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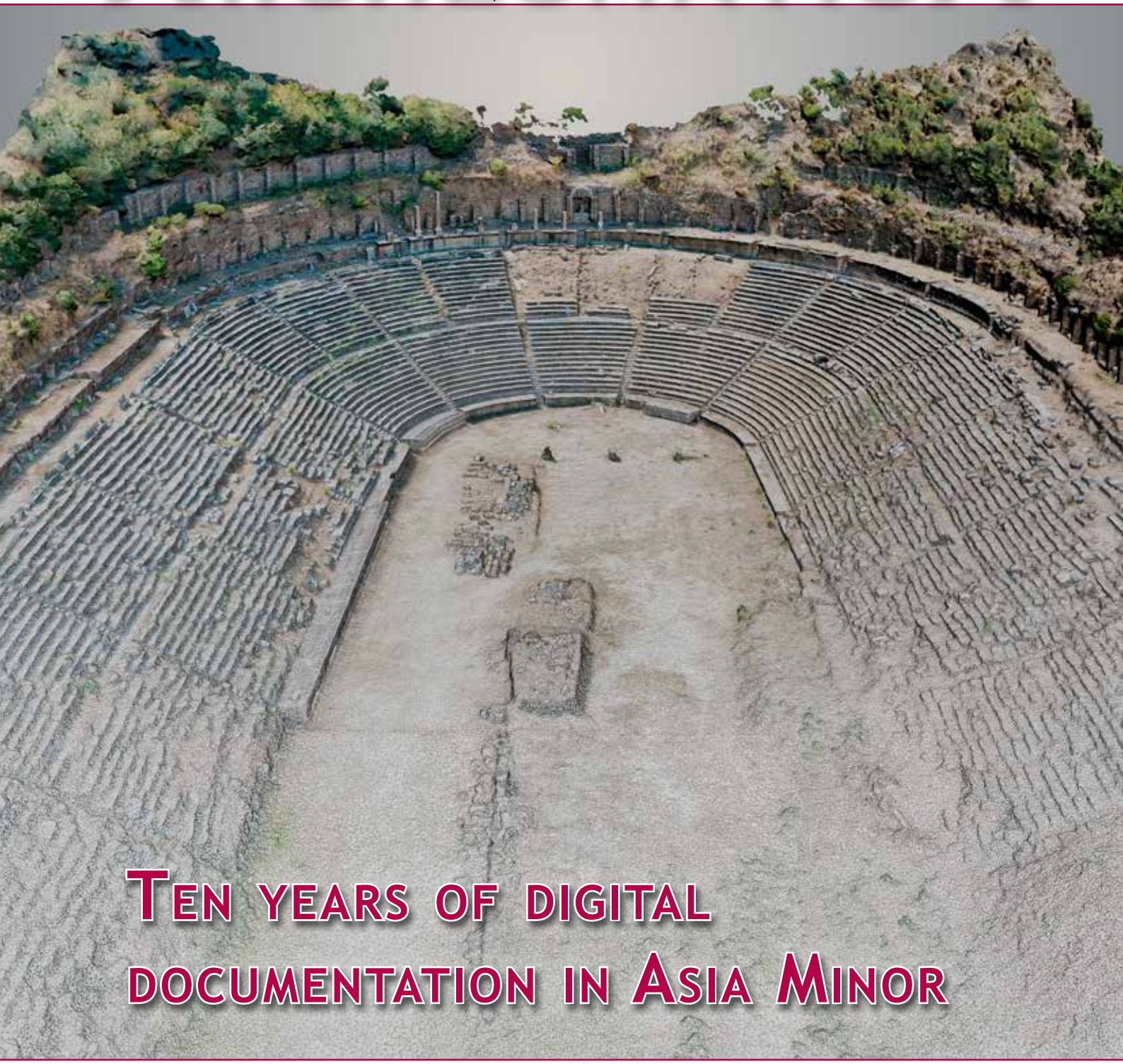

Ten years of digital documentation in Asia Minor

Heritage in Cyprus

Digital Technologies for Archaeology

Urban Digital Survey

METAVERSO

GAMIFICATION

REALTÀ AUMENTATA

SOLUZIONI E SERVIZI
PER LA FRUIZIONE DEI

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RIPRODUZIONE 3D

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xenia
SOFTWARE SOLUTIONS

Ten years of digital documentation in Asia Minor

The Built Heritage always tells the story of the human actions that conceived, constructed, altered, transformed, used, or even demolished it, whether in proper or improper ways. In the brief moment when we encounter a monument, a ruin, or an archaeological site, we perceive the resonance of those intentions and events that have succeeded one another over time in that very place. This is a phenomenon of superimpositions and integrations that has taken shape through an extended temporal process, defined by human choices and natural occurrences, leading to the appearance that these architectures present today. This appearance is itself destined to evolve further. The ability to read and interpret what emerges before our eyes is a complex operation, requiring rigorous preparation, specific skills, and a refined capacity for intuition. Over the past ten years, a sustained effort to promote educational activities dedicated to architecture in its most intricate historical forms, carried out with students (mainly in architectural training), colleagues, and collaborators, has, through both personal circumstances and fortuitous events, led to the collection of a series of experiences in Asia Minor, in contemporary Turkey. These experiences have been grounded in seminars conducted in places of exceptional value and fascination, consistently combining documentation and knowledge acquisition with surveying practices, contemporary technologies, and the active transmission to participants of new abilities in representation, thinking, abstraction, comprehension, invention, and design. All of this has been achieved through interdisciplinary and collaborative approaches, often within limited timeframes, but it is hoped that with meaningful outcomes, capable of embedding what was learned into the future experiences of architects and specialists devoted to the extensive built and artistic heritage encountered in diverse contexts. In this issue of *Archeomatica*, we are pleased to present a collection of excerpts from the workshops held between 2014 and 2025 in contexts of great architectural and urban complexity. All these initiatives share the intent to balance technology, education, and the capacity to produce outputs that serve an intelligent use of knowledge and a deeper understanding of the value of cultural heritage. A crucial transition, therefore, is to view the creation of digital heritage not as a mere mechanical act, but as an opportunity to stimulate, cultivate, and consolidate passion and interest for the specific values embodied in each place, building, and fragment, fostering a productive evolution that bridges experience and culture. In the pages that follow, the proposed itinerary begins on the island of Cyprus, then moves to, and repeatedly returns to, Istanbul, a key hub of exchanges and intersections between historical and architectural periods. It proceeds to more recent explorations of cities in the Hellenistic area and concludes with a reflection on itinerant artistic elements, which are often “restless” components in the Cultural Heritage scenario and that demand particular and attentive consideration.

Enjoy your reading!

Giorgio Verdiani & Alessandro Camiz

SUMMARY

The Stadium in Magnesia at the Meander, Turkey, Photogrammetry by G. Verdiani, A. Camiz and U. Özdemir, 2024.

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ARCHEOMATICA
CULTURAL HERITAGE TECHNOLOGIES
YEAR XVII, N° 3 - 2025

Archeomatica, quarterly published since 2009, is the first Italian magazine for dissemination, promotion and exchange of knowledge on technologies for the preservation, enhancement and enjoyment of cultural heritage. Publishing about technologies for survey and documentation, analysis and diagnosis, restoration and maintenance, museums and archaeological parks, social networking and "smart" peripherals. As a reference point in the field is the sharing media for the industry, the professionals, the institutions, the academia, including research institutions and government agencies.

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Built Heritage in Cyprus

by Alessandro Camiz, Carmine Canaletti and Zeynep Ceylanlı

Fig. 1 - View of the Church in the Acheropoietos Monastery, QR code to a video about the workshop 2014(https://youtu.be/5mGgEla-npc).

The two workshops held in Cyprus in collaboration with the Girne American University and the Ozyegin University, Istanbul, were aimed to the documentation and rethinking of new uses for the historical Built Heritage of the Acheiropoietos Monastery, in 2014, and of the Kyrenia Castle, in 2018. They were the first activities of this kind and showed how teaching, documentation and research can be applied all together in complex cultural heritage environments.

FIRST WORKSHOP IN CYPRUS: ACHEROPOIETOS MONASTERY

The first one was held in the Monastery called "Παναγία Αχειροποίητος" which gets the name from the presence of a sacred icon said to be «made without hands» which was one of the main relics in the church (Enlart, 1899). In this artwork there was the representation of the Virgin Mary, a work which was consi-

dered as created in a "miraculous" way, and thus protected from any possible iconoclasm. The date of its foundation is not known, thus, the katholikon appears to have been built during the XIth or early XIIth century (Canaletti & Camiz, 2016). The first written references to the monastery are no older than the XVth century.The analysis of the building revealed the presence of several consecutive construction phases: for first relevant architecture is a central plan church covered with a dome, probably built in the late-Byzantine period on the ruins of a paleo-Christian basilica, characterized by three-naves, then extended with three narthexes, this transformation changed the general aspect of the plan layout into the one of a longitudinal basilica. The construction of an enclosure wall around the church marked the limits of the monastery, this intervention was done in a series of phases, following a variety of expansions, demolitions and restorations.The monastery settlement is quite isolated from the modern town of Λάμπουσα (Lambousa, the resplendent), and stands on the northern waterfront of Cyprus.

The inclusion of the complex into a military barracks in the Seventies included the transformation of some parts and the addition of service structures. In the analysis made during the workshop, the one on the masonry types was capable in outlining the phases of construction for various parts of the original complex. The church in itself is not suffering from specific structural issues, even if it has lost a large part of internal finishing and artwork, the massive walls and vaults are still capable in showing an articulated layout and interesting architectural features. The situation is a little worse for the northern wing of the monastery, which suffered a heavy structural damage and was stabilized with some scaffholdings.

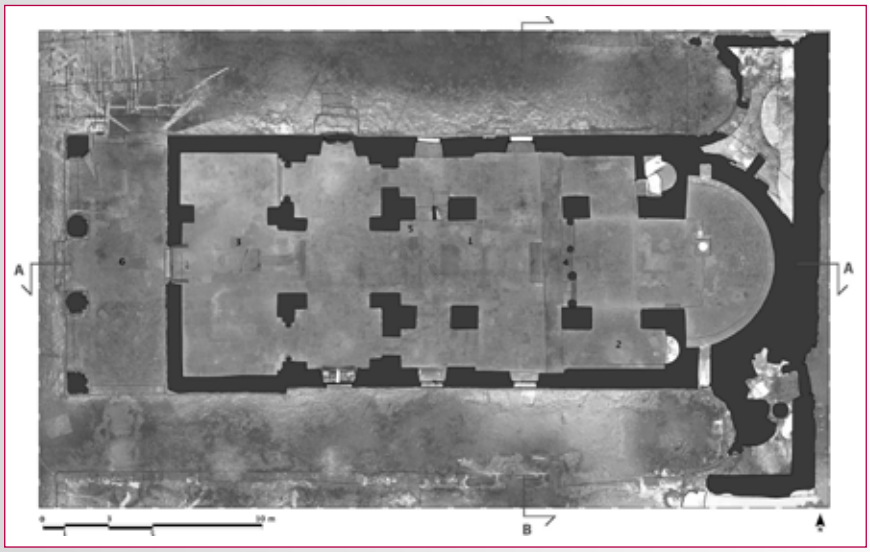

Fig. 2- Plan view of the Church, extracted from 3D Laser Scanner Survey 2018.

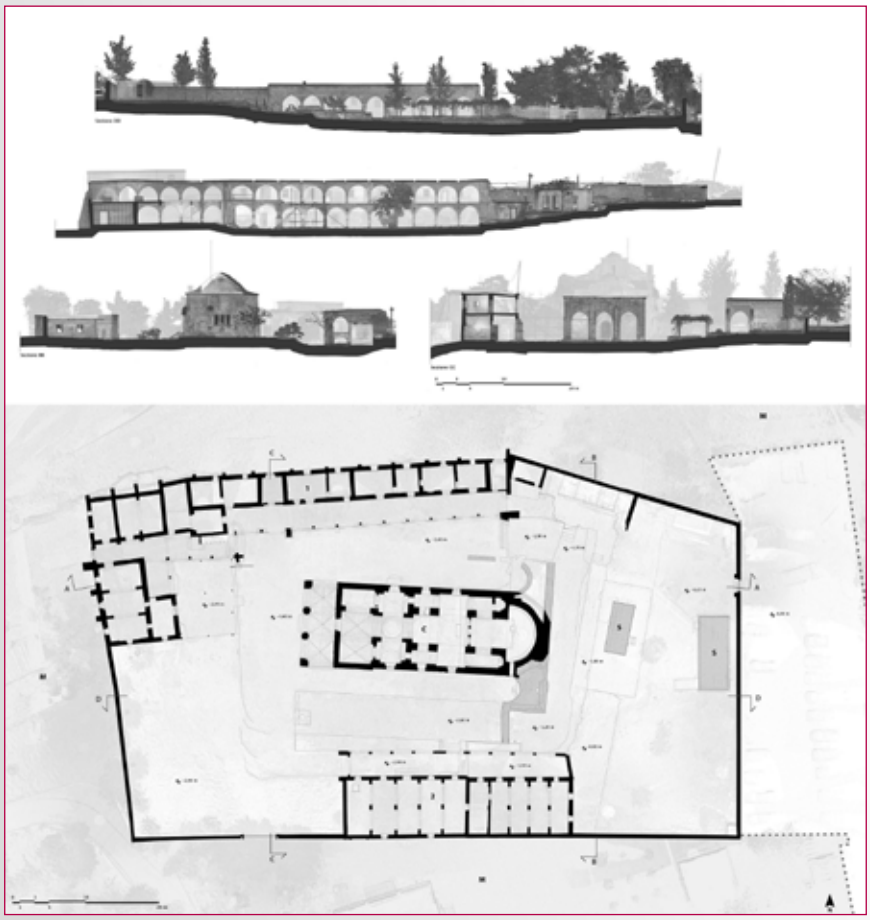

Fig. 3 - Plan view and fronts of the Monastery from 3D Laser Scanner Survey 2018.

Fig. 4 - View from the sea of the Kyrenia Castle and QR code to access a video about the workshop 2018. (https://youtu.be/1MCzjd-de3m8).

SECOND WORKSHOP IN CYPRUS: KYRENIA CASTLE

The second workshop in Cyprus was held in the Kyrenia Castle, which represents the main historical architecture on the waterfront of this area, presenting a very articulated transformation through time, evolving accordingly to the changes in weaponry technologies and the wills of its different owners (Camiz et al., 2016). The Kyrenia Castle shows three main periods of architectural development, representing a significant example of the evolution from a medieval castle to a fortress developed for using and resisting more modern weapons (Scott Petre, 2010). The three periods traceable in the architecture of the fortifications are Byzantine (330-1192), Lusignan (1192-1472) and Venetian (1472-1570) (Enlart, 1899). The special position of this fortification, with its strategic importance, dominating on the seafront, is underlined by archaeological evidence in the castle area, Indeed it Is possible to refer to remains of Roman mosaics and catacombs that suggest the presence of even earlier settlements. To this archaeological presence it is possible to match the "Kyrenia Shipwreck", which is the common name indicating the important finding of a ship from the IVth century BC in the waters in front of Kyrenia (Katzev, 1981). This important relic, representing one of the very first underwater archaeology interventions, is currently visible inside the castle museum (Katzev, 2008).

In both workshop cases, the digital survey intervention was conducted using a Z+F 5006h imager 3D laser scanner unit with the integration of photogrammetries for the most interesting parts and artworks and to give a more complete and detailed consistency to the digitalization of these two architectures. In 2014, the aim was to produce a complete documentation of the religious settlement with a proper level of details, supporting further reading and offering a first complete description of the Church and monastery. In this, the collaboration with the local archaeologists turned out for the most positive results, with an extended sampling of mural stratigraphies then connected to the pointcloud derived from the lasergrammetry and helpful in supporting the construction phase hypothesis.

In 2018, Kyrenia Castle was extensively surveyed with a specific attention to the spaces of relevant historical importance, and with a specific series of photogrammetry on the exhibited hull from the shipwreck and also on a specific mural element. In fact, in the same room where the ancient ship is kept, the top part of the internal wall shows a large part of plaster characterized by a series of graffiti representing ships and boats (Şevketoğlu, 2017). In most of the situations, assigning a date and correctly identifying the ship type in the graffiti is not a simple or certain task. However, as they are often on the walls of a building, on castle cisterns or churches, the building they are made on represents the terminus post quem, the date after which the graffiti was made.

CONCLUSIONS

Therefore, in this case it is possible to give only an estimated date standing in a wide span of time, probably between the XIIIth and the XVIth century. In the same way producing an appropriate photogrammetry of this artwork was quite challenging. The difficult light condition as well as the vibrations coming from the platform giving access to the graffiti required some specific shrewdness for completing a well usable photogrammetry. Following, the resulting

Fig. 5 - Digital 3d models of the shipwreck plaster with and links to access the models in sketchfab.com (https://skfb.ly/6WyRA and https://skfb.ly/oqFIQ) plus a video about the graffiti (https://youtu.be/Yqw1ZrdWH1A).

3D digital model allowed an accurate tool for better studying and visualizing the set of nautical representations exploiting virtual light solutions and then putting in evidence all the traces still existing on the surface of the plaster (Bertocci et al., 2020). In addition to the laser-grammetry survey of the caste, in the 2018 workshop, it was possible to operate a drone flight, which was a significant contribution to the completion and integration of the digital survey. The UAV unit available was a DJI Spark, equipped with a 12 Mp camera, conducting a series of flights and then producing a sub-selection of the best 1303 shots, covering the roofs and almost all the top parts of the walls, making it possible to generate an extensive, accurately detailed 3D model of the entire exterior of the castle and its adjacent area. The workshop in the Kyrenia Castle was the occasion to establish an operative base of knowledge and to gather a significant amount of data about a castle that represents a challenging monument in the Mediterranean scenario. The first digitalization of this fortification is the starting point of a series of studies. In between, a certain number of Master Degree and Specialization Thesis which included the development of an HBIM for some parts of the castle (Capparelli & Camiz, 2019). Among the various studies, a specific attention was addressed to proposals for a new museum, encompassing a strategic restoration plan and the improved display of key artefacts, most notably the Kyrenia Ship and multiple graffiti, supported by contemporary digital and virtual museum technologies (Ceylanlı et al., 2019). The historical value of the subject and the technically advanced intervention, mixed with professional and academic competencies has brought to a high-quality teaching moment, capable of putting in evidence historical values and specific features of a valuable built heritage.

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Abstract

This paper presents two workshops in Cyprus focused on documenting and rethinking the use of historical built heritage: the Acheiropoietos Monastery (2014) and Kyrenia Castle (2018). Using 3D laser scanning, photogrammetry, and UAV surveys, the projects revealed multiple construction phases, structural features, and historical layers. Special attention was given to the Kyrenia Shipwreck and wall graffiti. The resulting digital models supported architectural analysis, conservation strategies, HBIM development, and museum enhancement proposals. These workshops demonstrate how interdisciplinary approaches and advanced digital methods can effectively study, preserve, and valorize cultural heritage.

Keywords

HBIM; Kyrenia Castle; 3D Laser Scanning; Photogrammetry; Digital Survey, Acheiropoietos Monastery; Conservation;

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Urban digital survey in Galata/ Beyoğlu: remains of the genoese walls and of a Caravansary/Bazar

Fig. 01 – Views from the Caravansaray and drawings with orthophotos from the digital survey.

by Roberta Spallone,
Marco Vitali, Doruk Peker,
Silvia Michelon

A multidisciplinary investigation of Galata's waterfront that combines archival and cartographic research, architectural-historical study, stratigraphic urban analysis, and advanced metric digital surveying. By linking diachronic urban transformations to the physical evidence of surviving walls and structures, the work constructs a coherent narrative supporting conservation, interpretation, and public dissemination — an experience presented and discussed during the International Urban Design Workshop.

Galata, also known as Beyoğlu or Pera, is one of Istanbul's oldest and most stratified districts, it preserves a multilayered historical texture, a key aspect for understanding the urban palimpsest of the Golden Horn. The International Urban Design Workshop "Urban Façade: Istanbul Waterfront" took place from March 23rd to 30th, 2019, at the Faculty of Architecture and Design, Özyeğin University in Istanbul. The workshop was coordinated by Alessandro Camiz and Giorgio Verdiani in collaboration with the Italian Universities of Parma, Rome "Sapienza", Naples "Federico II", Firenze, Dipartimento di Architettura, Politecnico di Torino, Dipartimento di Architettura e Design, and Università Mediterranea in Reggio Calabria, the workshop focused on the architectural survey, analysis, and redesign of selected blocks along Galata's waterfront (Dixon, Verdiani, Cornell, 2017). The workshop's concept was not to teach the participants about design transformations

as arbitrary architectural objects but bringing them to see the urban elements as living organisms within the continuous formation of urban tissues (Camiz, Carlotti, Díez, 2017). The studied area represents an important connection between the seafront and the historic sectors in Galata; it acts like Istanbul's "urban façade" towards the Golden Horn (Cuneo, 1987).
The workshop addressed issues of contemporary Istanbul, such as the replacement of traditional urban tissues with new constructions offering globalized market and generic features (Verdiani et al., 2019). Urban growth demands substitution of building types, this is a certainty in any human settlement in any age, thus, recent interventions have often erased traditional structures, disrupting continuity with the past, and inserting alien typologies or even gross in-style replicas into consolidated contexts (Dallegio D'Alessio, 1946). The teams in the workshop were guided in distinguishing between two modes of transformation: one based on evolutionary systems, considered coherent with a diachronic urban process, and a disruptive one, aimed at a shifting in the development of creative contrasts with the existing context (Caniggia, Maffei, 1979). The raw data collected during the fieldwork formed the empirical basis of subsequent studies, despite occasional local opposition. The campaign proved successful in documenting the built heritage and fostering further research, including master's theses by Doruk Peker

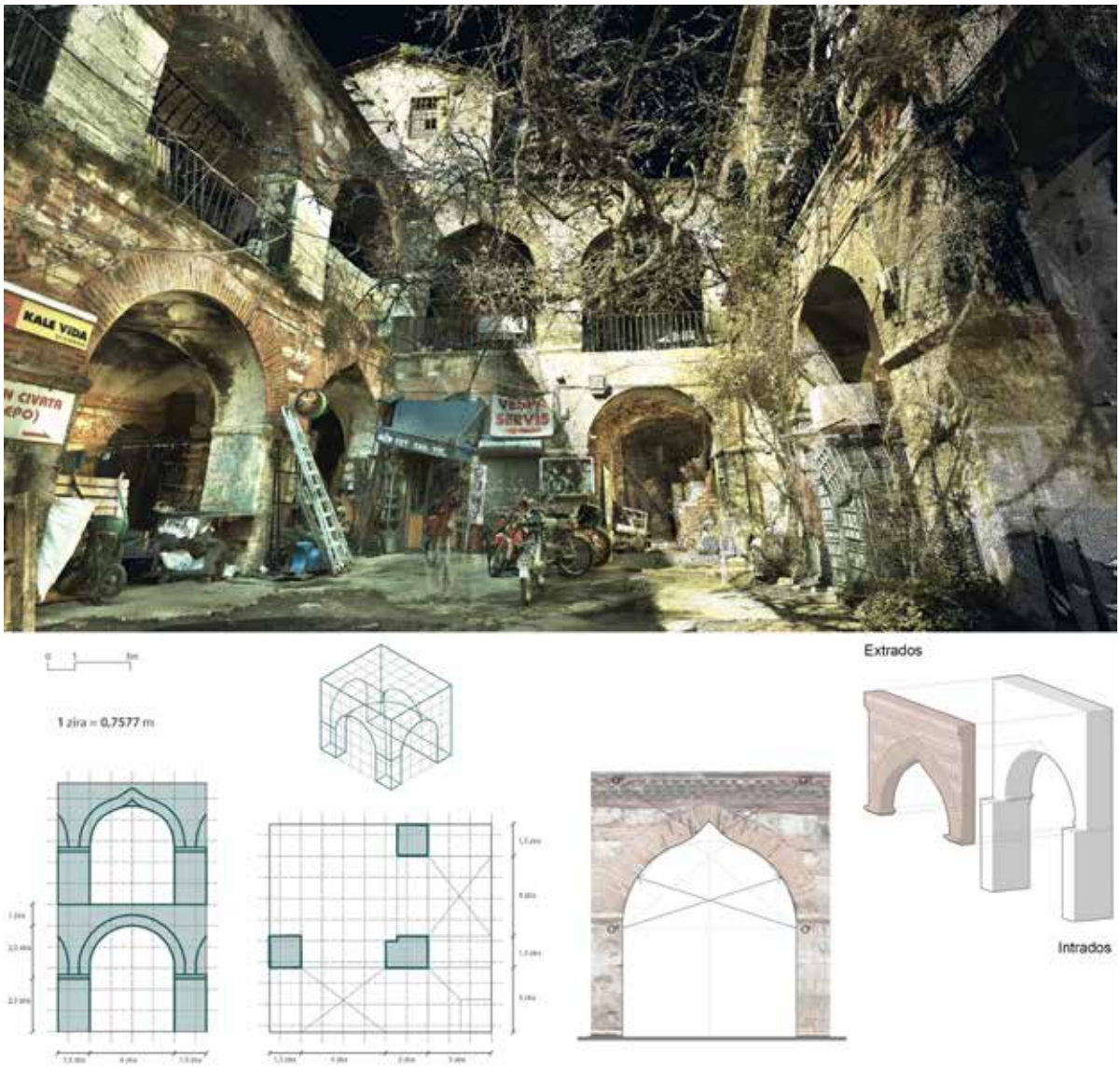

Fig. 02 – View of the point cloud from the Caravansaray and geometrical analysis of its recursive arch (S. Michelon).

(Politecnico di Torino, supervisors R. Spallone, A. Camiz, M. Vitali) and Silvia Michelon (University of Florence, supervisors G. Verdiani, A. Camiz). These works deepened the analysis of Galata's defensive towers, the Beyoğlu urban system, and the Caravansary/Bazaar (Bordini, Cottini, 2019). The interdisciplinary approach combined archival and cartographic research, architectural-historical analysis, stratigraphic reading, and advanced metric surveying, linking diachronic urban transformations to the physical evidence of walls and related structures, ultimately forming a coherent narrative supporting conservation, interpretation, and public dissemination.

URBAN TRANSFORMATIONS OF GALATA/BEYOĞLU

The topographical knowledge of Constantinople and its adjunct settlements is quite fragmentary, and the genesis and morphological evolution of Galata/Beyoğlu (identified in the "Notitia Urbis Constantinopolitana" as Regio tertiadecima) remain only partially reconstructed. While the Ottoman epoch of Galata is documented, earlier chronological stages rely on more limited evidence. Historically significant contributions include Dallegio D'Alessio's 1946 reconstruction, Paolo Cuneo's analyses (1983–1987), and recent studies on the Genoese presence (Saĝlam, 2018). Wolfgang Müller's cartographic proposals (1993) emphasize the Genoese walls as mainly Byzantine, a perspective partially echoed by Dewing's (2015) depictions that retain the Galata Tower (erected under Genoese administration in 1348) as the most identifiable medieval landmark. The diachronic reconstruction hypothesizes successive phases: the initial Megarean colony, the Roman expansions under Constantine and Honorius, and the later Justinian urban reforms. Corroborating evidence derives from sparse documentary sources, archaeological indicators (mostly hydraulic infrastructures) and orientation analysis of current urban patterns. The integration of these data permitted the production of a working topographical model localising primary components of the Roman and Byzantine settlement system in the Galata area, framing the fortifications within a broader urban evolutive trajectory.

DIGITAL SURVEY OPERATIONS

Documenting fragmented and altered fortifications requires meticulous planning to guarantee precision, comprehensiveness, and interoperability of results. The metric campaign adopted a Leica Geosystems ScanStation C10 3D Laser Scanner (time-of-flight), a unit with a declared working range up to 300 meters and point accuracy in the order of a few millimetres at short distances (Bini & Bertocci, 2012; Bianchi et al., 2016). The scanner records a full panoramic sweep, producing point clouds whose density was configured to roughly one point per centimetre at a 10 metres working distance for the majority of scan stations. The device's integrated imaging system captured photographic data for colour-mapping the point cloud without introducing parallax distortions, enabling better reading of the fronts in their overlays and material identification, rendering masonry, metal fixtures, fissures, voids, and displaced fragments with high visual fidelity. The overall scanning time took three days, covering an area of about 40.000 square metres with 98 scan stations, gathering about one billion of points. For the specific subject of the towers the fieldwork comprised 40 scans: 14 stations concentrated around the first tower (formerly subjected to industrial use), 10 taken from a distance around the second (which was at that time in complete abandon and without any possible direct access), 15 within the sector where recent building additions and a restaurant about the wall was still allowing interesting parts of original masonry work to emerge, and one elevated rooftop scan to enhance inter-sessions alignment. Restricted access and hazardous conditions prevented comprehensive interior scanning; however, exterior apertures and partial interior surveys permitted metric estimations of wall thickness and notable internal features. Data alignment exploited long-range tie features, including the Galata Tower and other distant rooflines, to integrate sectorial point clouds into a coherent global model suited for CAD-based restitution using Autodesk Recap and AutoCAD.

The focal artifact is the second tower located southwest of the Galata Tower: a U-shaped plan of approximately 9.80×7.70 metres and a height near 16 metres. The circular facade confronts a northern courtyard (currently a parking area), while the southern side intersects the city wall

adjacent to the local St. Peter's Church. Observational evidence indicates foundational contact with bedrock, attributable to historical soil lowering that gradually exposed foundational elements. Surface traces, remains of plaster, and imprinting phenomena attest to successive additions and demolished adjacent structures; presently, a marginal warehouse remains adjacent to the southwestern facade. Successive inappropriate adaptations (fenestration insertions, intermediate floor insertions, non-original claddings) have undermined structural coherence, generating cracks, projection of beams, and other deterioration signs. The absence of a weatherproof roof accelerates material decay. Given the incomplete internal metric data, interpretative restitution relied on the synthesis of the lasergrammetry taken

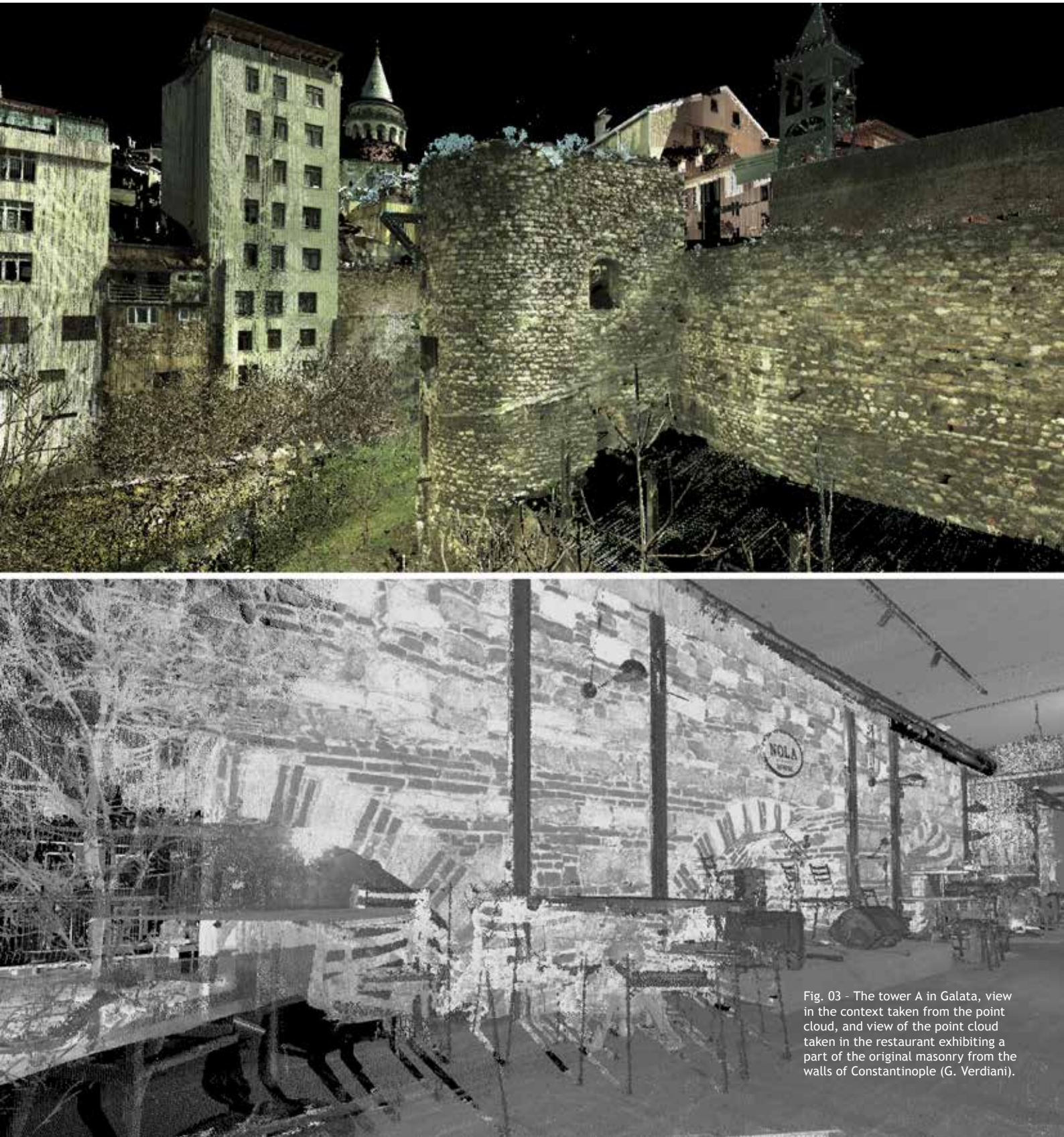

Fig. 03 – The tower A in Galata, view in the context taken from the point cloud, and view of the point cloud taken in the restaurant exhibiting a part of the original masonry from the walls of Constantinople (G. Verdiani).

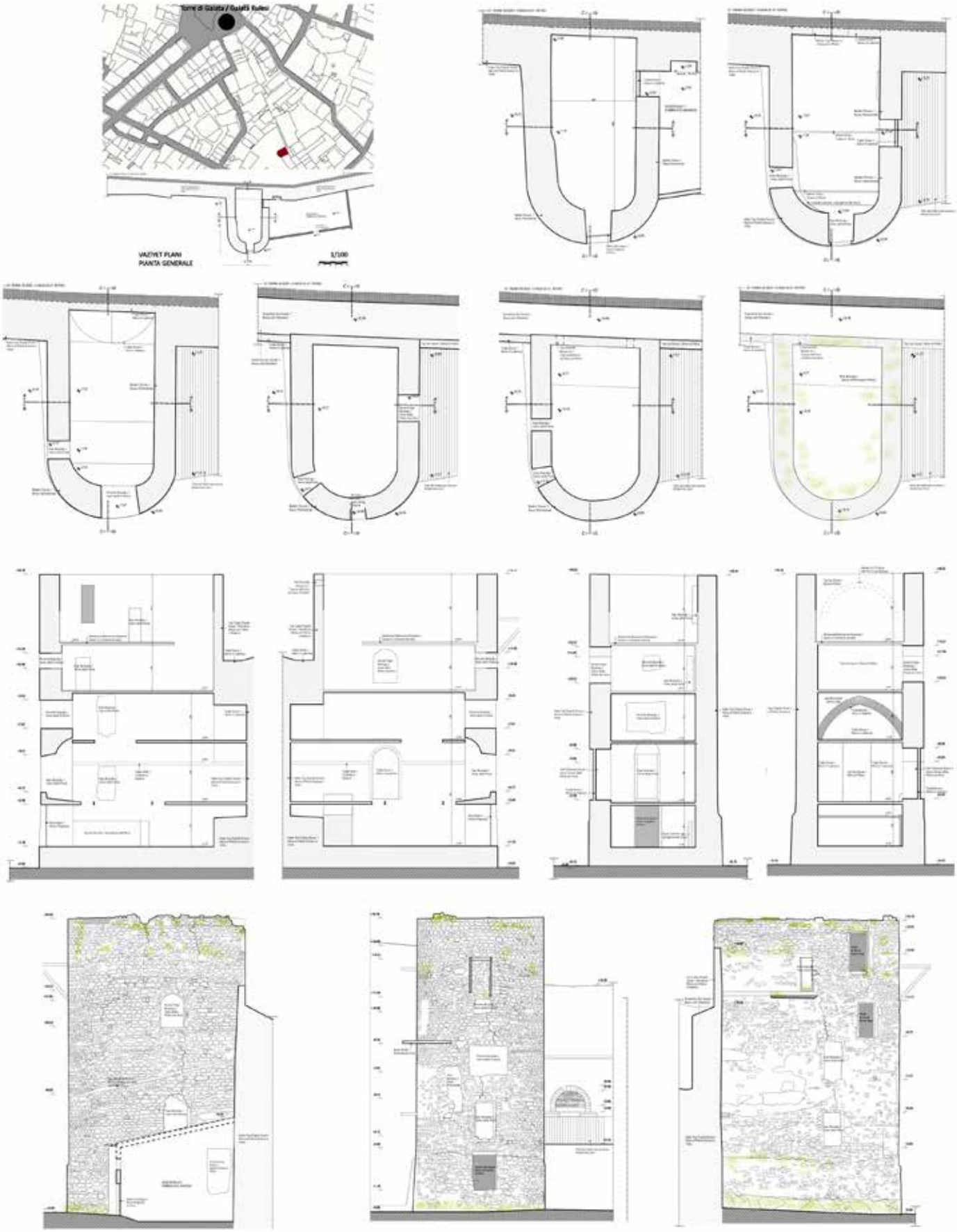

Fig. 04 - Graphic boards with the complete survey of the tower A in Galata/Beyoğlu (D. Peker).

on the external and with few scan stations operated in the interiors. So the profile of the walls was considered as an offset of the external profile getting a better accuracy using the integration of internal traditional measurements, on-site photography, and comparative analogies with better-preserved typologies. In the case of the Caravansary, there is the presence of a classic old market space like those found in Turkey and across the Middle East (Khan Madel, 1988). Currently, this specific one is used by a certain number of hardware shops and technical services. Some exceptions include a painter's studio and a bicycle shop. The robust structure, with thick walls, does a good job in preserving the original layout of the building. Changes to the architectural aspects have been small, mostly involving the adding of features or cutting into the walls for updating the cooling, electrical, and plumbing systems. However, little focus is placed on keeping up the external, internal, and common areas. The documentation of the Caravansaray was done on a partial lasergrammetry integrated and completed by photogrammetry.

The overall result was perfectly functional for analysing and studying the layout and the original features of the building, especially the use of arches and the geometry of the planning grid, allowing a possible attribution to Mimar Sinan himself or to his professional circle (Verdiani and Michelon, 2025). For these built heritage architectures, horizontal and vertical slices of the point cloud produced accurate profiles used to derive plans, elevations, and sections that were subsequently refined through AutoCAD after Recap pre-processing. This process yielded a comprehensive yet critically annotated graphic dataset that records both measurable geometry and conjectural reconstructions based on archaeological reasoning and stratigraphic reading. Graphic restitution functions as both documentary archive and an operative instrument for conservation planning. The restitution adopted a 1:50 scale which is adequate to represent material texture, door and window frames, and principal forms of degradation: structural fractures, lacunae, material washouts, detachments, and biological colonisation. Selection of horizontal section planes responded to the identification of original and secondary openings (including occluded voids) and to the placement of thin interior slabs surveyed by direct inspection. Plans at varied levels were produced to characterize vertical stratification; vertical sections articulate masonry discontinuities, revealing bonding changes, insertion planes, and back-elevation relations. Elevations derived from orthophotoplanes were supplemented by in-situ eidotypes and direct measurements. The resulting plates synthesise geometric accuracy with thematic mapping of materials, stratifications, and decay patterns, and were designed to be intelligible for conservation professionals, structural engineers, and curators. These drawings emphasize vulnerability hotspots and inform prioritised conservation interventions, underpinning the proposal for an open-air museum focused on urban memory and accessible interpretation.

CONCLUSIONS

Accurate surveys and systematic documentation of neglected architectural heritage are of real value, enhancing the building condition, enabling multi-user access to metric data, and giving a starting point for restoration, reuse, and virtual reconstruction. Indeed, in the case of total loss, drafts and detailed drawings remain valuable for at least partial virtual restitution and scholarly analysis. Digital documentation enhances the exchange between different professions-from architectural historians to conservation engineers-and opens paths to public engagement, education, and sustainable tourism. The description of masonries, morphological definitions, and stratigraphic interpretations obtained during the Galata case study enable new insights into the different construction phases and provide a basis for targeted interventions. Considering the high risk of loss and progressive alteration of the Galata area, the documentation helps to prevent the indiscriminate conversion of it into an homogeneous sector dominated by transient commercial activities.

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Abstract

Galata, one of the most historically layered districts of Istanbul, represents a critical site for understanding the urban palimpsest of the Golden Horn. The research focuses on the analysis and documentation of selected blocks along the Galata waterfront, investigating the relationship between surviving defensive structures, later architectural additions, and contemporary transformations affecting the district. The study adopts an interdisciplinary methodology combining archival and cartographic research, architectural-historical analysis, stratigraphic urban reading, and advanced metric digital surveying through 3D laser scanning. The resulting point clouds, orthophotos, and CAD restitutions enabled the reconstruction of diachronic transformations and the identification of alterations, discontinuities, and degradation patterns within key architectural artifacts, including the second tower of the fortification system and the historic Caravansary complex.

The integration of empirical survey data and historical sources facilitated the development of a coherent interpretative narrative linking urban growth processes to the physical evidence of masonry structures and spatial organization. This approach contributes to understanding the dynamics through which traditional urban tissues have been replaced by new construction driven by globalized market logic, often compromising typological continuity and authenticity. The outcomes support conservation-oriented strategies, promote informed decision-making for restoration and reuse, and provide a framework for future research and public dissemination. The work, presented and discussed during the International Urban Design Workshop "Urban Façade: Istanbul Waterfront" (2019), highlights the value of accurate documentation as a tool for preserving memory and guiding culturally responsible urban transformation.

Keywords

Digital metric survey, 3D laser scanning, Point cloud processing, Stratigraphic reading, Archival and cartographic research, Architectural-historical analysis, Orthophoto and CAD restitution, Urban morphological analysis, Diachronic transformation mapping, Heritage conservation strategies

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Time fragments: design proposal for Theodosius's Forum, Istanbul

by Alessandro Camiz

The 3D laser scanner survey of the remains of the Forum of Theodosius in Istanbul, conducted by Zemastek in cooperation with Giorgio Verdiani, was the foundation for the design developed during the international workshop Architecture and Archaeology. Theodosius' Forum, Istanbul. The design proposes the partial demolition of the Şimkeşhane building, defining a new excavation of the area of the forum, revealing the ancient Mese. The project also includes a small pavilion as the gate of the archaeological area, with an Analogical and digital Augmented Reality (AR) device displaying the reconstruction of Theodosius' arch.

Fig. 1 - The design proposal plan and section (DRUM Design, 2023).

PRELIMINARY NOTES ON THE TOPOGRAPHY OF THEODOSIUS' FORUM IN CONSTANTINOPLE

We conducted a preliminary research on the topography of Theodosius' forum in order to define a credible hypothesis on its form and location. To define the plan (fig. 1) we examined the archaeological findings of the area, the main historical sources, and the diachronic sequence of cartographical representations of the area starting from Giovanni Andreas Vavassore, Byzantivm sive Costantineopolis, 1535. The comparative analysis of the monuments described in the Notitia Urbis Constantinopolitana for the regions VII and VIII of Constantinople allowed us to establish the location of the Basilica Theodosiana on the northern side of the Mese. We identified the Thermae Carosianas on the north with the great Nymphaeum at the end of Valens aqueduct, and the porticus connecting this forum to the other one dedicated to Constantine. We defined the location of the tortile column of Theodosium, by comparing Vavassore's plan, where it is depicted still standing, with other later plans such as the Alman Mavilleri (1913-1914). This hypothesis seemed sufficiently coherent with the description of the forum given by the Patria Constantinopoleos.

"About Taurus. That in the Taurus there is a stele of the great Theodosius, but it was formerly of silver, Although he received those from the nations who came, there were former palaces there and a palace of

the "Romans", although in the so-called "Alonitzin". On top of the great column Theodosius was placed, and his sons, Honorius on the stone arch to the west, and Arkadius on the stone arch to the east, above the arches of the great tetradesians columns. And in the middle of the court is a great horse, whom some call Jesus the son of Naeus, and others Bellerophon, who came from the great Antioch. And the four-sided stone horse is covered with the history of the city's end, of the future gates of this city." (Preger, 1901).

The plan was essential for the design. Since the design intends to partially re-establish the forum within the surrounding most central area of Beyazit and its monuments and urban tissues, it was necessary to outline our interpretation of what the forum and its monuments used to be.

Designing within an archaeological area, in our opinion, is almost impossible without a detailed survey of the context. The needed survey is usually multiscalar, operating at the territorial scale, the building scale, and at the scale of the architectural fragments. Architectural fragments which in this case are abundantly lying on the sidewalks without any indication of their importance.

We are very thankful to Fahrettin Doğan Tekin (Zemastek Yapı İnşaat Restorasyon) for the LIDAR survey of Theodosius' forum and to Giorgio Verdiani (University of Florence) for the scientific coordination of the LIDAR survey and the photogrammetric survey of the architectural fragments. Without their contribution, it would have been impossible for us to define a credible design proposal. If we could generalise this principle, we should say that in an archaeological area, survey and design must walk together, at the same time, instead of being two separate and independent actions as usually happens. Upon this principle of scientific cooperation, we have based the action of more than 10 years of activity within the workshops and summer schools organised by the International Network for Architecture and Archaeology. INAA is an international network of scholars, researchers and practitioners who in the past 10 years have been working in the field of Architecture and Archaeology. Each year it organises a summer school open to students of architecture, restoration, archaeology and design. https://www.architecture-archaeology.com/

DIDa: Fig. 3 - 3D digital model of the stand designed to show the architectural fragments (DRUM Design, 2023).

THE ARCHAEOLOGICAL PARK OF THEODOSIUS IN ISTANBUL: DESIGN PROPOSAL

Currently the only visible remains of the forum are two bases of the columns of the monumental arch, and a collection of architectural fragments, mostly belonging to the arch as well, scattered along the sidewalk of Ordu Caddesi. The fragments consist mainly in marble elements belonging to the architectural order of the arch, very singularly a Heracles Corinthian. The columns had notches on the shaft, just as Heracles' classical statues depicted the club, and to enhance this symbolism, the column's imoscape displayed the hand of the mythical figure sculpted. The arch was built to hold the statues of the two sons of Theodosius, Arcadius and Honorius, and perhaps it was meant to express a menace to the population in times of trouble. The bases and the fragments are the result of an excavation, that was possible after the partial

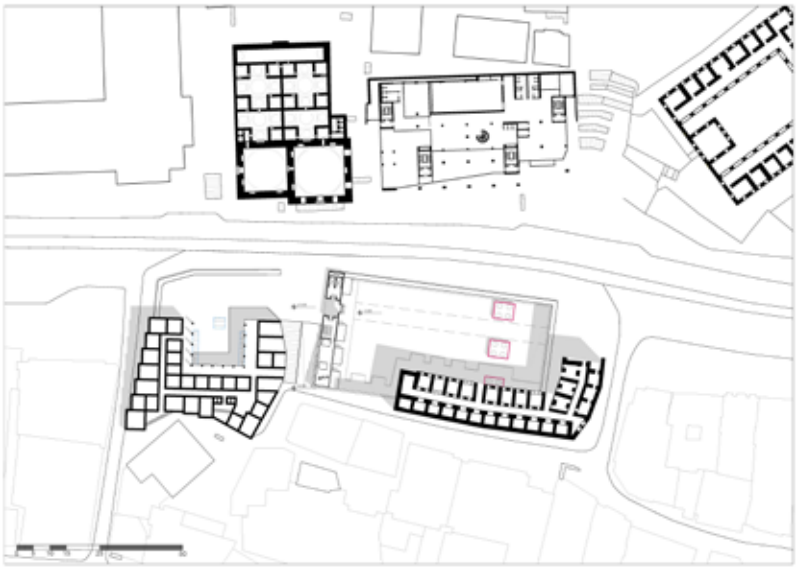

Fig. 2 - 3D digital model of the design proposal with materials (DRUM Design, 2023).

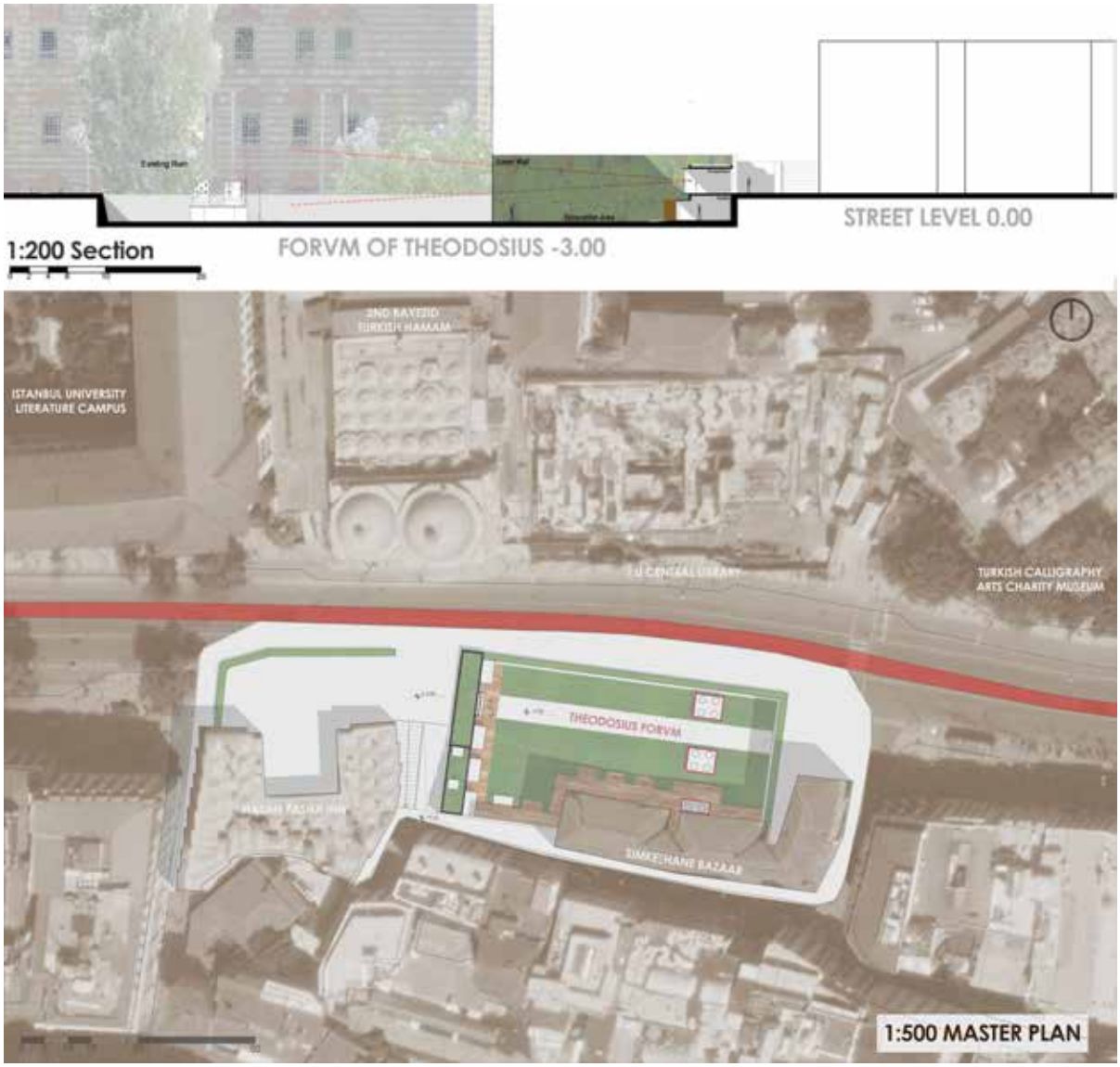

Fig. 3 - 3D digital model of the stand designed to show the architectural fragments (DRUM Design, 2023).

demolition of Şimkeşhane, by British archaeologists Stanley Casson and David Talbot Rice (1927-1928) leading to the discovery Theodosius triumphal arch (A.M.W. 1929). After the excavations, there was a partial anastylosis of some columns on top of the bases, still visible, the side of the Şimkeşhane was reconstructed in order to function as a market again, and another base is currently visible in one of the shops on the ground floor. After the understanding that most of the Şimkeşhane as we see it is not the original building but a modern reconstruction, we came to the conclusions that it could be possible to demolish it (partially) in order to establish a wider and deeper excavation capable of uncovering the pavement of the forum and the Mese. We based the design on this assumption and on a number of key design concepts such as time, limit/ enclosure, levels, entrance, fragments, public space and narrative. After the subtraction provided by the proposed archaeological excavation our proposal included the partial anastylosis of the columns over their bases, a small pavilion providing the entrance to the archaeological area on the street level, a vertical distribution to reach the archaeological level, small archaeological laboratories and deposits on the lower lever. Within the entrance gate, a glass with the printed reconstruction of the arch would provide to the visitor the analogic augmented

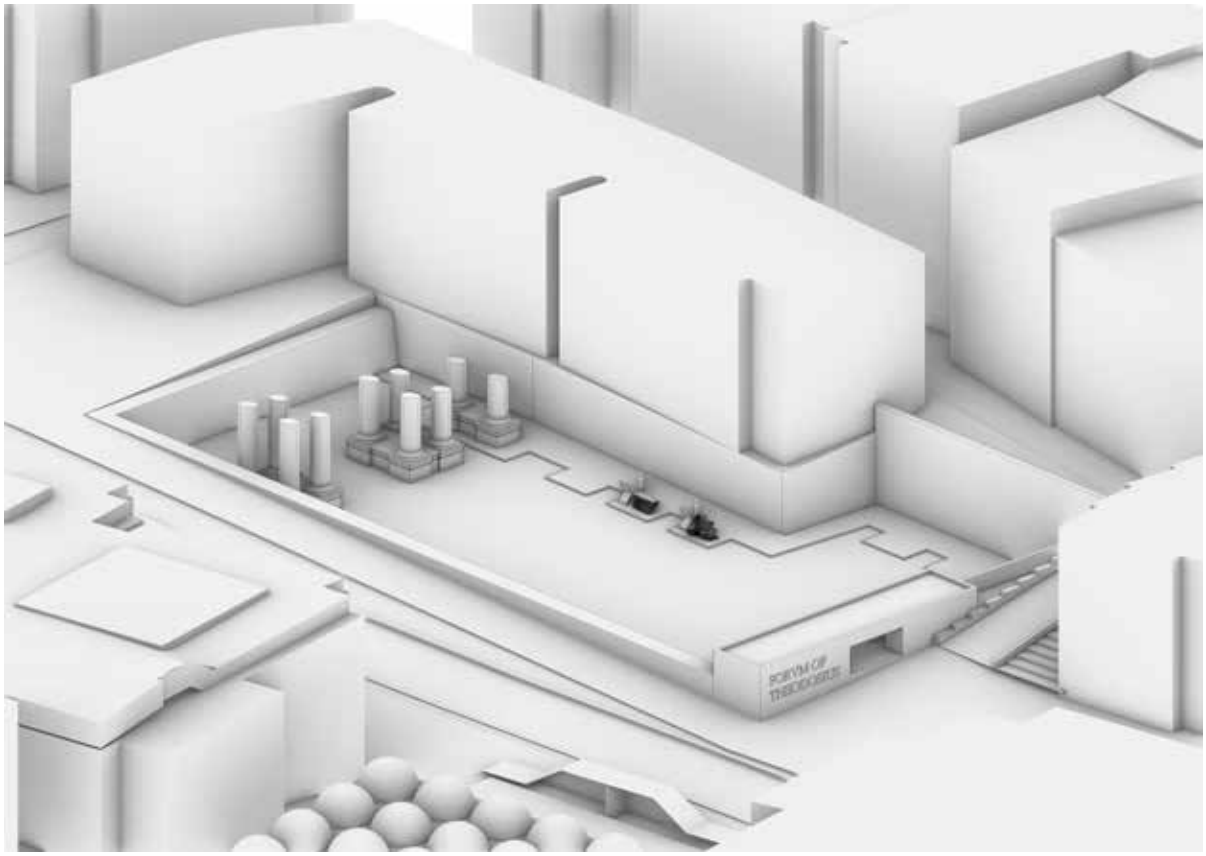

Fig. 4 - Analogical and digital Augmented Reality AR for the reconstruction of Theodosius' arch. (DRUM Design, 2023).

Fig. 5 - Analogical and digital Augmented Reality AR for the reconstruction of Theodosius' arch. (DRUM Design, 2023).a Fig. 5 - Analogical and digital Augmented Reality AR for the reconstruction of Theodosius' arch. (DRUM Design, 2023).

reality view of the forum. On the lower level, we designed a path for the visitor, displaying on properly designed stands with captions, the remaining fragments. We conceived the retaining walls of the excavation, as well as the pavilion itself, as entirely covered with a green wall system.

CONCLUSIONS

Not only as we mentioned, the digital survey of the premises were essential for the development of this proposal, but

also the deep understanding of the site and the ongoing identified process. A conformal design is based upon the understanding of all the phases, including the first construction, the collapse following the historical earthquakes, the subsequent ottoman buildings constructed atop, but also the modern excavations and restorations. The knowledge of these phases in an archaeological area is the starting point for a properly conceived design, a design conceived as the continuation of an identified ongoing process.

CREDITS

This project was developed during the +10 ISTANBUL RESEARCH WORKSHOP 2023, Architecture and Archaeology. Theodosius' Forum, Istanbul, organised by the Dynamic Research on Urban Morphology DRUM Lab, at the Faculty of Architecture and Design of Özyeğin University, Istanbul, from 10th to 21st July, 2023. The design team "DRUM Design: Theodosius' Forum, Time Fragments" was directed by Alessandro Camiz, (Özyeğin University) with the tutors Mariagrazia Leonardi (University of Catania), Hülya Yavaş (Özyeğin University), Berke Baybaş (Özyeğin University), Tan Atayurt (Özyeğin University) and Erdinç Can (Özyeğin University) and the students: Dur Ali Mohammed Mudhafar (Özyeğin University) and Vera Akbülbül (Özyeğin University).

Chronology

337-373 Valens Aqueduct
370, april 9 church of holy apostles inaugurated
373 Nymphaeum Maius (prefect Clearchus)
375 Thermae Carosianae
378 Valens dies at Hadrianopolis
379 Theodosius I Augustus
381 Council in Constantinople
383 Theodosius quinquennalia in Constantinople
386 Construction works start for the column
393 Forum Tauri is renamed after Emperor Theodosius I, and inaugurated as Forum of Theodosius
394 Theodosius I Emperor
395 Theodosius dies kal feb (Chron, Pasc. 565) in Milan
395 Column of Theodosius
395 Theodosius statue kal aug (Chron, Pasc. 565)
395 Arch of Theodosius
407 earthquake, "aereae tegulae Fori Theodosii a tectia excussae in Coenopolim delatae fuerint, (Chron, Pasc. 570)
465 Fire burns the Basilica (Mango, 1985)
480 Earthquake Statue of Theodosius falls
506 Statue of Athanasius replaces Statue of Theodosius
532 Nika riots
527-565 Basilica A
558 the central arch and the statue of Arcadius collapsed
740 Earthquake destroys the arch
1454-1458 Eski Saray is built
1460 Construction of the Mint (Sirmakesh Han)
1500-1505 Beyazıt Hamam
1500-1505 Bayezid II Mosque
1509 Earthquake damages Mosque
1540-1541 Eski Saray is destroyed by a fire
1535 Giovanni Andreas Vavassore, Byzantivm sive Costantineopolis
1557 Süleymaniye Mosque is built
1572 G. Braun and F. Hogenberg, Byzantium nunc Constantinopolis
1573-1574 Mimar Sinan restores the mosque
1625-1632 Eski Saray is restored
1687 Another fire destroys Eski Saray
1749 Fire-watch timber tower in Beyazıt
1756 Great Fire of Cibali destroys Beyazıt Tower
1836-1837 Ministry of Wa-rBâb-ı Seraskeri
1828 New Beyazıt Tower
1889 Earthquake damages the Beyazıt Tower
1927-8 excavations in Simkeş Hanı by British archaeologists Stanley Casson and David Talbot Rice.
1928 Discovery of Theodosius triumphal arch (Rice et al 1929)
1942 Sedad Faculty Istanbul University
1948 and 1961 Works to enlarge Ordu Street and Beyazıt Square

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Abstract

The Laser scanner survey of the remains of the Forum of Theodosius in Istanbul, conducted by Zemastek in cooperation with Giorgio Verdiani, was the foundation for the design developed during the international workshop Architecture and Archaeology. Theodosius' Forum, Istanbul. The design proposes the partial demolition of the Şimkeşhane building, defining a new excavation of the area of the forum, revealing the ancient Mese. The project also includes a small pavilion as the gate of the archaeological area, with an Analogical and digital Augmented Reality (AR) device displaying the reconstruction of Theodosius' arch.

Keywords

Architectural Design; Archaeology; Architectural Heritage; Urban Design; Urban Morphology

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Priene and Magnesia ad Maeander:

main architectures and urban morphology

by Görkem Kökdemir, Pelin Yoncaci Arslan

Despite differences in scale, origin, and topographical context, Priene and Magnesia ad Maeander share fundamental planning principles rooted in the Hippodamian urban model, characterized by orthogonal layouts and a clear hierarchy of civic, religious, and residential spaces. The impact of environmental dynamics, including seismic activity and fluvial processes, has a significant impact on the urban evolution of both cities. Recent digital survey campaigns using photogrammetry and 3D laser scanner technologies in the present time are essential tools for documenting, analysing, and interpreting these complex archaeological contexts.

The cities of Priene and Magnesia ad Maeander represent two important examples for the study of urban development, the relationship between environments and settlements, and architectural expression in the Hellenistic area, in a territory later known as Asia Minor. Both communities, situated in the Maeander valley of western Anatolia, reflect the dynamics of power in the aftermath of Alexander the Great's conquest and the subsequent events of his sudden and premature death, through the Roman conquest, subsequent transformation and abandonment. The two cities have different origins, scales, and urban trajectories, but both share a series of events in which the local Greek communities negotiated autonomy and identity within a rapidly transforming geopolitical environment until the Roman intervention. They also share a series of natural disasters and transformations that should impress and prompt reflections on how an odd environmental transformation may bring ruin and chaos to formerly wealthy settlements.

Their archaeological remains, particularly the well-preserved urban fabric of Priene and the monumental sanctuaries of Magnesia, offer opportunities to read and interpret the urban setup originally defined by the civic ideologies of Hellenistic cities and later adapted, expanded, and transformed in the Roman period. Both cities share the specific urban rational layout defined by Hippódamos of Miletus, with rigorous planning and a coherent integration of architecture, public, social, religious, and private spaces into a system that would shape and influence the future developments for centuries.

Fig. 01 - Map of the area with Priene, Magnesia and Mileto with the progressive transformation of the coastline, data from R.J.A. Talbert (base map from openstreetmap.org).

THE URBAN CONTEXT IN PRIENE

Priene is situated on the southern slope of Mount Mykale, overlooking what in antiquity was a gulf opening into the Aegean Sea. By the Hellenistic period, however, the silting of the Maeander had already begun to push the coastline westward, thus gradually detaching Priene from the seashore that had once defined its economy and strategic importance. The city was architecturally replanned in the fourth century BCE, providing a model for a rational, orthogonal urban plan organized into a series of large terraces. The sloppy topography imposed serious constraints that required a specific architectural attention, producing one of the clearest surviving examples of Hellenistic city planning.

Priene is a paradigmatic example of urban planning of that time (Wycherley, 1945). Its street grid, which recognizes Hippodamian principles, organises the city into regular sectors aligned with the cardinal directions, though subtly adapted to the mountain slope. Public buildings, including the Agora, the Bouleuterion, the Prytaneion, and the Theatre, share a coherent architectural vocabulary, offering specific solutions while remaining consistent with the city's layout. The Temple of Athena Polias, designed by the architect Pytheos, stands as the city's principal monument and embodies the refined Ionian tradition. It was dedicated by Alexander the Great during his campaign. The temple symbolised the city's religious devotion and its strategic engagement with broader geopolitical forces. At the same time, the city suffered from the compromise of the harbour; its economy likely faced serious problems from the progressive silting of its port, which probably led to a shift in efforts toward agriculture, craftsmanship, and cultural institutions, helping realign productive activities. At the same time, the occurrence of some unfortunate events, such as strong earthquakes and occasional rocks falling from the mountain's sides, certainly created difficult situations. After its final abandonment, the city preserved a substantial amount of its original architecture; the laborious work required to remove blocks probably made the ruins less interesting for

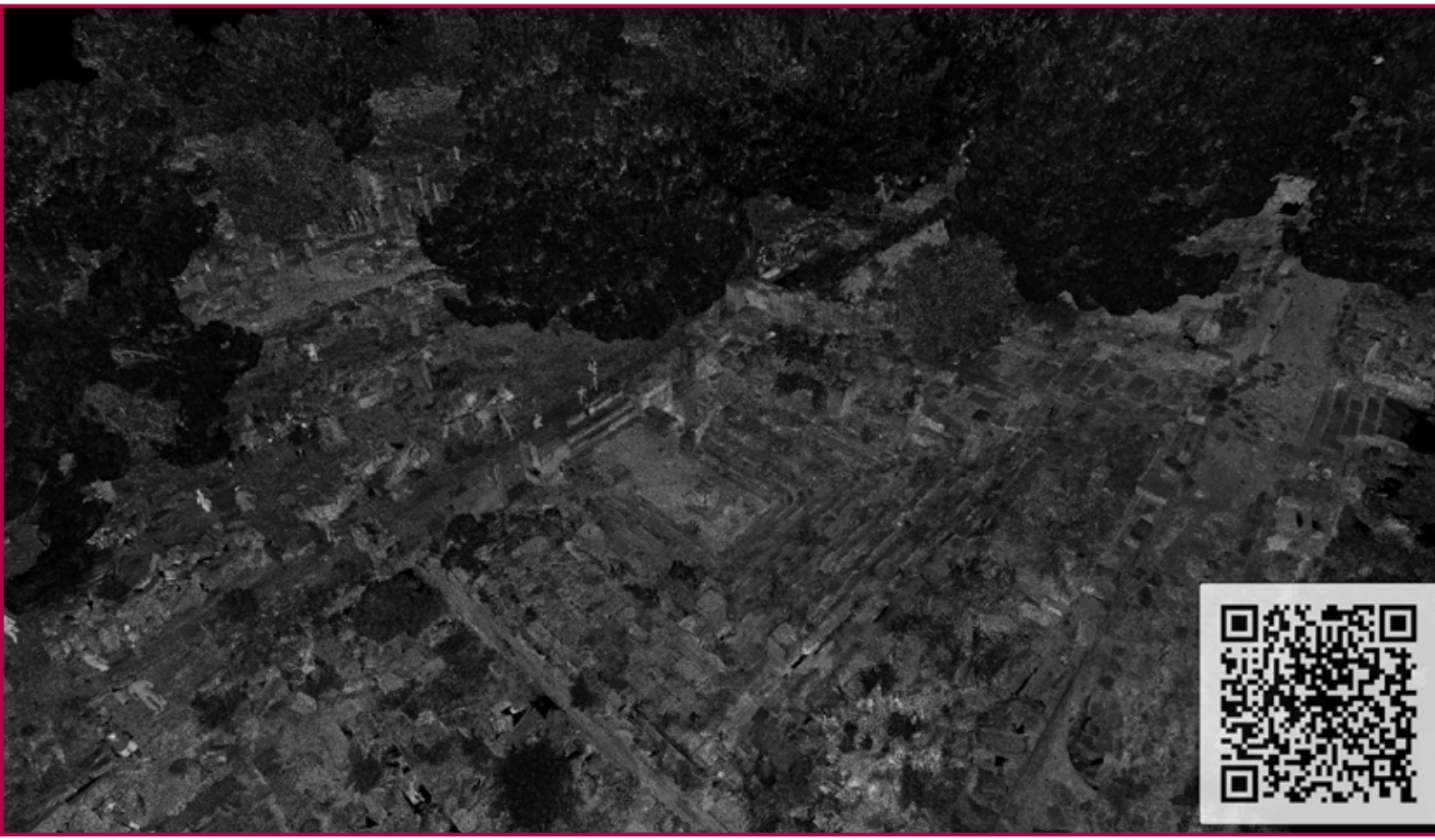

Fig. 02 - View on the Bouleuterion in Priene, 3D laser scanner pointcloud, July 2022, H.B. Yavuz, F.D. Tekin (Litech, Turkey), with a QR code to access a youtube video about the workshop held in Priene in 2022.

reuse, leaving them to wait for centuries before being rediscovered and excavated.

The German archaeological campaign at the end of the XIXth century brought to light the main buildings and revealed the urban pattern. Intervention by French and English missions led to the discovery and expansion of the excavated areas. The present Turkish activity led by Ibrahim Hakan Mert is mainly oriented to maintenance and specific exploring interventions.

THE URBAN CONTEXT IN MAGNESIA AD MAEANDER

Magnesia ad Maeander, instead, occupied a lowland setting on the south bank of the Maeander River, several kilometres East of Priene. Unlike its neighbour, Magnesia developed in a flatter environment that facilitated expansion and allowed the construction of monumental sanctuaries and civic spaces on a scale beyond the capacity of Priene's terraced hillside. Although less well preserved, Magnesia's remains, especially the Artemision and the stadium, demonstrate how a city with strong regional connections and external patronage could reshape its urban environment to communicate prosperity, cultural refinement, and political significance. Both cities navigated the shifting imperial administrations of the Hellenistic period. Initially subject to Persian authority, they were successively incorporated into the realms of the Diadochi, most notably the Seleucid and Attalid kingdoms. The interests of these monarchies, whether expressed through benefactions, administrative oversight, or military imposition, significantly influenced the development of the two communities. Yet both Priene and Magnesia retained strong civic identities, expressed in epigraphic culture, religious activity, and the maintenance of traditional institutions.

Magnesia's urban organization is less comprehensively preserved, but archaeological evidence suggests a dynamic and ambitious program of monumental construction, particularly during the second century BCE, when the city benefited from the patronage of the Attalid

Fig. 03 - View on the Agora in Magnesia, on the background, at the right, the Temple of Zeus, 3D laser scanner pointcloud, September 2025.

dynasty and later from Roman domination. The Artemision of Magnesia, dedicated to Artemis Leukophryena, was celebrated in antiquity as one of the most impressive temples in Asia Minor (Dunand, 1978). Designed by the architect Hermogenes, the building introduced the pseudodipteral plan, a significant innovation that influenced temple architecture throughout the Hellenistic and Roman worlds. The sanctuary served not only as a religious focus but also as a symbol of civic prestige, emphasizing the city's role as the guardian of a renowned cult and host of the Leukophryena festival, which attracted participants from across the Aegean. The urban fabric of Magnesia was further enhanced by its stadium, still well preserved (notwithstanding a series of significant disruptions), and by numerous public buildings. The scale and the quality of these structures show how a city positioned inland, away from the major coastal circuits, could nevertheless thrive through agricultural wealth and strategic alliances.

The city was economically shaped by its position in the Maeander valley, a fertile region that produced agricultural surpluses and supported a network of overland and fluvial trade routes. Magnesia probably enjoyed more sustained prosperity than Priene, due to its more adaptable geographical position and the benefits of royal patronage. Its sanctuaries attracted pilgrims and visitors, adding a religious dimension to the local economy. The recent archaeological discovery demonstrates the reuse and insertion of buildings over a wide span of time; the final abandonment caused the city to completely get lost in the mud of the floods until its rediscovery by French and German archaeological missions at the end of the XIXth century (Humann, 1904). After almost a century, the interventions resumed in 1984 with a mission led by Orhan Bingöl, which identified new sectors and improved the urban layout (Bingöl, 1998). The richness of the discoveries yet to be made is confirmed by ongoing archaeological work led by Görkem Kökdemir, which is unearthing

Fig. 04 - Photogrammetry of a series of columns in the Agora of Magnesia, September 2025.

vast, complex areas, limiting the still-present menace of floods, and reconstructing significant parts, giving visitors a better opportunity to read the original aspects.

DIGITAL SURVEY CAMPAIGNS

The digital survey interventions, operated in 2022 (Priene), 2024 and 2025 (Magnesia) allowed the gathering of both architectural and urban data, defining an archive previously usable for further research and study works. The interventions in 2022 and 2025 were conducted using 3D laser scanner units, terrestrial and aerial (drone/UAV) photogrammetry (the intervention in 2024 was based only on photogrammetry of the stadium and of some sparse findings). In this way, the level of detail gathered may range from the city scale to the single building to the specific detail, enabling a continuous reading in a real interdisciplinary mode. This was widely achieved through the use of 3D laser scanner units with a consistent operating range and high accuracy, UAVs combined with terrestrial image capture, and terrestrial photogrammetry with varying distances for specific details. In this way, we have obtained different densities in describing architectural parts and artworks while maintaining the overall context without increasing computational time or model complexity.

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Abstract

Priene and Magnesia ad Maeander constitute two emblematic case studies for investigating Hellenistic urban planning, architectural form, and the relationship between cities and their environmental settings in western Anatolia. Both settlements developed within the Maeander valley during the Hellenistic period, under complex political and cultural conditions following Alexander the Great's conquests, and later underwent significant transformations during Roman rule before abandonment. Despite differences in scale, origin, and topographical context, the two cities share fundamental planning principles rooted in the Hippodamian urban model, characterized by orthogonal layouts and a clear hierarchy of civic, religious, and residential spaces. Priene, founded on the steep slopes of Mount Mykale, represents one of the most complete examples of an orthogonal urban system adapted to a challenging terrain. Its preserved street grid, domestic quarters, and monumental buildings, including the Temple of Athena Polias, reflect the ideological coherence of Hellenistic urbanism. Magnesia ad Maeander, established in a flatter landscape, developed on a larger scale, enabling the construction of extensive monumental complexes such as the Artemision and the stadium, which expressed civic identity and regional importance. The impact of environmental dynamics, including seismic activity and fluvial processes, have a significant impact on the urban evolution of both cities. Recent digital survey campaigns using photogrammetry and 3D laser scanner technologies in the present time, are essential tools for documenting, analysing, and interpreting these complex archaeological contexts.

Keywords

Architecture; archaeology; urban development; survey; Hellenistic period; survey; 3D laser scanner; photogrammetry; UAVs; mapping

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Priene, an ancient tale about the fury of Nature

Digital technologies applied to the archaeological site

by Elisabetta Caterina Giovannini,
Vieri Cardinali

What remains today of the ancient city of Priene, a Hellenic settlement in Asia Minor, is an archaeological site located in the modern region of Aydın in Turkey. Nevertheless, the story behind these ruins highlights the rise and decline of an ancient population that endured natural disasters and enemy invasions. Advanced research using new digital tools makes it possible to identify traces of this past, offering insights into the city's development and helping to enhance the value of what survives.

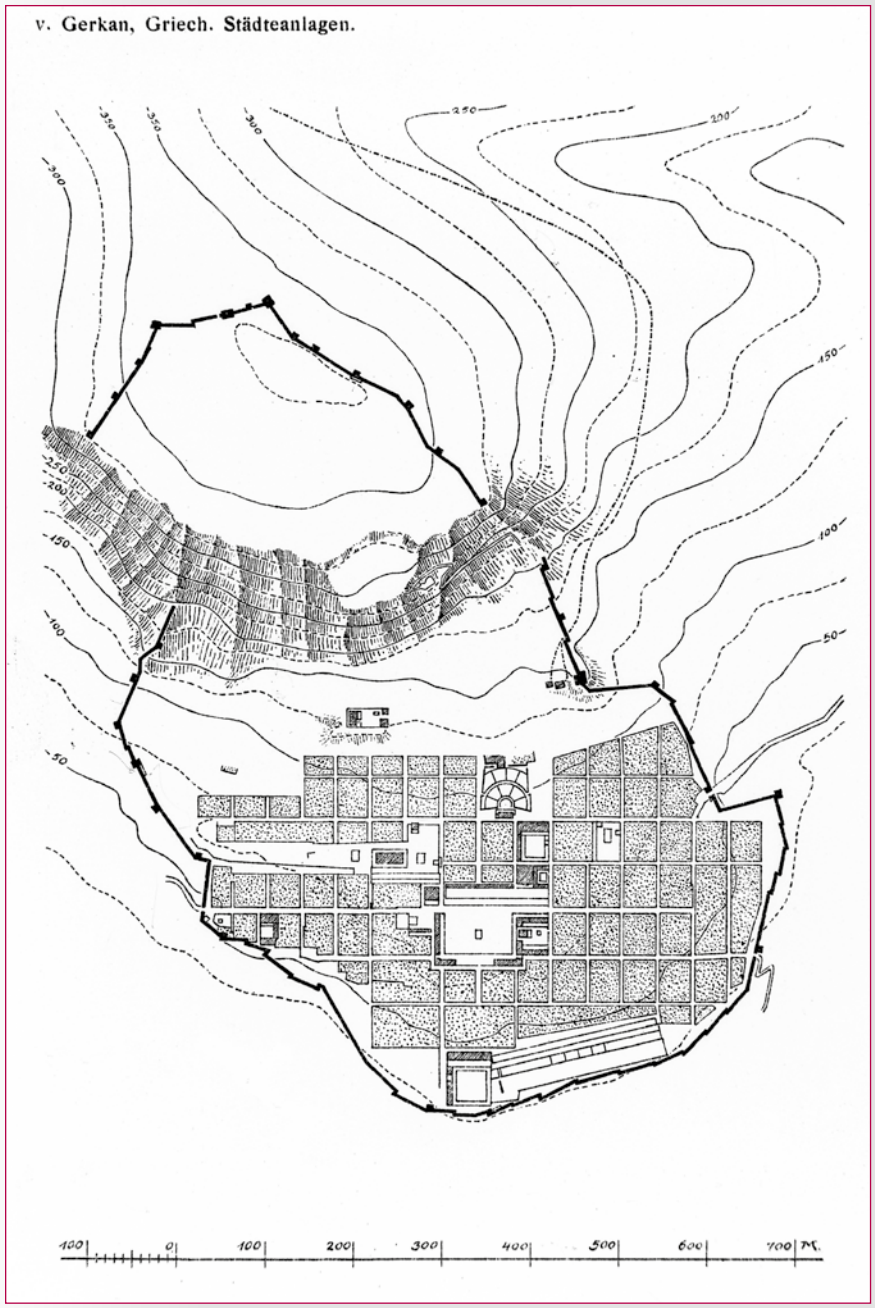

Fig. 1 - Plan of Priene, in Griechische Städteanlagen. Copyrighted work available under Creative Commons Attribution only licence CC BY 4.0. Credit: Wellcome Library, London.

In the natural context, the human being has always looked for places to live in safety. Shelters against predators, protections from the cold and the rain, the realization of houses to live in can be seen as an outcome of a research of protection.

At a wider scale, the urban settlements, the villages and the cities, have represented the association of more individuals into stronger societies. The anthropization of the environment has been, in history, the response to the human need to accommodate nature to their will, passing from an hostile place to an Eden garden providing foods and supplies.

Nonetheless, the unequal battle between humans and nature has revealed on many occasions the power of planet Earth, capable of destroying rapidly what has required years of work. Floods, storms, earthquakes, volcanos are the most catastrophic ways to point out the ephemeral presence of human settlements in the world.

In history, the battle for ancient civilisations was harder than nowadays. Despite the more famous events, e.g. the Pompeian destruction occurred in 79 BC., many minor episodes have led to the collapse of ancient societies. In this context, earthquakes are within the most dramatic natural hazards. The unexpected ground shaking is causing the collapse of the constructions, leading to death and injuries. In the unfortunate cases, this can bring further destruction. The most iconic and well-known example is given by the Lisbon earthquake of 1755; after the mainshock, which led to damage and collapse of constructions, fires started in the houses, while a tsunami hit the lower part of the city. When the fury of nature stopped, around 85% of the city was destroyed, with around one third of the population's death.

Dealing with the topic, when an urban settlement was devastated by an earthquake, in many cases, the easiest way to re-start was to relocate the city to another place.

This is something still documented in recent years (e.g. the case of Gibellina, in Sicily IT), as in ancient times.

NATURAL AND HUMAN FURY IMPACTING PRIENE

In minor Asia, the history of the city of Priene, its ascent and decay, are a testimony that reminds the perseverance of human beings to realize their spaces and protect them against the force of nature and the changes of the world.

According to tradition Priene was founded in the eleventh century BC by Aepytus, grandson of the legendary Athenian King Codrus, in association with the Theban Philotas.

Priene represented an important town in Ionia and according to ancient historical sources such as Pliny the Elder and Strabo, the city was struck by a devastating earthquake in the fourth century BC. The event caused significant damage, leading to the collapse of many buildings.

Priene was destroyed not only by natural disasters but also by human activity, enduring repeated attacks from the Cimmerians, Lydians, and Persians. Following the Persian Wars, it joined the Delian League under Athens, which intervened in 441 during a dispute between Miletus and Samos over control of Priene. (Cook & Spawforth, 2016) However, it appears that Priene was relocated to a different site during the time of Alexander the Great; he himself visited around 334 BC, and it was then that the transfer took place, reportedly accompanied by an inscription granting an exemption from tribute. The new city was built on a series of terraces along the steep slope of Mount Mycale, facing Miletus and overshadowed by its acropolis on Teloneia Hill.

This second Priene, relocated about 3.7 km from the original city (roughly twenty stadia), is a prime example of urban planning and the best surviving instance of a town from this period. With its walls stretching along a broad ridge, descending from the steep face of the Teloneia toward what must have been the estuary of the Maeander, the new settlement featured a systematic, symmetrical grid layout based on the Hippodamian grid plan, designed to accommodate a population of perhaps 5,000 (Fig. 1).

The most prominent building, towering above a lofty terrace with a Doric Stoa, was the sanctuary of Athena Polias. It was designed, according to Vitruvius, by Pytheus, the architect of the Mausoleum at Halicarnassus. Initially dedicated to Alexander the Great (though not completed at that time), it was later rededicated to Athena and Augustus. The shrine was adorned with various sculptural groups dating from the late fourth century BC to the early second century AD. In front of the temple stood a monumental

altar designed by the renowned Hermogenes of Priene (c. 150 BC), of which little has survived. (Cordan & Besgen, 2022)

Research has shown that the vulnerabilities and resilience of Priene's inhabitants shaped their responses to seismic activity, influencing the city's reconstruction efforts after major earthquakes recorded in various periods, including 68 AD and 1653. (Altunel, 1998; Topal, 2019; Mozafari et al., 2019)

These discussions highlight the interplay between cultural heritage, societal structures, and technological advancements in understanding and mitigating the impacts of disasters.

DIGITAL TECHNOLOGIES IN DISASTER DOCUMENTATION

Despite advancements in documenting Priene digitally, challenges remain, including the need for standardised methodologies and collaborative approaches among interdisciplinary teams. The integration of emerging technologies with traditional archaeological practices offers promising pathways to ensure the sustainability of cultural heritage while addressing ethical concerns about accessibility and community engagement. (Giovannini et al., 2023).

Digital technologies are vital for documenting and safeguarding the cultural heritage of archaeological sites, especially during disasters. As disasters become more frequent and severe, the ability to monitor, manage, and protect architectural heritage has become increasingly important. These technologies enable the creation of digital archives that not only record the current conditions of sites but also support disaster response and recovery efforts (Mendoza et al., 2023).

One of the primary methods used in disaster documentation is 3D scanning and photogrammetry. These techniques enable the collection of highly accurate data for the virtual reconstruction of archaeological artefacts and sites. The combination of historical records with 3D outputs improves understanding of site contexts and helps in conserving fragile items that might be threatened by environmental damage or disasters. The use of these technologies enables the creation of detailed digital models that serve as references for future preservation and restoration efforts. (Maietti, 2023).

Alongside technical documentation, digital technologies support the creation of virtual exhibits and online databases. Platforms like Europeana, the Smithsonian's Digital Collections or commercial

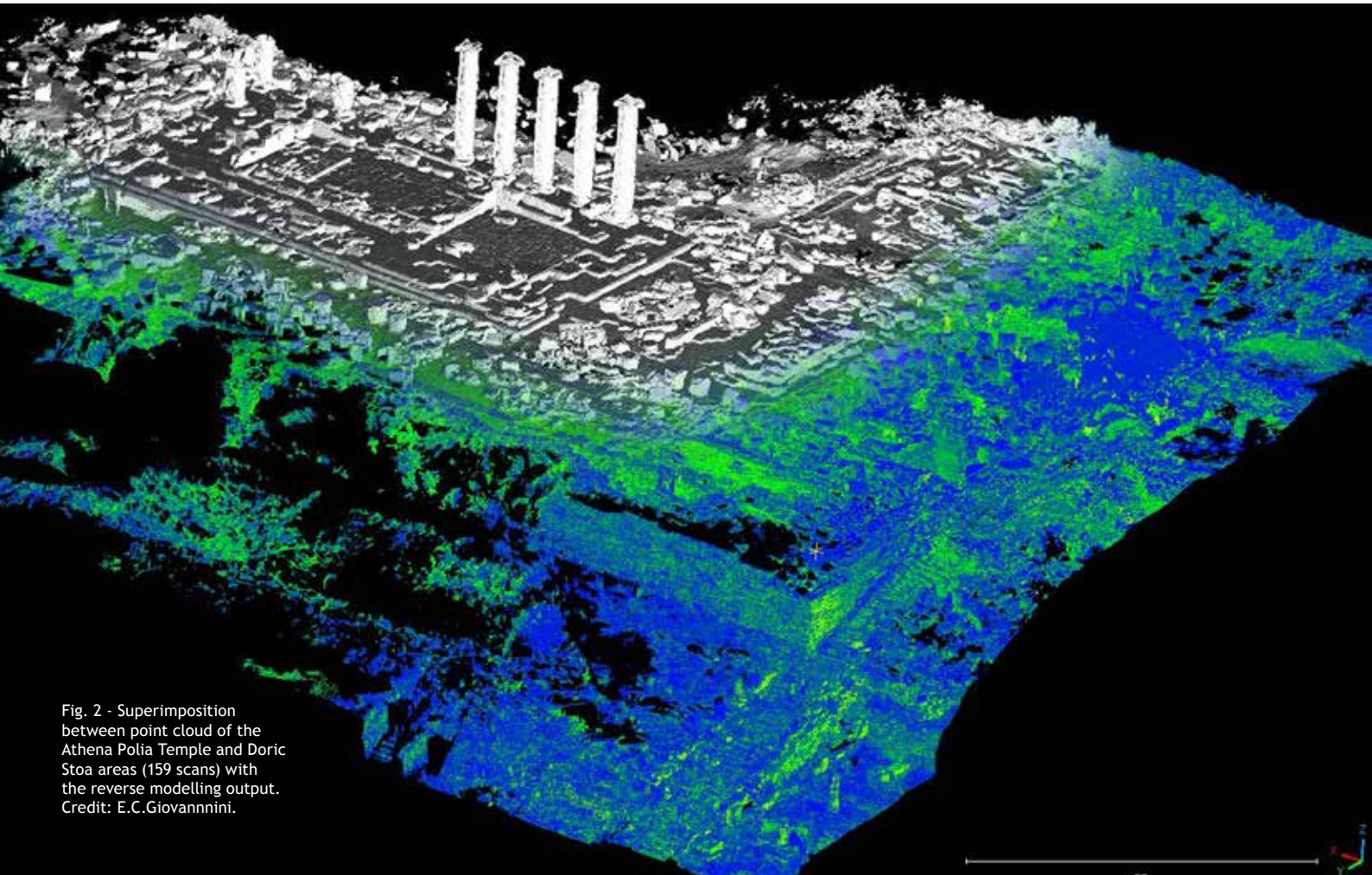

Fig. 2 - Superimposition between point cloud of the Athena Polia Temple and Doric Stoa areas (159 scans) with the reverse modelling output. Credit: E.C.Giovannnini.

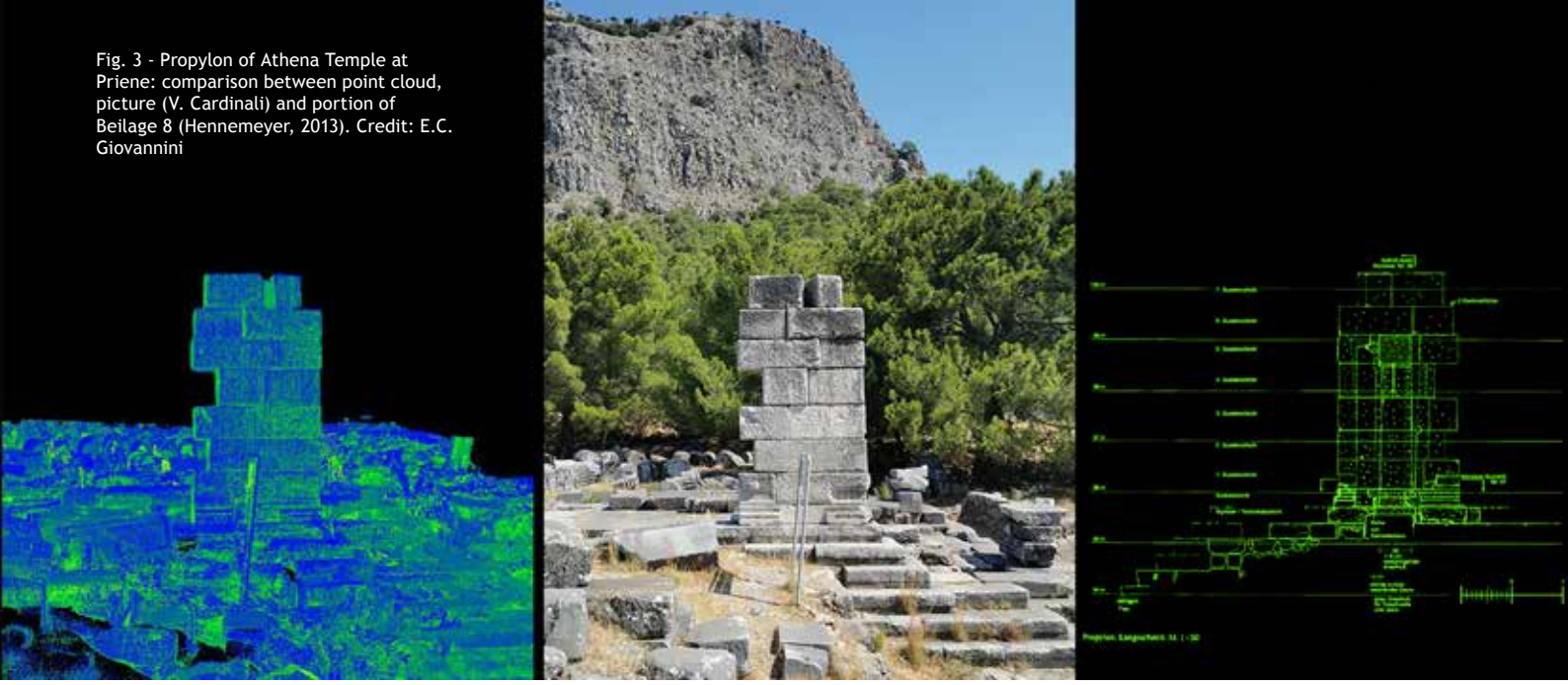

Fig. 3 - Propylon of Athena Temple at Priene: comparison between point cloud, picture (V. Cardinali) and portion of Beilage 8 (Hennemeyer, 2013). Credit: E.C. Giovannini

ones like sketchfab offer access to millions of digitised items, including artefacts threatened by disasters. By making these resources available online, researchers and the public can engage with and study objects that may be physically inaccessible due to fragility or location. (Champion & Rahaman, 2020).

DIGITAL TECHNOLOGIES APPLIED TO PRIENE RUINS

Digital preservation not only helps protect cultural heritage but also ensures that knowledge about these artefacts is shared globally. The methodologies used in the study of Priene involve a systematic literature review and bibliometric analysis based on previous German research. One of the main challenges is balancing technological innovation with the authenticity of cultural narratives. The risk of oversimplifying complex histories to engage broader audiences requires a careful approach to digital preservation.

As digitisation projects continue to digitise artefacts and create virtual exhibits, best practices for data management must be established. Within digital acquisition in Priene, an integrated workflow was

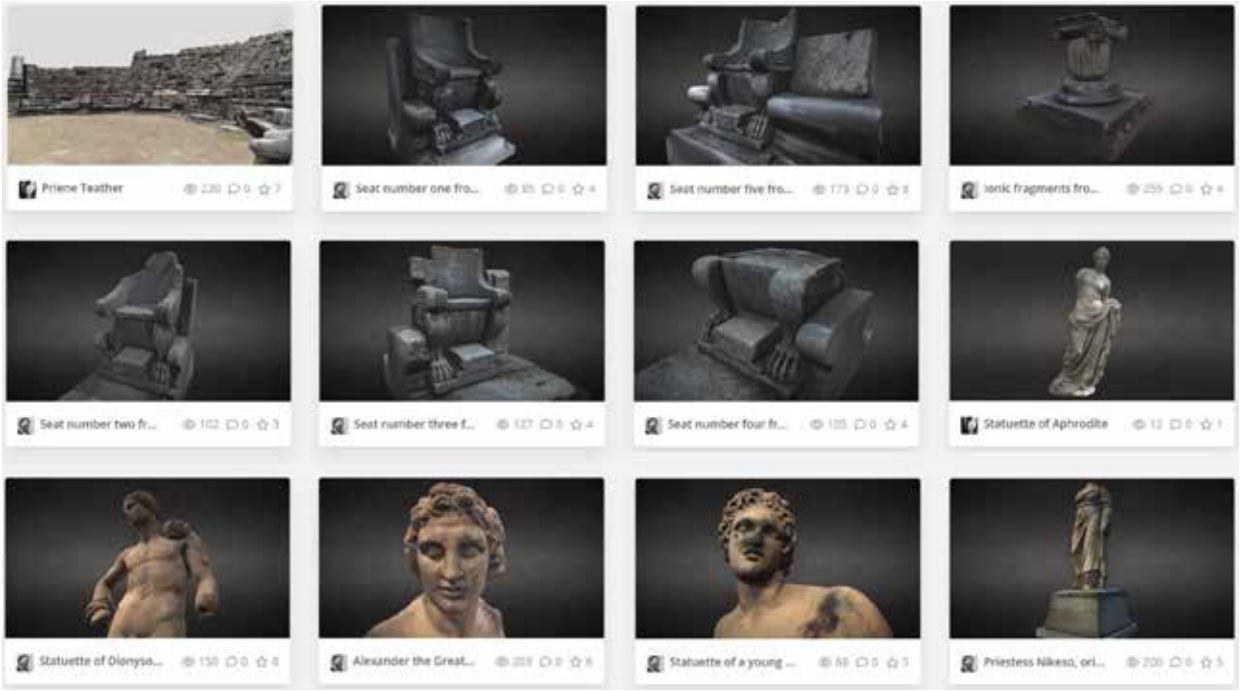

Fig. 4 - Collection of 3D models about monuments, fragments and statues of the Priene archaeological area. Credit: E.C. Giovannini & G. Verdiani.

implemented to acquire and disseminate Priene monuments digitally, demonstrating how digital technologies can transform the understanding, preservation, and communication of archaeological heritage (figs. 2-3). These approaches include the practical storage of raw collection data, processed files, and related metadata.

The point clouds obtained (raw data), document large-scale survey campaigns using laser scanning, UAV and terrestrial photogrammetry. 3D models (processed files) allow the analysis of major structures such as the Doric Stoa terrace wall and the Theatre, revealing construction methods, structural behaviour, and patterns of historical damage, particularly from seismic events. (Giovannini et al., 2024)

Archival research (from online platforms, e.g., iDAI.world repository or Census database) and 360° images and virtual tours provide remote, georeferenced access to Priene's artefacts. This includes not only monuments but also marble statues now housed abroad, showing how digital acquisition, object biographies, and virtual tours can virtually reunite objects with their original context (fig. 4). (Verdiani & Giovannini, 2024)

By integrating reality-based models, historical documentation, semantic structuring, and online dissemination platforms, the projects demonstrate how digital tools validate and expand prior archaeological knowledge, support conservation planning, and make cultural heritage more accessible to specialists and the general public.

As researchers continue to explore the complexities of the past, Priene stands as a testament to the enduring relationship between humanity and nature, illuminating the lessons learned from the past as we face the uncertainties of the future.

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Abstract

The paper describes Priene's long history of natural and human destruction, focusing on how earthquakes shaped its urban development and relocation. It highlights the role of modern digital technologies, such as 3D scanning, photogrammetry, and virtual archives, in documenting damage, preserving cultural heritage, and reconnecting dispersed artefacts. Through integrated digital workflows, the study demonstrates how these tools enhance archaeological understanding and support future conservation.

Keywords

Digital Archeology; Integrated survey; 3D digital assets; digital applications to archeology; virtual reconstructions

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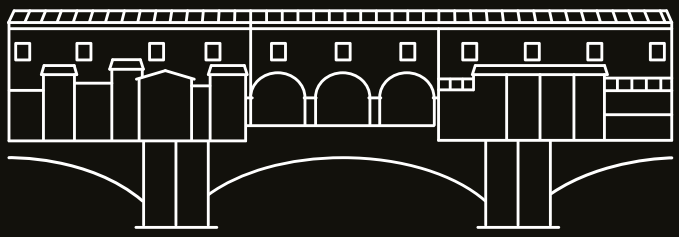

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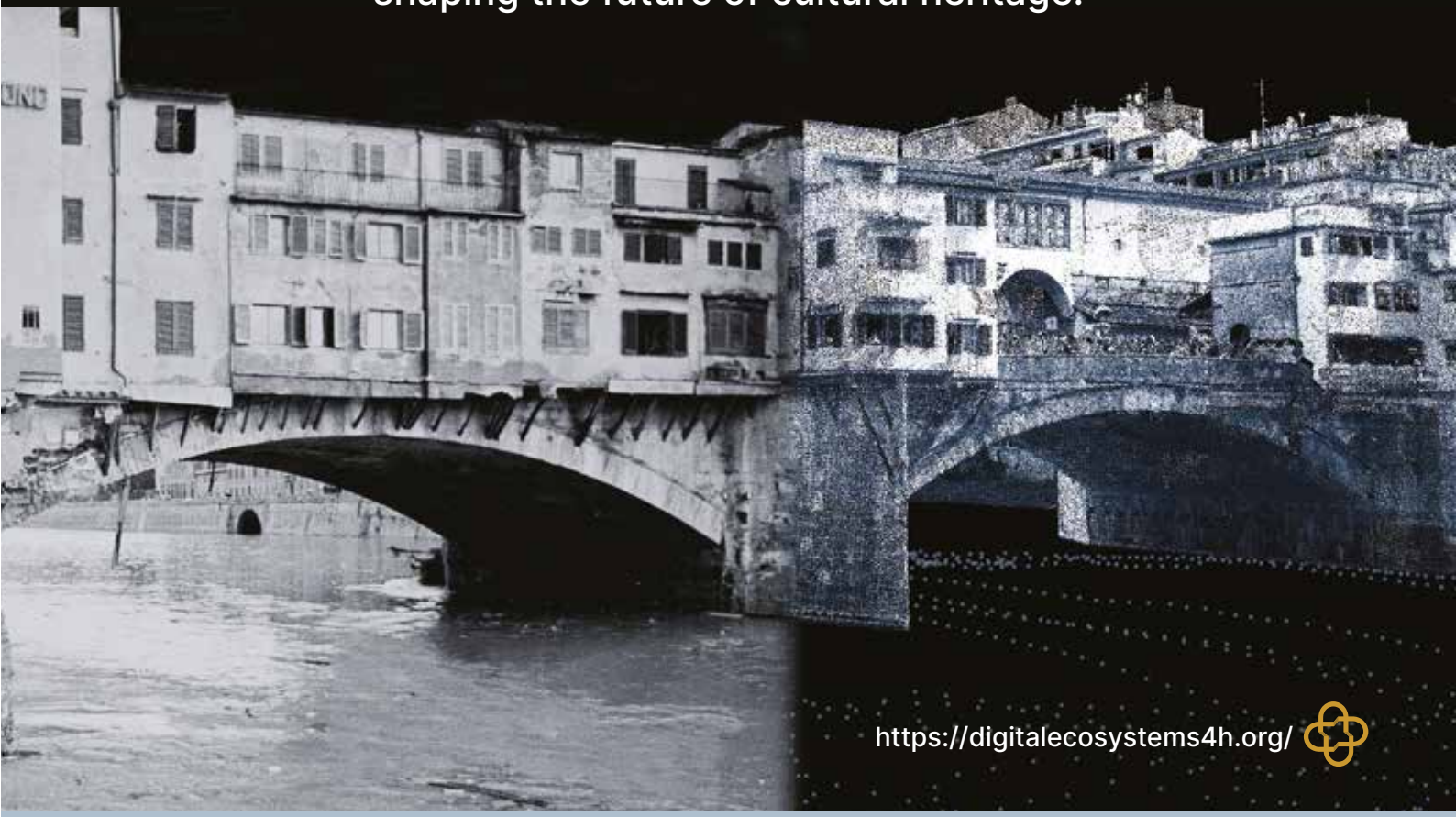

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Magnesia ad Maeander, the Stadium, a matter of scale

by Giorgio Verdiani, Francesco Tioli, Görkem Kökdemir

The Stadium of Magnesia represents a typical large architecture once dedicated to sport activities, the size and the relationship with its environment, together with the remaining details, make it a specific and fascinating survey subject

The Stadium of Magnesia ad Maeandrum is situated in the southwest sector of the ancient city, it was built in the Ist century AD exploiting the slopes between two hills oriented according to a North-South axis. It was built with the logic of a great structure, with a track length of about 189 meters (638 Roman Feet) and an estimated seating capacity of 30,000 spectators, it represents a significant monumental structure in the region and for that age. It was made on the border of the main historical settlement, thus it was thought as strictly connected to the city of Magnesia, as a high quality architecture. Its archaeological investigations had taken a significant step forward since 2008, with methodic excavations, unearthing the stands and starting the discovery of its architectural parts and functional artworks. In time,

Fig. 01 - Entering the Stadium in Magnesia, September 2024.

Fig. 02 - 3D model from UAV/Drone photogrammetry, two views from the textured model version.

the stadium had suffered from multiple old damages caused by seismic activity, terrain movements, floods, vegetative overgrowth, and the looting of stone for reuse and for lime production, but even after such a long series of small and great disasters the stadium remains one of the best-preserved examples in Anatolia and the wider Mediterranean world. Extensive excavation efforts, particularly those concluding in 2018 regarding the *sphendone* (the curved end of the stadium), have revealed architectural properties that distinguish this structure from known contemporaries (Bingöl, 2020).

The reason for the creation of such a complex and extended architecture may be found in its initial dedication to serve as the venue for the *Leucophryena*, a major festival dedicated to *Artemis Leucophryene* (Bingöl, 2005). In this event a series of games were used to take place, they comprised the three

Fig. 03 - Orthophotos from SfM/IM photogrammetry of relieves with gladiator's fights and carriage's races.

primary branches of gymnastics (athletics), equestrian events (mostly horse and chariot racing) and musical competitions. It is of some interest reflecting about the fact that the musical contests were intended for the Theatron, which appears as an incomplete building, which may suggest that the stadium may have served a multi-purpose function. Overall this last feature was not influencing the architectural choices in planning this architecture, which appears oriented to host efficiently equestrian activities and multiple parallel sport exhibitions or matches.

THE STADIUM ARCHITECTURE

The architecture of the stadium features three main technical installations for the administration of races: the start structure, located at the North end, features a complex arrangement of 24 pillars and arches. Excavation of the *postaments* (bases) revealed slots for a mechanism designed to ensure a simultaneous start for all the runners in the race.
The second is the finish line: Located 189 meters South of the start, the finish line is marked

by four double-prismatic free-standing pillars. The spaces between these pillars likely held ribbons to determine the victor. The third Structure is represented by the herms, which are the finish line pillars decorated with double busts, featuring both bearded and clean-shaven figures. These likely commemorate famous athletes, or they may symbolize a philosophical reflection on the duality of victory and life somehow recalling the "Two-Faced Janus" (Janus Duplex) allegorical figure (Casini, 2018). While the Leucophryena included equestrian events, architectural analysis suggests the stadium was ill-suited for heavy chariot racing. The presence of fragile free-standing pillars and Herms at the finish line would have posed a severe collision risk during the high-speed turns required in chariot races. It is therefore posited that the stadium hosted only symbolic or light equestrian events, while it is possible to suppose that full-scale chariot races were likely held in a separate, as-yet-undiscovered hippodrome. The stadium represents a multi-scale architecture, even in ruins the specific features in Magnesia demonstrate how the massive body of the main building is connected to the landscape itself, It is a sign and a trace visible from the distance and its “U” shape create a spectacular entrance from the side of the city. At the same time it soon varied its scale at the dimension of the details, with well defined particular use of rich materials, like multicoloured stones and marbles, creating a constant attention and curiosity in the visitor and a fascinating passage from territorial scale to minimal scratches on stones.

The stadium contains also a significant epigraphic archive, presenting a series of epigraphy elements connected to the ancient social stratification of the city. This is manifest with inscriptions found on seat backrests and podium façades offering insights into the social, economic, and political levels of the inhabitants of Magnesia.

But there are also writes that testify inter-city relations: an inscription on the podium marks a section reserved for the "Ephesians," indicating a formal protocol for hosting spectators from rival or neighboring cities. Other inscriptions tell about professional associations, like those on the 11th, 12th, and 13th cercises, while specific writings name unions and associations. These areas functioned not only as spectator seating but as designated spaces for guild meetings. In the end, the epigraphic writes testify the elite patronage: specific rows were allocated to prominent families. For instance, the "Council of Elders" and members of the Claudian family held reserved seating.

In the variety of sculpted writes, a particularly notable inscription, *Mangragoreiton*, can be found across two rows adorned with bull heads and a lion relief. This refers to the producers of mandrake (Mandragora), a root characterized by a sort of anthropomorphic shape, which historically was associated with aphrodisiac and medicinal properties.

To testify the variety of spectacular activities taking place in the arena, a significant contribution may come from the podium reliefs and their

Fig. 04 - Orthographic view of the whole stadium, September 2024.

clear iconography. In fact, a distinct characteristic of this stadium is the extensive use of reliefs adorning the podium walls of the arena. Although the original plan likely called for approximately 150 reliefs, only twenty-six have been found during the unearthed operations across the twenty-seven cercises (wedge-shaped seating sections). The most significant reliefs were dedicated to athletic and equestrian depiction: the reliefs portray various activities, like horse and chariot racing, alongside depictions of awarded prizes and some talamoni probably used to gather some "good luck" in superstitious gesture from the participants to the competitions. The reliefs representing gladiatorial contexts are undoubtedly extremely fascinating, and capture significant attention. Recent excavations have uncovered these reliefs depicting single and couples of gladiators. However, distinct architectural evidence suggests that the stadium was not the place of Bloody, deadly confrontations, so these reliefs probably do not represent lethal combats. Unlike other structures in the same area, dedicated to gladiatorial matches, likes the *stadia* at Perge or Aphrodisias, Magnesia lacks the protective barriers or high walls necessary to shield spectators from wild animals or desperate combatants. Consequently, it is hypothesized that these reliefs deficit gladiatorial training or exhibition matches rather than fights to the death. Nowadays, the principal group of reliefs is usually protected by a robust metal cage, used to avoid damages from the visitors or potential thieves or vandals.

DIGITAL SURVEY

To digitally document the Stadium and its rich set of artistic and cultural/social elements, it was planned a three step session based on photogrammetry, in September 2024, a team composed by G. Verdiani, A. Camiz and U. Özdemir operated a general coverage of the whole architectural surface of the stadium, operating about 1000 drone/UAV shots and about 5000 terrestrial shots, all these data were processed in a single photogrammetry producing a well detailed general model of the stadium, with an high level of details and full texturing. In September 2025, a unit composed by G. Verdiani, E.C. Giovannini, F. Tioli, A. Rosone, C. Mastroberti and E. Miho operated the photogrammetry of all the reliefs of the podium, getting them in a lucky moment, with all the cages temporarily removed. This produced about 4000 pictures from which It was obtained a full set of very high resolution models and orthophotos of these particular artworks.

The models derived from this second session showed interesting aspects, in fact, It is possible to notice some original features: the size of the stones in the podium is constant in height (about 82 centimetres) while the widths may vary. This variation sees the realization of the reliefs on one main stone, but then, they are easy at having parts on the consequent block, even for just minor details or small parts of the figures. In this way there is often the presence of richly sculpted stones connected to almost flat ones if not for single details. This may allow us to hypothesize the original presence of painting completing the scene and having the reliefs emerging in colours and from a flat scenario. Something impossible to verify, while time and nature have completely cancelled any trace of paint from the surfaces, but something stimulating the speculation about the original aspects of the arena and worth of further research. In the end, the third session would be planned in the future for completing the survey of the writes and decorations along the stands. The aim is developing a 3D map of this specific built heritage using the main model of the stadium as a reference for each detail making possible and easily accessible a multi-resolution model of this fascinating building.

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Abstract

The Stadium of Magnesia ad Maeander represents one of the most monumental and well-preserved athletic architectures of Asia Minor, distinguished by its scale, architectural complexity, and rich cultural significance. Built in the first century AD along the slopes of two hills, the stadium accommodated approximately 30,000 spectators, closely connected to the city's civic life. Archaeological investigations have progressively revealed its architectural layout, installations for athletic competitions, and extensive sculptural and epigraphic programs. Originally associated with the Leucophryena festival dedicated to Artemis, the stadium hosted a wide range of events. Architectural analysis, however, suggests that its design was optimized primarily for athletic and light equestrian activities rather than full-scale chariot racing. Of particular importance are the reliefs decorating the podium walls and the numerous inscriptions carved on seating and architectural elements, which provide valuable insights into social stratification, professional associations, inter-city relations, and elite patronage within Magnesia. Recent digital documentation campaigns employing UAV and terrestrial photogrammetry have enabled the creation of high-resolution 3D models of the stadium and its sculptural elements. These digital datasets support multi-scalar analysis, enhance interpretative possibilities, and contribute significantly to the long-term study, conservation, and dissemination of this exceptional architectural complex.

Keywords

Architecture; Archaeology; 3D model; UAV; Drone; photogrammetry; mesh; texture

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On Stage in Antiquity, On Screen in the Digital Age:

Two Thousand Years of urban presence and integration of the Theatre in Priene

by Giorgio Verdiani, Andrea Rosone

The theatre of Priene, among the best-preserved in Asia Minor, represents an exemplary case study for testing integrated methods of digital surveying, procedural modeling, and virtual reality applied to archaeology.

ANCIENT PRIENE AND ITS THEATRE

Priene was founded in the Caria region of the western part of Anatolia, the present Turkey, the settlement is situated on the southern slope of Mount Mykale, overlooking what in antiquity was a gulf opening into the Aegean Sea. From the Archaic period to the Hellenistic age, however, the silting of the Maeander river, once entering the sea at the East of Priene, had gradually pushed the coastline westward, detaching Priene from the seashore that had once defined its economy and strategic importance. The city was architecturally realised in the IV century BCE, providing a model environment for the implementation of a rational, orthogonal urban plan, organized in a series of large terraces, the sloppy topography imposed constraints that required a specific architectural attention, producing one of the

Fig. 01 - View of the theatre, July 2022; View of the archaeological site of the theatre. Panorama taken during the photographic survey phase.

clearest surviving examples of Hellenistic city planning. Priene is a paradigmatic example of urban planning of that time (Wycherley,1945). Its street grid, in which It Is possible to recognize the Hippodamian principles, organises the city into regular sectors aligned to the cardinal directions, though subtly adapted to the mountain slope. Public buildings at Priene, including the Agora, the Bouleuterion, the Prytaneion, and the Theatre, participate in a coherent architectural vocabulary, presenting specific solutions, but remaining coherent to the city layout.

The Theatre of Priene is situated on the third urban terrace of the ancient city, in an intermediate position between the agora and the sanctuary of Athena Polias. The building, exploits the terrain and cliff slope and has most of the additional parts and all the external elements constructed in marble blocks. It exhibits the canonical articulation of Greek theatres (Lawrence, Tomlinson, 1996): cavea, proedria, orchestra, proskenion, stage building, and parodoi. The cavea is organized into five radial sectors, separated by six stairways approximately 0.92–0.96 metres wide. The lower rows are carved directly into the rock, while the upper ones rest on an artificial foundation made of regular stone blocks; only part of these upper rows survives today, while many of the benches have been lost. The seats consist of superimposed slabs with an average height between 39 and 40 centimetres, calibrated to the natural slope of the hillside.

The curved layout of the benches, reconstructible thanks to historical surveys and comparison with photogrammetry, shows slight irregularities suggesting the use of arcs with non-coincident centers. This aspect, apparently secondary, becomes relevant in digital modeling because it requires avoiding geometric simplifications that are too rigid and would misrepresent the original construction logic.

Between the cavea and the orchestra lies the proedria, arranged as a paved band of stone blocks that hosted the row of honorary seats. In this area, five marble thrones and a central altar are still preserved, elements likely added during a later phase compared to the original configuration. The thrones feature articulated bases, lion-paw legs, ivy motifs, and curved backs with Ionic-volute armrests; the quality of the carving and attention to detail confirm the representative function of this zone, reserved for civic and religious authorities. The orchestra measures 18.65 m in diameter and corresponds almost exactly to the length of the proskenion. The latter represents one of the distinguishing features of the Theatre of Priene, as it preserves twelve frontal pillars and several lateral ones still standing. The Doric entablature, now fragmentary, originally displayed rich polychromy: triglyphs outlined in purple, metopes alternating in black and white, red cornices and fillets, blue architraves. These painted traces, documented by Wiegand and Schrader, were adopted as references for defining materials in the digital reconstruction (Wiegand, Schrader, 1895-1898). From the proskenion façade, stone beams project toward the rear, connecting the scene front to the back wall and supporting the wooden floor of the upper level. The stage rooms, now completely lost, were accessible through five doors whose positions are reconstructible thanks to historical drawings. The stage building, particularly its vertical development and its relationship with the proskenion, was reconstructed following the hypothesis proposed by Armin von Gerkan, which integrates the Priene data with typological comparisons to other theatres (Gerkan, 1921). The parodoi, located on the sides of the scene, still preserve their masonry access structures and constitute an additional point of comparison between the existing state and the reconstruction.

Overall, the Theatre of Priene stands out for the exceptional amount of preserved lower architectural elements and for the quality of the historical documentation available. This dual condition makes it possible to produce a digital reconstruction that does not merely offer a formal restitution but explicitly clarifies the relationship between what is preserved, what can be reconstructed with reasonable certainty, and what remains hypothetical.

THE PHOTOGRAMMETRIC SURVEY

The definition of the current state was carried out through a photogrammetric survey that combined ground-based and drone-based imagery. A total of 824 images were acquired: 795 ground shots taken with a SONY ILCE-6000 mirrorless camera and, for the detailed recording of

the proedria, with a Nikon D800e equipped with a macro lens; and 29 aerial images, produced using a DJI Spark drone flying at low altitude above the orchestra and the cavea. The ground shots followed a radial path along the cavea and a linear path along the proskenion, with multiple fan-shaped captures to ensure redundant coverage of shaded areas.

Processing was performed in RealityCapture. The initial alignment of the images generated several separate components due to the presence of vegetation, visual discontinuities, and scale differences between aerial and terrestrial shots. To bring the model into a single reference system, shared Control Points were identified across the various components, placed on clearly recognizable elements (slab edges, throne bases, joint intersections). Introducing at least three common points made it possible to merge all components into a single macro-model.

DIGITAL MODELLING

The goal of the digital modeling process was not to produce a single static model, but

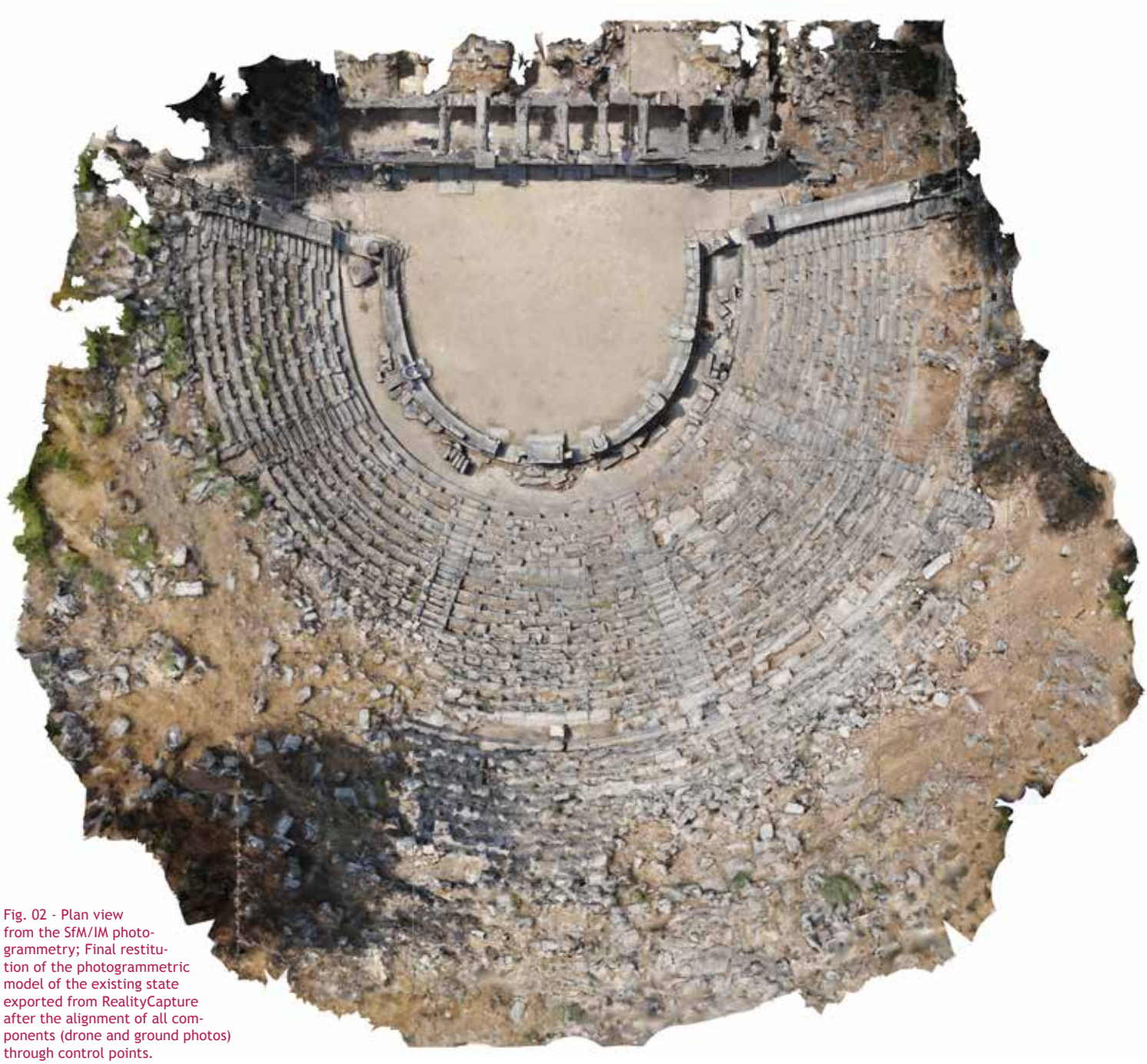

Fig. 02 - Plan view from the SfM/IM photogrammetry; Final restitution of the photogrammetric model of the existing state exported from RealityCapture after the alignment of all components (drone and ground photos) through control points.

Fig. 03 - Digital reconstruction of the theatre; Final phase of the modelling process in Blender, after importing the construction details through metadata via a Python script. The resulting model was obtained by refining the construction details through sculpting and texturing using OpenShadingLanguage.

to construct an information structure capable of explicitly describing the geometric and typological functioning of the theatre. To this end, the work was carried out in Rhinoceros 7 with the support of Grasshopper, organizing the complexity of the monument into a network of objects, instances, and metadata.

Deconstruction and macro-structure

The theatre was divided into five macro-groups: cavea, proedria, orchestra, proskenion and stage building, and parodoi. Each group includes sets of recurring elements: steps, benches, bases, backs, thrones, columns, pillars, beams, slabs. For each typology, a single reference object was modeled, conceived as a simple geometric "prototype." The repetition of elements within the theatre occurs exclusively through instances, generated and controlled parametrically.

This choice makes it possible to drastically reduce the computational weight of the model, simplify updates, and make the relationship between typology and occurrence explicit. Any modification to the reference

object automatically propagates to all its instances, maintaining the overall coherence of the system.

Generative elements

Generative elements are abstract geometries that define the spatial arrangement of the components. Linear elements rely on points and vectors, curved ones on oriented curves, and complex joints on reference planes or surfaces. The curves were extracted from the photogrammetric model by projecting the outlines of the cavea, the proedria, and the proskenion onto plan view and removing local irregularities.

These curves were parametrized within the 0–1 interval, assigning each parametric value a point in space and a local reference system (a triad of axes). On these planes, the transformations required to place the instances, translation, rotation, and, where necessary, slight scaling, were calculated. This ensures that the repetition of seats or proskenion blocks follows the real curvature of the theatre, including small deviations from an ideal geometry.

In areas where the original blocks are no longer present, particularly in the upper part of the cavea, the arrangement was reconstructed by interpolating the available data: the average distance between slabs, the apparent radius of preserved sectors, and the alignment with the retaining walls. The geometric assumptions adopted were explicitly marked in later stages through metadata categorization (Rosone, Verdiani, 2024).

The resulting mesh was densified and subsequently simplified, maintaining high definition in key areas (proedria, proskenion, orchestra) and reducing detail in peripheral zones. A set of high-resolution textures preserved the chromatic and material information necessary for the reconstruction phase. Metric verification was carried out by comparing the model with the measurements recorded by Wiegand and Schrader: the deviations observed fall within an acceptable margin for an indirect survey, making the model suitable for the subsequent phase of procedural modeling.

Objects, instances, and deformations

The objects were modeled in Rhinoceros as low-complexity meshes, sufficient to clearly describe the basic form of each element. The instances are generated in Grasshopper, which calculates for each one the full set of transformations derived from the generative elements. This procedure produced thousands of components with complete control over their positioning.

For curved elements or those adapted to non-planar surfaces, such as the backs of the proedria or certain slabs of the cavea, the process continued in Blender using CurveDeform and similar modifiers. In practice, the linear object is “wrapped” along a reference curve while maintaining consistent proportions and detail. Here as well, the deformation is described within the metadata, ensuring that the relationship between object, curve, and instance remains fully traceable.

XML metadata

The informational structure of the model is defined through a metadata system exported in XML format (Erik T. Ray, 2001). Each object and each instance corresponds to a node within the XML tree and is described through:

- the name of the typological object;
- the path to the reference mesh file;
- any associated generative curve or surface;
- position, rotation, and scale coordinates;
- the assigned morphological variant;
- the reliability category (existing state, confirmed reconstruction, hypothesis).

This structure allows the model to be reloaded and regenerated across different environments without loss of information. The XML file therefore does not simply list objects: it describes the procedural logic that determined their spatial arrangement, enabling the entire process to be reconstructed directly from the data.

Once the procedural model was generated, it was imported back into Rhinoceros and overlaid onto the photogrammetric mesh. Verification concerned both geometric coherence and the relationships between parts (alignments, symmetries, distances between key elements). To express the degree of reliability across different portions, a chromatic classification system was adopted: green for elements matching the surveyed existing state; yellow for parts

reconstructed with strong support from historical sources; red for hypothetical elements, especially in the upper portions of the stage and the higher levels of the proskenion.
This visual distinction, combined with the categories stored within the metadata, allows anyone using the model to immediately recognize the nature of each element, avoiding the misconception of a unified reconstruction when in reality it is based on very different levels of certainty.

DIGITAL RENDERING AND PHOTOREALISM

The transition from procedural modeling to graphical rendering

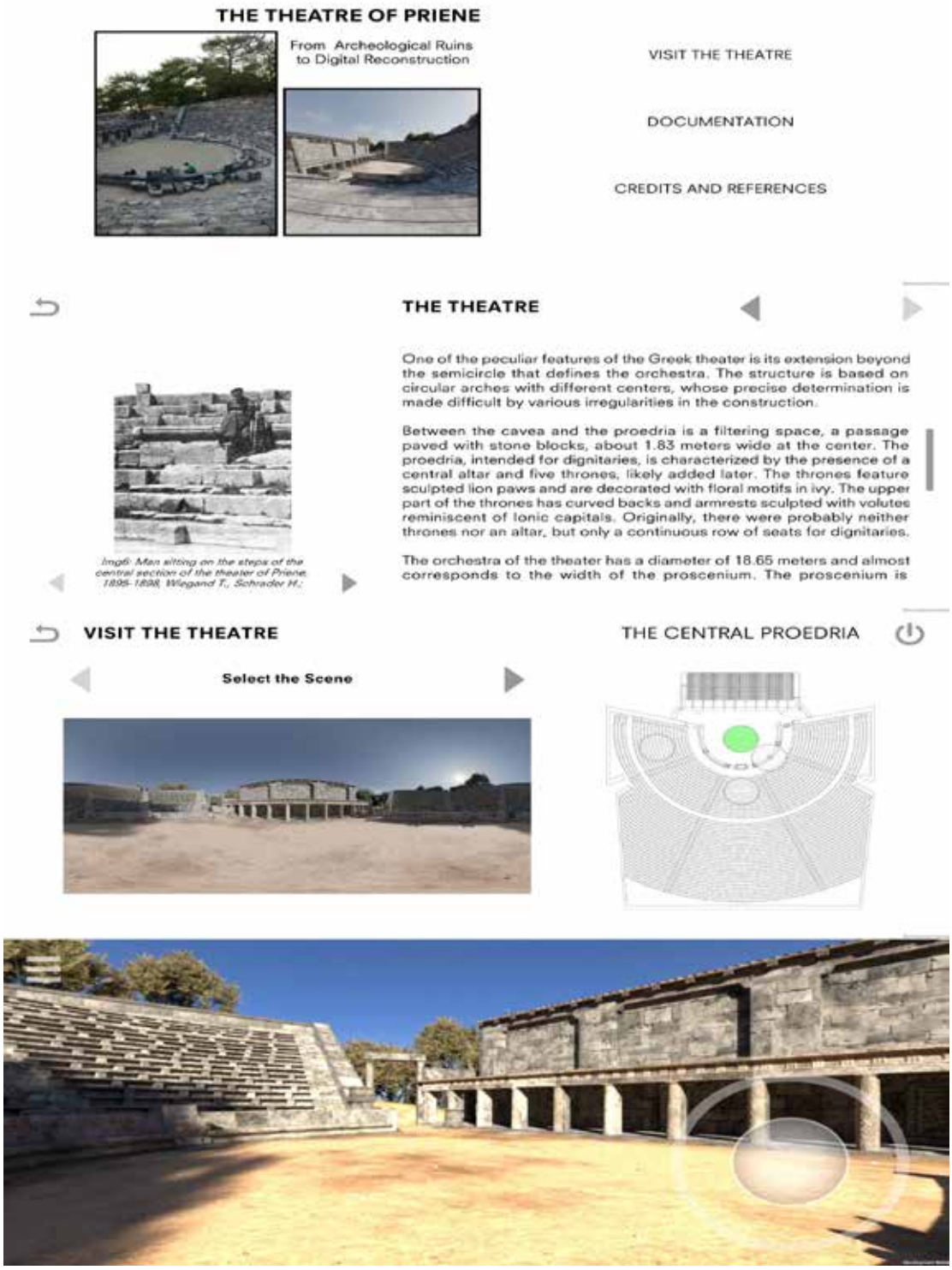

Fig.04 - The APP for the virtual visit, screenshot from the 3D and contents; Through the app, created with Unity, it was possible to select viewpoints exported from the final model as HDRI panoramas for the exploration of the reconstructed site according to the archaeological hypotheses.

took place in Blender, where the model was imported together with its XML metadata. The goal was not merely to obtain a convincing image, but to construct a scene consistent with the historical period chosen for the reconstruction, corresponding to the Doric phase documented by Wiegand, Schrader, and Gerkan, while excluding later additions from the advanced Hellenistic and Roman periods.

Sculpting and morphological variants

Although typological objects had been modeled correctly, they initially appeared too "perfect" when compared to the real appearance of stone blocks. For this reason, each object underwent a sculpting process (Xury Greer, 2022), which involved temporarily increasing polygon density in order to add micro-irregularities such as chipped edges, abrasions, small fractures, and depressions. The work was carried out using a graphics tablet, treating the elements as proper digital sculptures.

From each base object, several variants were then produced, differing in the intensity of imperfections and fracture patterns. During scene generation, these variants were assigned to instances through a controlled randomization system, avoiding visual repetition and restoring the natural heterogeneity of the materials.

Procedural materials

In parallel with geometric work, material definition was developed. Based on the photographic dataset from the survey, reference textures were created and integrated with procedural maps in Blender's Shader Editor. Normal, roughness, and displacement maps were combined to reproduce the grain of the stone, surface absorption variations, and ageing effects.

The procedural component, managed also through Open Shading Language (Larry Gritz, 2020), introduced microscopic random variations in color and roughness without requiring an excessive number of distinct textures. Here too, the link between material and instance is stored within the metadata, enabling controlled regeneration of the model in different environments.

Environment and context

The theatre was placed within a simplified environment reproducing the current landscape of the site, without reconstructing the entire ancient city to keep computational costs and complexity under control. The main slope, selected vegetation masses, and an HDRI-based lighting setup were modeled and calibrated to simulate neutral daylight. This configuration allows for a clear reading of the theatre's volumetry, cast shadows, and the overall visual effect of the scene reconstructed according to Gerkan's hypothesis.

VIRTUAL REALITY

The model, once prepared, was exported into Unity for the creation of an immersive environment (J. G. Bond, 2017). The goal was to offer a virtual visit experience useful for comparing the current state with the proposed reconstruction.

Importing and optimization in Unity

Within the game engine, several panoramic camera positions were created, corresponding to significant viewpoints: the orchestra, the proedria, the lateral sectors of the cavea, and the lowered viewpoint at stage level. Each position was transformed into a 360° panorama, allowing the user to explore the surroundings through gyroscopic sensors or standard joystick-based controls.

Interface and interpretative functions

The navigation interface features a simplified map of the theatre, with buttons enabling rapid selection of the desired viewpoint.

The application was developed for Android devices and desktop computers, with the possibility of use both through VR headsets and in "flat-screen" mode. This dual configuration makes it suitable for exhibition and museum contexts as well as for educational and research scenarios.

CONCLUSIONS

The work carried out on the Theatre of Priene shows how the integration of historical sources, photogrammetric survey, procedural modeling, and virtual reality can generate a digital model that is not merely a three-dimensional replica, but an actual tool of knowledge. The centrality attributed to Armin von Gerkan's reconstruction hypotheses for the scene, verified

and integrated in light of the survey and the documentation of Wiegand and Schrader, demonstrates how digitalization does not replace archaeological judgment, but makes it more readable, verifiable, and communicable.

The decomposition of the theatre into typological objects and instances, described through XML metadata, enabled the construction of a scalable, updatable, and interoperable information model across different software environments. The rendering phase in Blender transformed this abstract model into a photorealistic scene able to convey the material quality of the marble, the imperfections accumulated over time, and the spatial articulation of the complex. The implementation in Unity finally made the theatre an explorable environment.

In this sense, the Theatre of Priene becomes a laboratory for defining procedures that can be transferred to other contexts of archaeological heritage: a method that starts from historical documentation, compares it with digital surveying, builds a transparent procedural model, and returns it in accessible an d immersive forms. The scene, which in antiquity hosted theatrical performance, became today a space for the representation of knowledge, no longer only a place of spectacle, but an interface between data, interpretations, and contemporary audiences.

From a methodological point of view, one of the most significant outcomes is the possibility of keeping three levels separate yet in continuous dialogue: the measured data, its geometric abstraction, and its immersive translation. The transition from the survey to the VR scene does not occur in leaps, but through a chain of traceable transformations, each of which leaves a “signature” within the metadata. This makes the model not only reusable but also open to critical revision: a hypothesis can be replaced, a parameter updated, an entire section regenerated without having to start again from scratch. In a context where technologies evolve rapidly, this capacity for adaptation becomes a fundamental requirement for any digital archaeology project that aims to endure over time.

Abstract

The Theatre of Priene is a well-preserved example of Greek theatrical architecture, offering an exceptional case study for the integration of historical documentation and digital methodologies. The theatre dates to the late Classical and early Hellenistic period and preserves cavea, orchestra, proedria, and proskenion. It was the subject of extensive documentation during late 19th-century excavations, which provides a solid foundation for interpretative reconstruction. This study presents a comprehensive digital workflow combining photogrammetric survey, parametric modelling, and virtual reality visualisation. UAV and terrestrial photogrammetry allowed producing a metrically reliable 3D model, subsequently refined through data cleaning and validation against historical sources. The model was then transposed into typological elements governed by generative rules, enabling the creation of a metadata-based system. The integration of detailed modelling and material rendering further enhanced the legibility of architectural forms and surface characteristics. Finally, the digital model was implemented within a virtual environment to support immersive exploration and comparative analysis between the current state and reconstructed hypotheses, demonstrating how the convergence of archaeological evidence, digital survey techniques, and advanced visualisation tools can produce a coherent and accessible narrative for both scholarly investigation and public dissemination.

Keywords

Architecture; Archaeology; 3D model; UAV ; Drone; photogrammetry; mesh; texture; Virtual Reality, APP; digital reconstruction;

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The value of itinerant fragments between Asia Minor and Europe

by Giorgio Verdiani, Pelin Arslan, Elisabetta Caterina Giovannini

Fig. 01 - Photogrammetric 3D model of the statue of priestess Nikeso (inv. Sk 1928), with QR code for direct access to sketch-fab.com (https://skfb.ly/

Built heritage embodies accumulated layers of human activity, including construction, transformation, abandonment, reuse, destruction, and rediscovery. Each monument or archaeological site constitutes a palimpsest whose interpretation requires both technical rigor and intellectual sensitivity. When the life of a building brings it to the present time, in the form of archaeological remains, it may appear as a fascinating ruin or a poor mass of rubbles. In any case it may offer an interesting occasion of reconstruction and a complex situation of musealization or reuse. It may bring in its ruins the presence of invaluable artworks, statues, mosaics, frescoes, past items for everyday life, and even old weapons.

These elements are well known by archaeologists or other professionals in the field of cultural heritage, in practices that often collect and may take in a short trip these findings to a restoration and then to a local museum or to some abroad destination. This second condition was extremely common during the past two centuries. The collection and exhibition in the museum of findings from the smaller to entire parts of architectures, was a procedure seen as aimed at the preservation of important materials from difficult context and was supported by the early passage from a logic of "collection" to the one of "patrimony of humanity". Thus, when architectural fragments have been removed from their context and relocated to museums, the results in spatial and interpretive disconnections may complicate reconstruction efforts. The "itinerant" artworks,

parts or other archaeological findings, may be resumed into two main categories: the first collects those items, like small statues, tools, accessories and artworks which are independent from the architectural setup of a place, which may have a minimal impact on the aspect and readability of an archaeological site and/or its physical or virtual reconstruction. The second regards statues and architectural parts that are key elements in the reading and interpreting the original shape of the archaeological building, which once removed and placed in a museum cause a lack in the possibility of reading their balance between the architectural dimension and the displaced part. For example, in the course of the XIX and XX centuries, archaeological exploration of monumental sites in Asia Minor led to the discovery of large urban scenarios, recovering significant sets of findings and moving them to European museums for restoration, study, safe storage and exhibition. About one century later, digital technologies provide the means to mitigate the spatial and interpretive fragmentation caused by historical removals. Photogrammetry, modelling from point-cloud dataset, and 3D visualization enable precise comparisons between objects preserved in museums and those remaining in situ. These techniques allow scholars to virtually reunite dispersed materials, reconstruct their architectural relationships, and reassess hypotheses regarding their original placement or function. Even more, the creation of proper digital replicas, potentially allow the physical reconstruction of dispersed items, their completion with missing parts, interpolation by abstraction, or using reference models, and then allow the production of real parts that may be put back in place in the best affordable conditions. In fact, it is important to remember that all the displaced items have no chance in going back to their original site, they may, at the best, go back into another museum, while an accurate reproduction can go back on site, in a digitally enhanced anastylosis that put no threat to the original piece.

Fig. 02 - Entrance of the Demeter and Kore's Sanctuary in Priene, partial view of the area where once the statue of priestess Nikeso was placed. September 2025.

Developing researches in this field appears extremely interesting, recomposing the parts has also the additional value of recreating a two ways condition that is very valuable, from one side it is possible to bring back virtually or even physically one or more missing parts to their original location, not as ruins, but as working part of a reconstructed system; from the other it is possible to enrich the present location of the item or parts with a virtual environment that re-connect the subject to its original location. A sort of double site-specific setup that can be considered one of the most innovative progresses in exhibition setup.

Taking as subject a small set of statues and architectural remains from Priene, in the Hellenistic area of the actual Turkey, whose excavation and subsequent dispersal of artefacts, particularly to Berlin, appeared like an ideal test research aimed at the digital reunification of items and places using digital solutions. The occasion to start this experiment of virtual recompositing of the parts between Priene and the European museum

Fig. 03 - Photogrammetric 3D model of the partial reconstruction of an altar, Priene, Sanctuary of Athena Polias, ca. 200 BCE, Pergamon Museum, Berlin, with the QR code for direct access to sketchfab.com (https://skfb.ly/pEuOw).

was supported by the kind availability from the Altes and Pergamon Museum in Berlin, in the specific, a special thank goes to the director of both museums, Martin Maischberger, who hosted and gave full availability welcoming and trusting a first series of surveys in both museum collections. In October 2022 and in May 2024, two single days of photogrammetric operations allowed taking the data from some significant items and starting a study about how to restore a link between places and elements using digital models. The Altes museum hosts mostly statues, with only one, the Priestess Nikeso, with a clear and specific relationship with the architectural space; all the architectural parts are instead preserved at the Pergamon museum. In the case of the statue of Priestess Nikeso, its finding happened in 1898 in the

Fig. 04 - The 3D digital model of the entablature from Priene exhibited in the archaeological museum in Mileto, with the QR code for direct access to sketchfab.com (https://skfb.ly/prJS9).

ruins next to the statue in-situ plinth, in front of the main entrance to the Sanctuary of Demeter and Kore. The sculpture consists of two main parts: the statue, missing the head, and its plinth, the overall height is of about two metres. The statue of the priestess is made of fine-grained yellowish-white marble, while the plinth is made of grey crystalline marble it may be supposed to be a reused element, on it there is a write in Greek indicating "Nikeso, daughter of Hipposthenes, wife of Eukritos, priestess of Demeter and Kore". The figure is upright, with her upper body and shoulders slightly turned left. The other statues digitalized at the Altes Museum and coming from Priene are: a Statuette of Dionysus (height: 70.5 cm), a Statuette of Aphrodite (height: 61.5 cm), a Statuette of a Young Man (height: 76.5 cm), a fragmented statuette of Alexander the Great (partial height: 31.6 cm). All these statues present a high artistical value, thus they can't be defined as key elements of an architectural space. Instead, the statue of Nikeso looks clearly in a robust relationship with the spatial organization of the Demetra's Temple, defining a specific aspect of its entrance. The architectural parts at the Pergamon museum were a partial reconstruction of an altar, with a statue and a small fragment of bass-relief coming from the Sanctuary of Athena Polias, ca. 200 BCE, a partial reconstruction of the Sanctuary of Athena Polias' entablature, and a partial reconstruction of the temple entablature, from the Temple of Asklepios, the Agora, IVth-Ist centuries BCE. For the entablature from Athena Polias, it was possible to have a parallel with another part, this time hosted at the Archaeological Museum in Mileto, Turkey another part of the same architecture, migrated not that far, but another fragmentation of the original building. The full survey work in Berlin was conducted by photogrammetry, using specific cameras and lenses to help achieve the most complete and optimized results and with the benefit of using movable scaffolding in the case of the Pergamon Museum. The survey operation in Priene was completed using both photogrammetry and 3D laser scanner survey, this second option was extremely efficient for the survey of the large architectural remains in Priene in 2022 during the workshop. The photogrammetry was instead used on architecture for the Demetra's temple, covered by a combination of terrestrial and drone/UAV shooting as side activity during the workshop in Magnesia in 2025. At the moment of writing the development of the research is still ongoing, the first complete digital recompositing will be probably the virtual recoloration of the Priestness Nikesa in the ruins of the Demetra's temple on the Priene hill.

Abstract

Built heritage constitutes a layered record of human activity, often surviving as fragmented architecture and dispersed artefacts. Historical excavation practices frequently removed architectural elements from their original contexts, generating spatial and interpretive disconnections. This study explores the potential of digital technologies to virtually reunite displaced heritage, focusing on selected statues and architectural fragments from the Hellenistic city of Priene, now divided between the archaeological site and museums in Berlin. Through photogrammetry, laser scanning, and 3D modelling, the research investigates original spatial relationships and proposes a dual framework in which digital recomposition enhances both archaeological interpretation and museum presentation while preserving the integrity of the original artefacts.

Keywords

Built heritage; digital recomposition; digital technologies; fragments; photogrammetry; laser scanning; 3D modelling; spatial relationships

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Other Subjects, same approaches

By Andrea Pasquali, Ylenia Ricci, Stéphane Giraudeau.

Contemporary architectural practice often privileges new construction, risking the loss of architecture's socio-cultural dimension in favour of standardized, market-oriented production. This paper argues for the re-emergence of reuse as a fundamental design strategy, rooted in historical building practices that emphasized adaptation and material continuity.

The contemporary evolution of people's identities and the fragmentation of cultures developed in the modern age, supported by current geopolitical ideologies, define a highly urgent landscape. Today's conception of architecture tends to consider the boundary of the territory as a rigid and defined category, fixing languages, methods and materials within coherent but obligatory design models. We are faced with a form of engineering of design thinking that could lead to the loss of the socio-cultural component of architecture in favour of a consumerist application of the activity of building. The danger is that architecture will become more of a product to be consumed than a cultural act, transforming itself into something standardised, fast, productive and market oriented. Although much of contemporary practice concerns existing heritage, the imagery of today's architecture continues to emphasise new construction as the prevailing model of innovation. Technological progress and the demand for low-impact buildings have led to architectural works being conceived as a set of new components, created or assembled at the same time as the building itself.

This approach to design reached its peak in the second half of the XIX century and continues today as the correct and canonical method, defining architectural design as the use of "the new" as the only strategy for resolving a project. Looking at the history of architecture and construction, particularly before the industrial revolutions, and more markedly in the former but subsequently also in the civil/popular sphere of the latter, the act of building (adapting and reconstructing) has always been associated with strategies for reusing and adapting architectural components and building materials. By its very nature, reuse, both as a practice of stripping and as recovery from rubble, is not subject to a codifiable method or a defined proportional measure, and constitutes an essential element of design identity. The rhetoric of the new introduced by industrial society and amplified in the twentieth century by the shift away from the rural world has gradually marginalized this dimension. However, in contemporary times, reuse must re-emerge as an integral part of the act of building. A mindset oriented towards reuse can facilitate the search for design solutions capable of minimising the impact of new works on the environment and, at the same time, attributing a higher identity and historical value to the building. Looking back at history, where the use of non-contemporary architectural fragments in new constructions is a recurring practice, it is possible to recognise in these grafts the strongest elements of cultural continuity and memory of the built environment. Furthermore, the presence of such elements helps us to understand the evolution of the property and adds to the architectural object's response to living a method of archiving, not only of the artefact but also of the historical events that took place during its construction. The interpretation described above has matured in our contemporary age thanks to cultural movements and dialogues that emerged at the dawn of the

Fig. 01 - Rendering of the current state inside the Basilica Cistern.

modern world. structuring the interpretation of architecture from a historical perspective. It is easy to accept that the design philosophy of the past was not guided by this awareness but rather by a functionalist approach that led to the choice of existing components because they were more advantageous both in economic terms and in terms of optimising processing times. This outlines a basic structure more consistent with the functionalist perspective of post-industrial modernist thinking, which finds accuracy in the statement "architecture is an image of its time because it is the fruit of that time". So, what is the architecture of this time? Can our contemporary world still conceive of building as a form of writing with characters and methods generated entirely from scratch, or, learning from the past, evolve into a more reasoned form that allows for reuse and goes beyond the functionalism for which it was created, arriving at a more culturally evolved and useful profile?. This line of reasoning aims to open up a possible interpretation of the design structure without providing a final summary. The input of interest is to describe cases addressed in past research and work that define a useful set of elements to justify the reasoning profile. A case study particularly relevant to this theoretical framework is represented by the Medusa protomes preserved in the Basilica Cistern in Istanbul. These are two stone blocks carved with the head of Gorgon, most likely belonging to previous monumental contexts and reused during the construction of the great cistern commissioned by Justinian in 535 AD (Önlü, 2010; Kaldellis, 2016). Their current location, used as bases for two columns, is an eloquent example of the transition from spolia in se to spolia in re (Settis, 1984): the elements, created with a specific symbolic and apotropaic function, lose their original meaning and take on an entirely pragmatic and structural role within the new architectural structure.

Their reuse, devoid of iconographic intent and determined by considerations of material availability and constructional functionality, has nevertheless produced a paradoxical effect: it is precisely this practical reinterpretation that has ensured the preservation of the artefacts to the present day. The protomes, which survived because they were transformed into simple supporting elements, are therefore an emblematic example of how reuse can alter, suspend or overwrite the original cultural value while ensuring the material survival of the object.

Survival that is perpetuated over time thanks to recent technologies for the digitisation of architectural heritage, which allow specific means and methodologies to be used to collect data (Guidi, 2013), produce material and bring to light faded morphologies of ancient ruins, giving them new life in the digital age. A new dimension of usability is created for the asset, and the reused fragment becomes a cognitive artefact, capable of inhabiting digital, virtual and immersive scenarios, inaugurating a third life in the present.

One of the further potentials of digitisation lies in its ability to restore context to fragments that, for various reasons, have found themselves without a background capable of enhancing them. A representative case is that of the Tetrarchs of St. Mark's Square in Venice (Verdiani, 2019), a double group of statues in Egyptian red porphyry depicting four figures in high relief, located at the corner of St. Mark's Treasury. During their removal, one of the statues lost a foot, but the fragment, now preserved in Istanbul, is nevertheless deprived of its original context and displayed in a secondary position. This creates the risk of a lack of knowledge and requires an interpretative awareness about the artefact. Digitisation can help to remedy through virtual reconstruction and a new narrative of its historical and material value, promoting its dissemination to the masses (Verdiani et al., 2022).

In light of these considerations, the issue of reuse takes on a dual significance. On the one hand, it constitutes a current and necessary design approach, capable of reducing the impact of new works and restoring meaning and identity to buildings. On the other hand, it is precisely the reuse adopted in past centuries that has allowed the survival of numerous architectural elements which, reinserted into subsequent structures, have survived the passage of time to the present day. It is thanks to this material continuity, the result of layered grafts and reuses, that we now have a rich heritage, ideal for digitisation, documentation and accessibility through contemporary digital survey technologies.

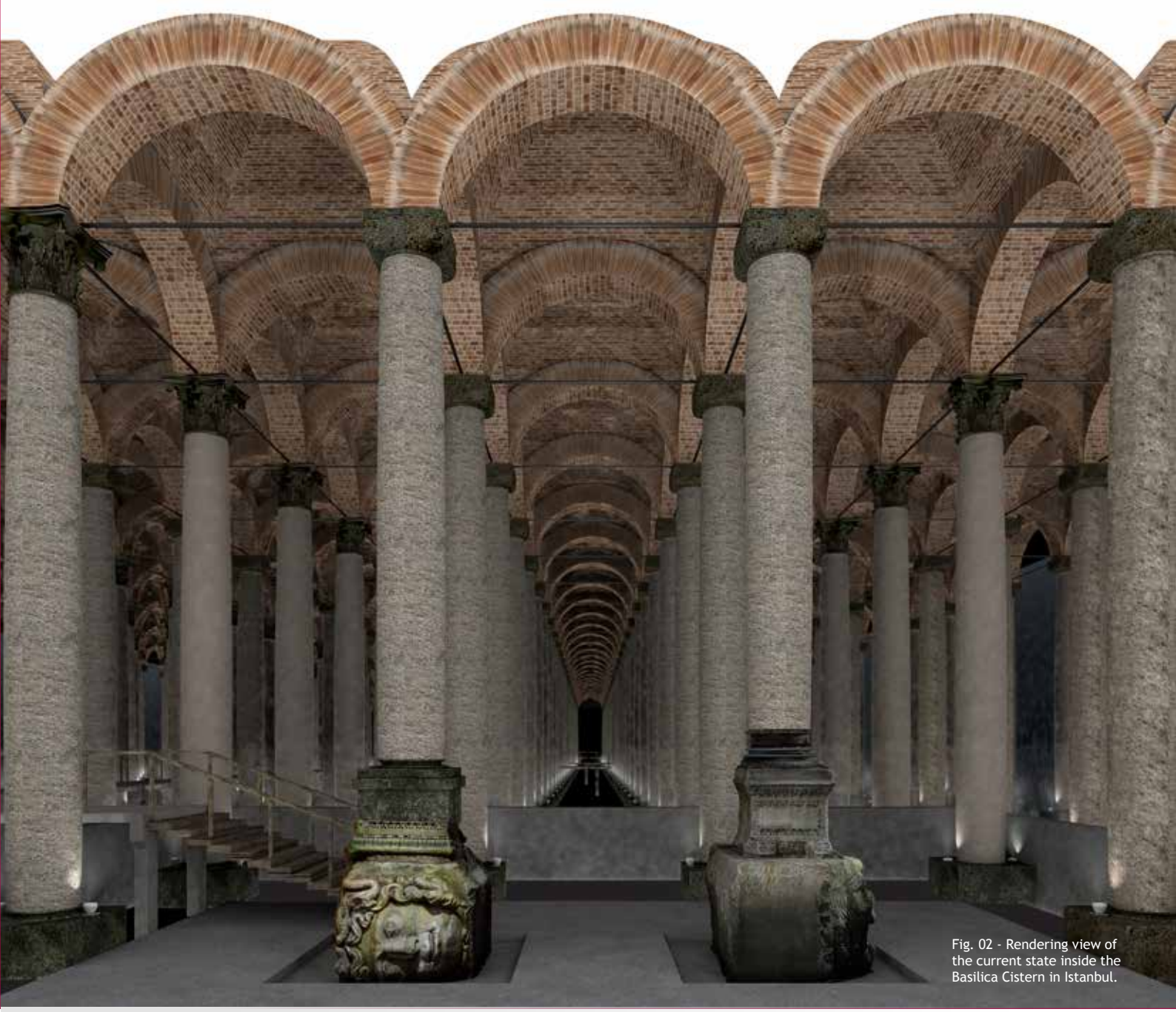

Fig. 02 - Rendering view of the current state inside the Basilica Cistern in Istanbul.

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Abstract

Contemporary architectural practice often privileges new construction, risking the loss of architecture's socio-cultural dimension in favour of standardized, market-oriented production. This paper argues for the re-emergence of reuse as a fundamental design strategy, rooted in historical building practices that emphasized adaptation and material continuity. Through the lens of architectural spolia, reuse is interpreted as both a pragmatic and cultural act, capable of preserving memory while transforming meaning. Case studies such as the Medusa protomes in Istanbul and the Tetrarchs in Venice illustrate how reuse has ensured material survival. Digital technologies further extend this process, enabling contextual reconstruction and inaugurating new cognitive lives for reused architectural fragments.

Keywords

3D model; rendering; digital heritage

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CONCLUSIONS

THE VALUE OF WORKSHOP TEACHING AND SOME REFLECTIONS

BY GIORGIO VERDIANI, ANDREA PASQUALI

Beyond the pleasure coming from working in beautiful places, operating on extremely interesting architectures, getting feedback from the participants and seeing them taking significant step forward as professional and cultural operators, the lessons learned from fourteen different workshops and from a large set of activities in Archaeological areas, Built Heritage and valuable Cultural Heritage items in the past ten years, is double. On one hand it comes clear that a correct dataset, proper documentation and following archiving is always a valuable resource for the management of the Patrimony and allows the real development of knowledge and the connection between the historical value and any following event along the way. In any possible future case, from new research to possible transformations of the surveyed subjects, these archives are a witness that goes far from the simple photos and fix a robust point in the state of knowledge about a place and its architectures. Operating in articulated scenarios, like it is for the "recomposition" of itinerant items moved from the place of finding to far (and very far) museums is a classic sample of how the research may be widening a field and pose solutions in line with the Logic of "Patrimony of the Humanity" which is a strong concept that should be reasoned keeping the distance from nationalistic or just melancholic logics of real or supposed belonging. What comes out from this variety of activities, May appear fragmentary, isolated, a series of sparse parts in episodic research. But this can be more a point of strength than a weakness. Indeed, at now the structuring of rational national and international digital archives is on the way, pretty far for being completed and efficient, a number of tentatives in years have taken their way, proposing more or less innovative approaches and interventions in the creation of dedicated archives that rarely remained alive after the end of each financed projects. But things are ongoing and this progress is on two fronts: the first correspond to the group of large, structured archives, like the Italian National Digitalization Program (Progetto Nazionale di Digitalizzazione - PND) and Internet Culturale (Biblioteca Digitale Italiana - BDI) or Portale Inventari & Archivio Digitale (Sistema Archivistico Nazionale - SAN) and Europeana, which may considered the most aged tentative of defining an extended catalogue, at the moment their real capacity in offering access to digital survey products is quite inconsistent, but not out of the intentions. The other front is one of the initiatives from the school, academic, research and enthusiast communities, single or multiple tentatives, at small or even medium size, that aim at the production of specific contents and are spontaneously creating a vast and sparse archive of contributions. They may look dispersive, but in their multiplicity they contribute to other research and produce results and enhancements to the knowledge in the most various fields. In this series of products the use of existing platforms for sharing and presenting contents is quite common, with results that are sometimes solid and durable, sometimes live just the time of each project. In this scenario, keeping durable, efficient, archives of the materials is not helped by the software development, which tends more in a stubborn innovation with poor real benefits than in promoting easy recovering procedures for the older data. The logic of "throwing away" old things seems uncompliant with any Digital Heritage intentions, but is constantly applied in the software market. For this, producing and storing the original data "as acquired", developing them in the most various software, but in the whole producing basic, long term compliant

formats, looks like the best way to give a future chance to gather data. Storing them online can be a proper solution, thus a wearisome, time consuming and quite expensive physical backup (especially on optical supports like DVD and Blue-Ray discs) is still nowadays an extra safeguard for important contents. Some updates on the data formats, along the years, may contribute to an even more complete and efficient long life of the digital survey datasets.

This first point, obviously, does not solve how this procedure leaves an apparently incoherent group of original and processed data. The most effective reply to this condition is probably leaving them in this way and embracing the logic of dissemination "from the base", taking time for producing accurate and shareable models and representations exploiting existing platforms that make these archives easy to retrieve and find. A model uploaded in sketchfab.com can be found by a variety of people searching for that specific item; one or more graphic boards or short reports produced from a thesis or at the end of a research may be uploaded and shared on zenodo.org or figshare.com with instant and efficient DOI (Digital Object Identifier) attribution, so to make their localization a constant from that moment. A short video, even without a professional cut or montage, may take part to the youtube.com or vimeo.com platforms, allowing the fast communication of some results or leaving a trace of that workshop or research activity. The interlinking of these contents to other scientific products may expand and enhance the quality of papers in conference proceedings and journals, bringing them a step forward in the digital heritage scenario and extending the options for clear and exhaustive communication.

In conclusion, until the definition of archiving protocols that take into account the preservation of usability and guarantee the maintenance of future readability of the data, both collected and processed, the open dissemination of all the components of the studies and projects is to be considered the most appropriate strategy for improving the longevity and integrity of the scientific documentation of the Cultural Heritage.

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