine hill and the Colosseum valley, in particular in 3D surveying and integrated geophysical prospecting [4]. During these years a big amount of raw data has been preserved in two different repositories, while only final elaborations were shared by the research group: now it's our intention to unify the separate archives in a single spatial database, for investigation purposes but also for deontological instances in order to leave a complete and single testimony of all activities carried out in this important archeological place site during these decades.

E.B.

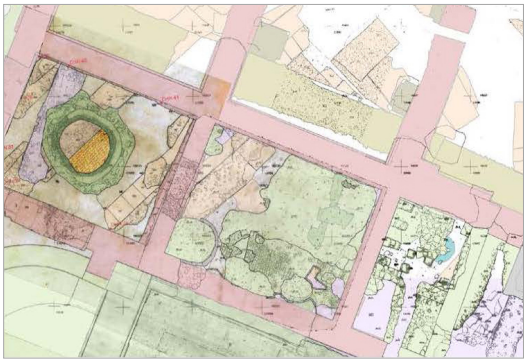

Fig. 4. Intra site GIS: old graphic data management

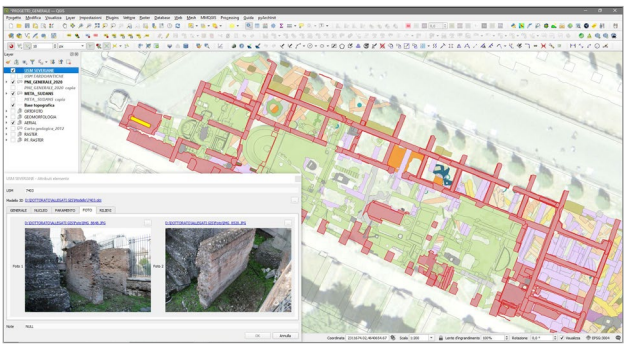

Fig. 5. Graphic and photographic data management

II. METHODS AND TOOLS

The study of ancient architectures today can adopt survey tools able to detect objects in 3D with a certain precision and quickly: through these tools we have produced ortho-photo-plans that, gradually, have joined the traditional 2D documentation but we have also proposed three-dimensional sequences of excavated stratigraphic sequences as well as the reproduction of some ancient artifacts, suggesting their virtual-digital restoration. In the study of ancient walls, the use of new *image-based-modeling* photogrammetry techniques based on *Structure From Motion* (having accuracy and photographic texturing) brought us to the realization of a new very detailed 3D documentation of the ancient walls [5].

The new documentation included also a DBMS recording updating the usual formats for ancient structural features following the guidelines suggested by the "archeology of construction" and by the "archaeology of architecture" [6].

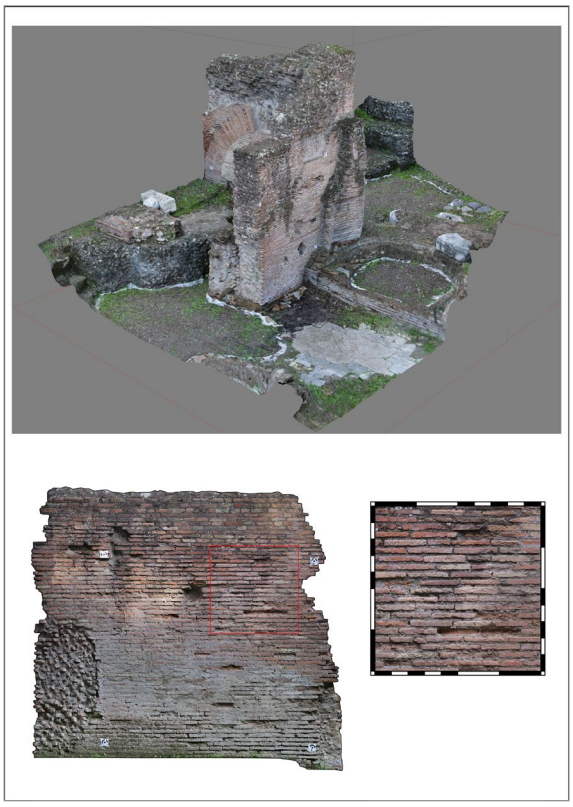

Fig. 6. Digital photogrammetry of ancient walls

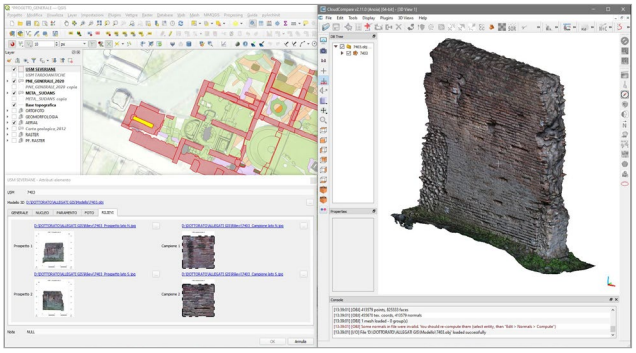

Fig. 7. GIS management of digital photogrammetry and walls sampling

We have planned a new file-card format dedicated to register information about the logistic of the ancient construction yards and the related dynamics on material production and ancient building organization, in addition to data relating to their measures, composition and nature. In this way the chrono-typological analysis, which traditionally focuses on the recognition of the single construction features by material aspect, has been expanded with the collection of information related to building methods such as, for example, structural expedients for static stability, specific materials selection in relation to particular needs or quantification of the work in terms of time and number of the workers.

Defining trends, measures and treatments of specific building materials can help us to identify diachronically the processes and resources of the ancient construction yards, while the stratigraphic analysis of the walls, with its identification of constructive temporal sequences, is crucial to understand the formative dynamics of the ancient architectures and must be done through observation of details on the basis of a precise and clearly legible survey. Obviously, in order to normalize the data entry and editing, we have encoded standard glossaries while the detailed morphometric information, derived from autoptic analysis of samples taken from wall facades (normally their size is 1 square meter), is managed by sub-cards where each "constituent" (i.e. brick, block, etc.) is organized by type, use/reuse, material, manufacture, finishing, and measures.

Starting from these assumptions, the analysis of ancient architecture was carried out with a workflow that, as usual, started from the autopsy analysis and survey of each wall.

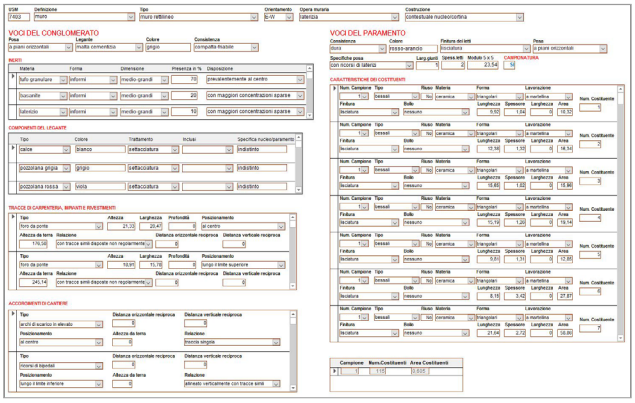

Fig. 8. DBMS for ancient constructions data

Elaborations from photogrammetry have been subjected to a vectorization process and subsequently inserted into the general spatial archive in GIS. For this purpose, next to the module dedicated to the analytical database of the ancient walls, a new apparatus has been created for the collection of all the data relevant to the documentary base. Here, photographs, 3D models acquired from scratch, sections and elevations, drawings and all the graphic documentation produced during the excavations, have found their place. In this way, through a simple query, it is possible to trace the whole corollary of raw and elaborated data that constitute the starting point for the analysis of each context.

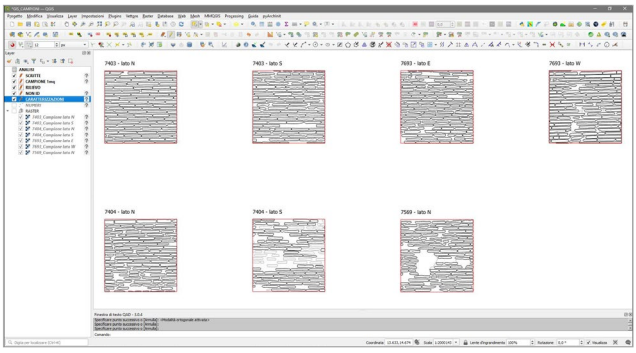

Fig. 9. Vectorization and quantification of ancient walls samples

For the quantifications of information coming from wall-facades-samples we have performed differentiated GIS analysis procedures, comparing the DBMS data taken directly on the field (counting bricks and measures on wall facades) and those obtained automatically on spatial vector drawings made on very detailed orthophotos; these measures were taken on the same sampled wall-facades but in different way: despite the different tools and procedures the results were indeed very similar, giving us a good indicator of a correct method.

Through a series of expressions specifically prepared, it is also possible to calculate automatically and expeditiously the variable of the constituent / conglomerate ratio, but also the dimensions of the components of the facades with their degree of homogeneity and variability [7].

L.F.

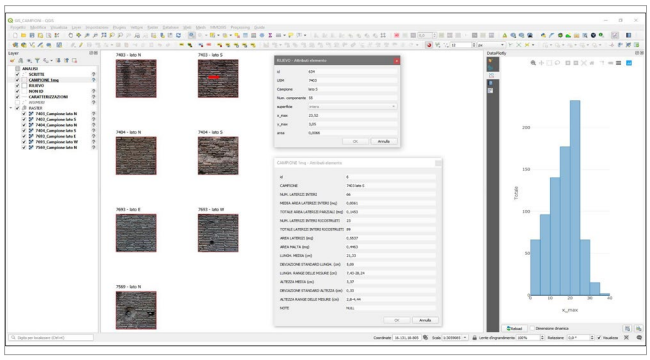

Fig. 10. Data analysis and evaluation.

III. CONCLUSIONS

Through the methodologies and tools described above it is now possible to evaluate specific aspects of the ancient construction yards for each period, such as the extent of resources supply, the reuse index and building materials selection level and consequently refine the chronological sequence of the construction phases of the individual buildings.

Furthermore, being able to have such a complex sequence of building interventions and referring to buildings of both public and private character, it is possible to plan a comparative analysis of the construction techniques adopted in relation to both chrono-typological aspects and to particular contingencies.

Finally, we have a bigger chance to clarify the structural and contextual relationships of each construction yards with the surrounding buildings, in order to formulate wide-ranging and multi-temporal reconstructive hypotheses.

Some first outcomes of our work can be briefly exposed here.

First of all, our “very-close-range” photogrammetry approach to structural archaeological evidences, using very high definition shoots and supported by total station, with automatic measurement of vectorial features, has given results very encouraging if compared to measures directly taken, with a tape and one by one, on the ancient walls: the dimensions of bricks and other building components of the archaeological structure are always almost the same in both cases and mismatches are very few and very little.

In addiction the colours and the type of materials can be clearly distinguished.

This means that a mensio-chronological approach using this method can be correct; obviously a total analysis of building materials and their treatments (specially for mortars, concretes and conglomerates) still needs a direct autopsy, physical and material, of archaeological evidence.

Another result, which will be better studied during future research, is of architectural nature and concerns the accentuate reuse of building materials during the severian age which, compared to the topographical context (we are next emperor's palace in Rome) and the chronology (generally this building practice in the Capital is peculiar of late antiquity), seems to be an avulsed phenomenon.

However, as already detected here by previous study of brick stamps found *in situ* which show the use of Hadrian's bricks in severian masonry [8], our overall analysis of the walls belonging to this period seems to confirm a very accentuated use of fragmented and heterogeneous bricks that do not seem to be of new manufacture but recovered from older structures.

This recovery was probably facilitated by the state of the rubble after the fire of 192 CE and by the fact that the brick facades were covered with decorative layers and surfaces.

In conclusion we want to stress that our research was also focused on giving access to the scientific community and interested people not only to the data but also to the analysis system itself: paying great attention to the issues of open-data and ArcheoFoss we have tested the migration of the entire dataset and its interrogation criteria and tools on an open source GIS platform [9].

Here, starting from the general site map, it is possible to decompose the single architectures into their structural contexts and features and verify the cognitive process for each one of them: passing from photos to 3D models, then to elevations, wall-samples up to the general synthesis of file-cards and records of ancient structures.

E.B. and L.F.

REFERENCES

[1] We want to thank all the staff of the *Parco Archeologico del Colosseo (MIBACT)* for the permission and support to our work, in particular Dr. Giulia Giovanetti. For a general archaeological framework see C. Panella (ed.), "*Meta Sudans I*. Un'area sacra in *Palatio* e la Valle del Colosseo prima e dopo Nerone", Roma, 1996; C. Panella (ed.), "I segni del potere. Realtà e immaginario della sovranità nella Roma imperiale", Bari, 2011; C. Panella (ed.), "Scavare nel centro di Roma. Storie uomini e paesaggi", Roma, 2013; E. Brienza, "Valle del Colosseo e pendici nord-orientali del Palatino. La via tra valle e foro: dal dato stratigrafico alla narrazione virtuale (64 d.C.-138 d.C.)", Roma, 2016.

[2] For more detailed information on the different phases see L. Saguì, M. Cante, F. Quondam, "Le Terme di Elagabalo. I risultati delle ultime indagini", Scienze dell'Antichità 20, 2014, pp. 211-230; C. Panella, S. Zeggio, A. F. Ferrandes, "Lo scavo delle pendici nord-orientali del Palatino tra dati acquisiti e nuove evidenze", Scienze dell'Antichità 20, 2014, pp. 159-210; L. Saguì, M. Cante, "Archeologia e architettura nell'area delle Terme di Elagabalo, alle pendici nord-orientali del Palatino. Dagli isolati giulio-claudii alla chiesa paleocristiana", Thiasos 4, 2015, pp. 37-75; C. Panella, A. F. Ferrandes, G. Iacomelli, G. Soranna. "Curiae Veteres. Nuovi dati sulla frequentazione del santuario in età tardo-repubblicana", Scienze dell'Antichità 25v vol.1, 2019, pp. 41-71.

[3] E. Brienza, "Un GIS Intra Site per la valle del Colosseo: concetti, metodi, applicazione", Scienze dell'Antichità 13, 2008, pp. 123-139; C. Panella, E. Brienza, "Il geodatabase della valle del Colosseo e del Palatino nord-orientale ed il trattamento digitale del dato archeologico", Bollettino della Società Italiana di Fotogrammetria e Topografia 3, 2009, pp. 9-18; C. Panella, M. Fano, E. Brienza, "Dallo scavo alla valorizzazione: l'esempio della valle del Colosseo delle pendici nord-orientali del Palatino", Proc. of 2nd SITAR - Sistema Informativo Territoriale Archeologico di Roma, 2013, pp. 145-189; C. Panella, M. Fano, E. Brienza, "30 years of urban archaeology: measuring, interpreting and reconstructing", Proc. of 1st IMEKO International Conference on Metrology for Archeology, 2015, pp. 49-54.

[4] S. Piro, "Indagini Georadar ad alta risoluzione nell'area delle pendici nord-orientali del Palatino, Scienze dell'Antichità 13, 2008, pp. 141-156.; C. Panella, S. Piro, S. Zeggio, E. Brienza, Indagini geofisiche ed archeologiche in area urbana. Il caso delle pendici orientali del Palatino, Proc. of. "Geofisica per l' Archeologia. Possibilità e limiti, 2008, pp. 117-124; C. Panella, R. Gabrielli, C. Giorgi "Le Terme di Elagabalo sul Palatino: sperimentazione di un metodo fotogrammetrico 3D applicato allo scavo archeologico", Archeologia e Calcolatori, XXII, 2011, pp. 243-260; C. Giorgi, "Terme di Elagabalo. Il balneum tardoantico: studio archeologico e rilievo 3D" in C. Panella, L. Saguì (eds.), "Valle del Colosseo e pendici nord-orientali del Palatino. Materiali e contesti 1", Roma, 2013, pp. 55–86.

[5] About these techniques see M. Russo, F. Remondino, G. Guidi, "Principali tecniche e strumenti per il rilievo tridimensionale in ambito archeologico", Archeologia e Calcolatori, XXII, 2011, pp. 168-198; F. Remondino, S. Campana. (eds.), 2014, "3D surveying and modeling in archaeology and cultural

heritage. Theory and best practices", Oxford, 2014; S, Bertocci, S. Parrinello, "Digital survey and documentation of the archaeological and architectural sites", 2015, Roma; E. Stylianidis, F. Remondino (eds.), "3D Recording, Documentation and Management of Cultural Heritage", Dunbeath, 2015; D. Tsiafaki, N. Michailidou, 2015, "Benefits and problems through the application of 3D technologies in archaeology: recording, visualisation, representation and reconstruction" in Scientific Culture 1, 3, 2015, pp. 37-45; H. Kamermans, Ch. Piccoli, Ch., W. de Neef, A. G., Posluschny, R. Scopigno (eds.) "The Three Dimensions of Archaeology", Proc. of the XVII World UISPP Conference, 2016, Oxford; J. Zachar, M. Horňák, P. Novaković (eds.), "3D digital recording of archaeological, architectural and artistic heritage", Ljubljana, 2017; F. Bianconi, M. Filippucci, "La fotomodellazione per il rilievo archeologico", Archeologia e Calcolatori, XXX, 2019, pp. 205-228; N. Dell'Unto, G. Landeschi, A. M. Leander Touati, M. Dallepiane, M. Callieri, D. Ferdani, "Experiencing ancient buildings from a 3D GIS perspective. A case drawn from the Swedish Pompei Project", Journal of Archaeological Method and Theory, XXIII, 2016, pp. 73-94; M. Canciani, M. Michelini, M. Saccone, A. Scortecci, M. Zampilli, "Le Mura Aureliane: dal rilievo 3D al GIS", Proc. of Le Mura Aureliane nella storia di Roma. 1. Da Aureliano a Onorio, 2017, pp. 193-207; A.A. Zappani, "Riflessioni sul rilevamento architettonico. I mutamenti indotti dalle tecniche ottiche di misura 3D", Roma, 2017.

[6] S. Camporeale, H. Dessales, A. Pizzo (eds.), "Arqueología de la Construcción I. Los procesos constructivos en el mundo romano: Italia y provincias occidentales", Mérida, 2008; S. Camporeale, H. Dessales, A. Pizzo (eds.), "Arqueología de la Construcción II. Los procesos constructivos en el mundo romano: Italia y provincias orientales", Madrid-Mérida, 2010; S. Camporeale, H. Dessales, A. Pizzo (eds.), "Arqueología de la Construcción III. Los procesos constructivos en el mundo romano: la economía, de las obras", Madrid-Merida, 2012; J. Bonetto, S. Camporeale, A. Pizzo (eds.), "Arqueología de la Construcción IV. Las canteras en el mundo antiguo: sistemas de explotación y procesos productivos", Mérida, 2014; S. Camporeale, J. DeLaine, A. Pizzo (eds.), "Arqueología de la Construcción V. Man-made materials, engineering and infrastructure", Madrid, 2016; G.P. Brogiolo, A. Cagnana, "Archeologia dell'architettura. Metodi e interpretazioni" Firenze, 2012.

[7] M. Medri, V. Di Cola, S. Mongodi, G. Pasquali, "Quantitative analysis of brick-faced masonry: example from some large imperial buildings in Rome", Arqueología de la Arquitectura, XIII, 2016, pp. 1-8; M. Serlorenzi, S. Camporeale, "Anatomia di un muro romano: dati preliminari sullo smontaggio e quantificazione di alcune strutture in laterizio di epoca adrianea dallo scavo di Piazza Dante a Roma, Archeologia dell'architettura, XXII, 2017, pp. 21-33; M. Medri, "Studio dei paramenti laterizi delle Mura Aureliane. 1. Osservazioni generali", Proc. of Le Mura Aureliane nella storia di Roma. 1. Da Aureliano a Onorio, 2017, pp. 41-67; V. Di Cola, "Studio dei paramenti laterizi delle Mura Aureliane. 2. La selezione dei campioni", Proc. of Le Mura Aureliane nella storia di Roma. 1. Da Aureliano a Onorio, 2017, pp. 69-91; S. Mongodi, "Studio dei paramenti laterizi delle Mura Aureliane. 2. Analisi statistica", Proc. of Le Mura Aureliane nella storia di Roma. 1. Da Aureliano a Onorio, 2017, pp. 93-101.

[8] D. Botticelli, "Epigrafia del costruito. Bolli laterizi dallo scavo delle pendici nord-orientali del Palatino (Area IV, anni 2007-2008)" in C. Panella, V. Cardarelli (eds.), "Valle del Colosseo e pendici nord-orientali del Palatino. Materiali e contesti 3", Roma, 2017, pp. 49–96.

[9] On ArcheoFoss, free and open source software for archaeology, and the numerous international workshops organized from 2006 until today see http://archivio.archeofoss.org/.