

# ASMOSIA X

*Proceedings of the Tenth International Conference*

## *Interdisciplinary Studies on Ancient Stone*

*Edited by*

Patrizio Pensabene

Eleonora Gasparini



«L'ERMA» di BRETSCHNEIDER

## Interdisciplinary Studies on Ancient Stone

ASMOSIA X

Proceedings of the Tenth International Conference of ASMOSIA  
Association for the Study of Marble & Other Stones in Antiquity  
Rome, 21-26 May 2012



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P. PENSABENE, E. GASPARINI (eds.)

«L'ERMA» di BRETSCHNEIDER

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## PRESENTATION

Presenting the Proceedings of the ASMOSIA X Conference, first of all we wish to underline that the seat of Rome has substantially influenced the contents of the meeting. In fact, the study tradition on marbles that started in Italy during the XIX century has never interrupted.

In particular in Italy marble was the object of a rhetoric attitude that had its major expression under the Fascist period, when there was a relaunch of the use of Italian marbles, specially the Carrara marble, that culminated in the deed of the obelisk in the Mussolini Forum. Its transport from the quarries to Rome became a great propaganda action of the regime, that was compared to those of the Roman Empire.

The necessary break in the interest for the history of the Empire of Rome that followed the end of Fascism implied a silence of the studies on marbles too. But at the end of the Sixties the Comitato per lo Studio del Marmo e della Pietra nell'Antichità was created just in Rome. We want to remember it since it played an important role for the birth of ASMOSIA and for the development of the subjects that are treated in its Conferences. Between its members we shall quote J.B. Ward-Perkins, Th. Kraus, R. Gnoli, F. Braemer, G. F. Carettoni, M. Floriani Squarciarapino, F. Castagnoli, A. M. Colini, C. Pietrangeli and P. Pelagatti. As an immediate consequence of this initiative some important studies were carried out: the analyses of Ward-Perkins on the distribution of sarcophagi and on Nicomedian marble; the researches of Th. Kraus and J. Roder on *Mons Claudianus*; the study and the plotting of the quarries of Docimion in Phrygia; the volume of R. Gnoli *Marmora Romana*.

These works have been essential in the continuation of the studies on marbles, giving new inputs to the research on the topics of quarries and productions. The results appeared few years later with the publication of the quarry marbles of Porto by P. Baccini Leotardi and of the microasiatic sarcophagi with colonnettes: M. Walkens identified indeed their provenance and followed the path opened by Roeder investigating the Phrygian quarries and their productions. The Comitato sowed the seeds of a research method that went completely beyond the prevailing tradition in the previous studies on marble. This can be identified with the works by Bruzza and Dubois, that were focused exclusively on

the imperial marbles used in Rome or, little later, with the works by Hirschfeld on the public administration of the quarries, that were carried on by means of the interpretation of the sources and of the quarry inscriptions. On the contrary, in the Seventies and the Eighties, the prevalent research aims become the understanding of the economic meaning of the quarry productions and their distribution, the mechanisms of contracts and rents and the extension of the investigation from the imperial toward the provincial quarries.

As a consequence of this process, the archaeometric studies grew in importance, since they were the means to determine the provenance of white marbles and then to reconstruct in a correct way the economic and ideological aspects connected to the use of imperial and local marbles (F. Braemer).

The road of scientific research was ready for the organic approach to the exact sciences, that was greatly encouraged by the work of Norman Herz. Archeometry established itself as an indispensable tool for understanding the phenomenon of marble. All these instances, kept alive during the Seventies and the Eighties from various individual initiatives, have resulted in ASMOSIA, which developed them considerably over the time. They also leaked in the title that now prevails in the publication of the Proceedings of the ASMOSIA Conferences: *Interdisciplinary Studies on Ancient Stones*. Over the years, predetermined topics based on the above mentioned traditions have been established: *Applications to Specific Archaeological Questions - Use of Marble*; *Provenance Identification I: Marble*; *Provenance Identification II: Other Stones*; *Advances in Provenance Techniques, Methodologies and Databases*; *Quarries and Geology (Quarrying Techniques, Organization, Transport of Stones, New Quarries, Stone Carving and Dressing, Hazards to and Preservation of Quarries)*; *Stone Properties, Weathering Effects and Restoration (as related to diagnosis problems, matching of stone fragments and authenticity)*; *Pigments and Paintings on Marble*. But it must be said that each ASMOSIA Conference had a specific character also conditioned by the place, by the scientists and the organizations who took charge of the Congress. It became clear that the issues mentioned above were not sealed containers, but open to the scientific innovations caused by the progress of the search.

The ASMOSIA X Conference could not escape the

conditioning that came from being held in Rome and organized by university researchers and by officers of the departments of Cultural Heritage of the City of Rome, in continuous contact with the greatest monuments of the Roman Empire. The history of the relationship of the city with the marble through the centuries, the tradition of nineteenth-century studies, the fact that scholars like Ward-Perkins, Kraus, Gnoli have been operating in the city, ended up into a scientific heritage that can not be ignored, but must be integrated.

During our meeting we have profiled some trends. The insistence on ideological meanings of the use of marble; an on time increasing interest for the provincial quarries and the relationship between them and the cities; a need for a more open confrontation between the archaeometrists involved in the identification of marbles and other stones. This last aspect has emerged in heated discussions on the methods used for the analyses of the marbles of Göktepe. In the Conference continued to be present those issues that can not be depleted, because of increasingly sophisticated historical and archaeometric investigations and because of new discoveries: the study of quarries in Skyros, in Albania, in the Medol in Tarragona, until we reach the basalt quarries in India. The history of the use of the specific qualities of marbles and colored stones such as thasian for specific kinds of sculpture (small statues, bath-sarcophagi), troadense granite for column shafts; moreover, the story of the fortune of individual stones, such as Almaden de la Plata marble at Astigi (Ejica), the marble of Estremoz in its continuity of use in late Roman Hispania, the Cottanello in Sabina; shipwrecked loads (San Pietro in Bevagna in the Gulf of Taranto, Camarina and other sites in Sicily); the marbles and other stones used in a particular city or monument. Precisely, in this regard numerous contributions have been presented: they concern cities like Lyon, Barcino, Pola, Leptis Magna, the island of Pantelleria, the houses of Aquileia, the Baths of Ostia, peristyle monuments of Palmira, the villa of Trajan at Arcinazzo, the floors in *opus sectile* of Herculaneum and Cyrene, the marble veneering of the baths of the Villa at Piazza Armerina etc. Finally they dealt with the themes of marble imitation in painting, restoration and the fortune of marble in the light of collections and furniture inlaid with marble.

In almost all of these interventions archaeometry has been essential to define the characteristics and assist in the identification of the stones. Just the greater security afforded by such analyses has allowed to go beyond the

simple issue of origin, with new approaches, ranging from the economy to semantics. Precisely, this was the sense of the theme launched by the Special Session of Rome: Orders, Repertoires and Meaning of Marble within the public and the domestic circle from antiquity till post-antique time.

The Congress has been crossed by some news, such as the proposed databases which can summarize the multiplicity of results and the problems connected with the reconstruction of color on white marble sculptures and architectural elements. On this respect, the results were not only surprising and impressive, but sometimes ambiguous and misleading. The same portrait could take the same picture tone or so different tones, that we have faced with the need to perfect this method. It is also true that the statue chosen as the logo of ASMOSIA X, the Matidia of Sessa Aurunca, just for the two qualities of the bigio morato that compose it, evidences that in the ancient world it was not unusual to combine different tones that have a basic colour match. Perhaps for this reason a uniform colour must not be searched. We must remember the words of Susan Kane, who read in the union between the artistic value and archaeometric interest offered by this sculpture a summary of the meaning of ASMOSIA.

\* \* \*

We wish to thank the ASMOSIA Executive Committee and the President Yannis Maniatis for the scientific and organizing support not only during the Conference, but also in the stages that preceded and followed it. Thanks also to the commitment and the professional collaboration offered by Marilda De Nuccio of the Sovraintendenza Capitolina ai Beni Culturali, Vicepresident of the ASMOSIA X Organizing Committee and to Massimo Carlucci for the work of translation in English in the organizing stages and during the Conference. For the constant and careful work in the Secretary we thank Giuseppe Restaino and finally all the staff of the Organizing Committee composed by Tommaso Bonanni, Valerio Bruni, Francesca Caprioli, Monica Cottini, Leandro Cucinotta, Javier Á. Domingo Magaña, Dimosthenis Kosmopoulos Giacummo, Enrico Gallochio, Vincenzo Graffeo, Adalberto Ottati, Stefano Palalidis, Bruno Vivino.

PATRIZIO PENSABENE, ELEONORA GASPARINI  
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1. APPLICATION TO SPECIFIC ARCHAEOLOGICAL QUESTIONS  
USE OF MARBLE

# ARCHITECTURE WITH CONCAVE AND CONVEX RHYTHMS AND ITS DECORATION IN HADRIAN AGE: THE MARITIME THEATRE AND THE SOUTHERN PAVILION OF PIAZZA D'ORO IN HADRIAN'S VILLA

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## Abstract

*Constantine Some buildings in Hadrian's Villa, as the Maritime Theatre and Piazza d'Oro, show trabeation with a characteristic curvilinear shape, decorated with figured friezes. The dispersal of most of them in public and private collections involves difficulties in replacing the friezes in each building. A new integrated approach applied to the study of the curvilinear shape friezes, allowed us to make new reliable assumptions about the replacement of the architectural decoration. Starting from digital survey of the original fragments, and of the still preserved masonry in situ, is possible to acquire an amount of information useful to recompose the figurative cycles of the Maritime Theatre and of the southern pavilion of Piazza d'Oro. The study of decorative architectural system based on the new methodological approach and the comparison of the formal and metric features obtained with those of the architectural remains in the Villa, allowed us to propose synthetic solutions on which the virtual reconstruction assumptions can be based.*

## Keywords

Hadrian's Villa, virtual anastylosis, 3D laser scanner survey

## Introduction

This ongoing study on architectural decoration from Hadrian's Villa has been carried out under the supervision of Soprintendenza per i Beni Archeologici del Lazio that coordinates the work of many researchers from different countries and it is part of a wide set of multidisciplinary analyses on this UNESCO Site. Thanks to new technologies is possible to achieve more accurate results than in the past, in particular about architectural decoration and virtual anastylosis. The themes of our research can be considered as updated and in some cases deeper investigations inspired by former studies (HANSEN 1960; RAKOB 1967; CONTI 1970) on the pavilions characterized by concave and convex

entablatures as the Maritime Theatre and Piazza d'Oro (Figg. 1-2). The high degree of accuracy provided by active sensors such as 3D laser scanner (Fig. 3) together with new 3D geometric modelling tools let us obtain more reliable locations of marble friezes – and fragments – that nowadays are exhibited or stored in the Villa and in other Italian and European private and public collections.

## The study of concave and convex entablatures

The first survey campaign carried out by means of 3D laser scanner on the Villa's figured entablatures was held in September 2009; it was focused on the friezes stored inside the Triboletti's didactic museum (actually closed) and some other fragments forming part of the anastylosis made during the past century inside the Maritime Theatre (1957-1958). The first gratifying results achieved by virtual replacement "in situ" of a fragmentary curved marble frieze from the island private dwelling of the emperor, were disseminated in international conferences about the role of new technologies for Cultural Heritage (CHNT-14 Workshop, Vienna 2009; Adembri, Di Tondo, Fantini 2010; CAA 2010, Granada; Adembri, Di Tondo, Fantini) and in the exhibition "Villa Adriana. Una storia mai finita" held at the Canopus' Antiquarium in 2010, among the new research fields recently activated (ADEMBRI 2010). This first collaboration led the research team to carry on and develop this methodology on other pavilions of the Villa with mixtilinear entablatures, as Piazza d'Oro. During September 2010 and 2011 we extended the laser scanner survey to other marble pieces and buildings, characterized by similar features and subjects (figured friezes with Erotes engaged in chariot races, hunting and sea-thiasos). The main aim, in this case, was to extend the digital database of models, not just adding new files, but also having measured models of the marble friezes and improving the representation quality of them in order to provide a better quality of visualization during all the next steps of virtual anastylosis.

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Fig. 1. Hadrian's Villa. Maritime Theatre.



Fig. 2. Hadrian's Villa. Piazza d'Oro southern pavilion.

During the last four years the deep collaboration between archaeologists, experts of laser scanner survey and 3D modelling made possible the development of a customized combination of different techniques, each one coming from different fields: reverse modeling, entertainment software, real-time and game engine applications. Friezes belonging to the Maritime Theatre and Piazza d'Oro (characterized by curvilinear shape) could be virtually replaced in the correct original location thanks to the combined analysis of different scale surveys: from the general architectural scale to the detailed decorations (ADEMBRI, DI TONDO, FANTINI 2011).

Also Hansen (HANSEN 1960) and Ueblacker with Caprino (UEBLACKER 1985, CAPRINO 1985: 62) already tried to carry out an anastylosis of Maritime Theatre's architraves through the use of morphological features (in particular the bend radius of curved elements), but their results were affected by a lack of accuracy of the survey, done with traditional measuring instruments.

Pirro Ligorio's<sup>4</sup> writings and drawings underline the importance of Piazza d'Oro since Renaissance: it was a very interesting and inspiring subject for architects and

scholars because of its richness and conservation especially of the figured friezes. In the last years many authors dealt with those topics concerning Piazza d'Oro (CONTI 1970, Bonanno 1975, Bonanno 1977, Mari 1994, Sirano 2000), giving once again prove of the relevance of the peculiar architectural decorations inside the design of the whole complex.

#### Aims of the project

The first aspect that we are carrying out deals with the systematic documenting and cataloguing of all the known pieces with concave and convex rhythms found at Hadrian's Villa, using the more accurate and proper survey solution in order to produce a virtual repository at disposal for researchers. Metric and formal characteristics of every fragment will be investigated by means of 3D interactive visualization thanks to real-time application from the field of entertainment software such as game engine.

The second aspect has to do with the use of virtual models from 3D laser scanning technology and pho-

4. Pirro Ligorio, "Trattato delle Antichità di Tivoli et della Villa Hadriana fatto da Pyrrho Ligorio Patritio Napoletano et dedicato all'Ill.mo Cardinal di Ferrara", Cod. Barb. Lat 4849, ff. 17 v – 18 v.



Fig. 3. 3D survey operations: A) 3D survey at Piazza d'Oro. B) 3D survey of a figured frieze.

togrammetry as bases for virtual reconstructions and anastylosis of all the known elements concerning curvilinear trabeation from Teatro Marittimo and Piazza d'Oro.

In particular for Piazza d'Oro it was decided to split the research in two different ones: one focused on hunting friezes belonging to the two lateral porches of the southern area of the pavilion (ADEMBRI, JUAN VIDAL, MARTÍNEZ ESPEJO 2012); the other would have deepened the knowledge of the curvilinear nymphaeum, characterized by a very rich architectural decoration<sup>5</sup>.

Among these purposes should be underlined the experimental approach of new technologies inside the whole research. In the majority of cases neither one of the hardware and software solutions used for our main research aims was designed for archaeology: it means that our team had to merge together applications and pipelines coming from other fields as, for example, computer aided industrial design, reverse engineering and 3D computer graphics for entertainment. In other words, to allow the use of highly detailed 3D digital models, it was necessary an experimental phase that permitted to our team to combine and manage architectural surveys with fragments and smaller elements without losing the accuracy of the measurements and their appearance.

## Research methodology

Every member of the research team plays a different role inside the frame of this project, archaeologists, ar-

chitects, experts of computer graphics, topographic surveyors, etc. All together work for re-ordering, documenting and cataloguing original fragments, both those preserved at Hadrian's Villa and those in private and public collections, both in Italy and elsewhere in Europe. But the research is not just based on the 3D acquisition of the items shape; we are acquiring graphic (engravings and old drawings) (Fig. 4) and photographic (historical photography) documentation concerning the friezes, with the aim of amassing the greatest amount of information in order to recompose the figurative cycles.

The methodology we developed inside the frame of this international collaboration is formed by different steps: laser scanner survey to obtain 3D accurate models of archaeological remains and decoration; then an extensive use of reverse modeling techniques to determine formal features and relevant measures (bend radius, angles) that could provide clues for virtual reassembling; and third, an optimization process of dense meshes in order to provide 'easy to use' textured models. This last step, which takes a lot of the time in the whole process, is very important because it allows the use of high detail models inside a single 3D environment where it is possible to review the suggested alignment of the fallen pieces.

Reverse modeling applications are extensively used in the field of mechanic engineering and design: for this reason we just use a small set of the tools at disposal inside this complex software. In our case is very important to achieve a highly detailed model that will be aligned to the more convenient reference system, then we define other planes that will be used to determine all the important sections of the marble entablature. It

5. The first team is from Universidad Politecnica de Valencia, prof. Francisco Juan Vidal, PhD. Student Isabel Mtnez-Espejo Zaragoza; the other team is formed by the authors of this paper and starting from 2012 also Fabio Ristori, architect was included inside the group.



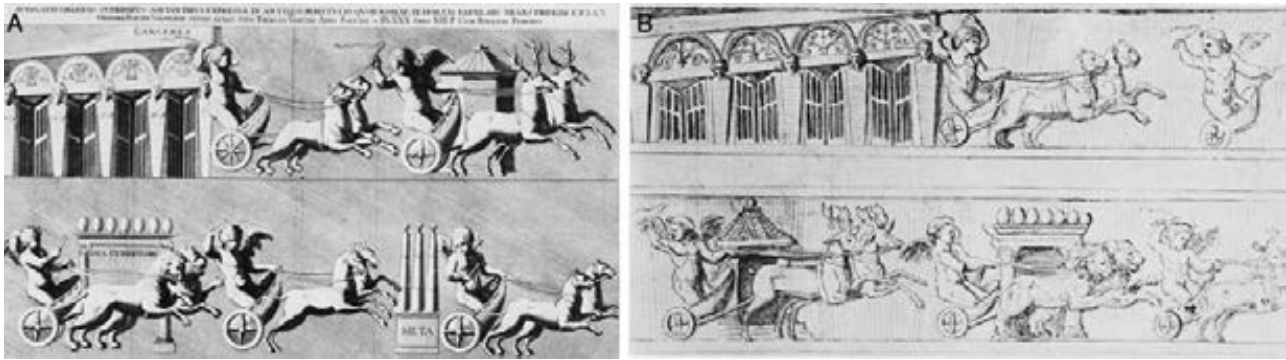


Fig. 4. A) Onofrio Panvino: drawing of a figured frieze representing chariot race. B) Codex Berolinensis. Berlin, Staatsbibliothek Preußischer Kulturbesitz: drawing of a figured frieze representing chariot race (from Ueblacker 1985).

is very important to choose the right position of these planes in order to detect all those formal features designed by ancient architects to facilitate their assembling. For this reason we decided to give priority to the survey of all those that could provide the greater quantity of morphological and metric information for the anastylosis: that is the elements which formed part of a corner, or a terminal part of the architrave, and also the pieces which show very clearly a change of profile (mixtilinear elements), and of course the bended pieces that can provide the curvature radius. For every fragment we obtain sections and projections, then used as templates for drawing planar geometric figures that best fit with the section: in the case of the bended friezes, it will be a circle. Different radiuses allow us to guess different location inside the architecture remains. All the metric tests were developed on two-dimensional schemes (plan elevation and section), suitable for the validation of reconstruction hypothesis on the design process that led to the construction of the building which the architectural friezes were referred to. In all the cases we converted the contemporary measuring systems in the anthropometric one used during roman imperial age and we applied the graphic algorithms coming from ancient treatises for example Vitruvius's rules about architectural design so as other ancient texts that in the whole concur to let us understand the phases of the ancient design.

## Results

In the exhibition held at Hadrian's Villa among April the 1st to November the 1st 2010 a number of pieces, originally located in the famous dwelling of the Emperor, were brought back to the Villa and exhibited inside the Canopus Antiquarium; between them there was a fragment of concave frieze with the theme of chariot driven by erotes preserved in the British Museum, formerly belonging to a private collection and originally coming from the Maritime Theatre. During the preparatory phases of the exhibition it was possible to scan this piece, by permission of the British Museum, and other

two friezes, both removed from the famous Pirro Ligorio's Fontana della Rometta at Villa d'Este in Tivoli, one of them originally belonging to the Maritime Theatre, the other to Piazza d'Oro. The state of conservation of these architraves is quite bad because they were formerly placed in the fountain and consequently were negatively affected by a long time inappropriate location.

A little at a time, ongoing research is trying to solve the dispersal problem of the friezes from the Maritime Theatre and Piazza d'Oro and put in order and consider what has already been written by scholars, trying to rectify and integrate the specific literature. Although the differences between the two buildings, the Maritime Theatre and the Piazza d'Oro have points in common that can be understood by an integrated and interdisciplinary research. Good results in terms of documentation and cataloguing by means of new survey techniques were achieved: many elements of the architectural decoration belonging to the two complexes were identified in more probable original location. The reliable match between the measures of those elements and the measures of the extant walls or basement proves that our proposal is correct if compared to the previous assumptions, that often led also to incorrect anastylosis (as in the Maritime Theatre or Piazza d'Oro, then removed). We found that these two paradigmatic architectures of the Villa have lots of common features and solutions that scholars ignored and undervalued.

On the other hand, this new approach to the research let us consider new chances of cataloguing and recording the data and of disseminating the results to the scientific community without losing any detail: from the organization of the file-cards (going beyond the Italian Ministry for Cultural Heritage format) to the usage of 3D real-time application for interactive evaluation of morphological and metric aspects of each piece. In the following table are briefly explained the results concerning some case studies. The identification code of each frieze is based on the following criteria: TM: Maritime Theatre; PO: Piazza d'Oro; S: South Pavilion of Piazza d'Oro; E: East Pavilion of Piazza d'Oro; the room numbering follows the ones adopted in Guidobaldi 1994 (Figg. 5-6).

Frieze	Present Location	Figured cycles	Architrave	Other side	Curvature	Bend Radius (cm)	Replacing Hypothesis
TM_01	Hadrian's Villa, Canopus Antiquarium (inv. 114770)	SEA-THIASOS (final)	not preserved	Turned into a slab during the modern era.	concave	458	Maritime Theatre, Island Vestibule (Room 7 south side)
TM_02	Hadrian's Villa, Triboletti Museum (inv. 114768)	SEA-THIASOS	not preserved	Turned into a slab during the modern era.	convex	498	Maritime Theatre, Island Vestibule or Tablinum Porch (Room 7 south side / Room 12 north side)
TM_03	Hadrian's Villa, Canopus Antiquarium	CHARIOT RACE (once reused in the Rometta Fountain, Villa d'Este)	not preserved	Turned into a slab during the modern era.	concave	713	Maritime Theatre, North-South Ambulatory of the Island (Room 10 North side / Room 10 South side)
TM_04	Hadrian's Villa, Maritime Theatre: Island Vestibule	SEA-THIASOS	Tripartite; smooth Kyma	CHARIOT RACE	Convex	the small size of the fragment does not allow to fix the bend radius	-
TM_05	Hadrian's Villa, Maritime Theatre: Island Vestibule	SEA-THIASOS	Tripartite; smooth Kyma	SEA-THIASOS	convex	430	Maritime Theatre, Room 11/ Room 22
TM_06	British Museum	CHARIOT RACE	not preserved	Turned into a slab during the modern era.	concave	631	Maritime Theatre, East-West Ambulatory of the Island (Room 10 East side/ Room 10 West side)
POS_01	Hadrian's Villa, Triboletti Museum	SEA-THIASOS	not preserved	Turned into a slab during the modern era.	convex	450	Piazza d'Oro, South Pavilion: Hall 6A/6B
POS_02	Hadrian's Villa, Canopus Antiquarium (deposit)	SEA-THIASOS (final)	Tripartite and marked by bead-and-reel; Lesbian kyma	Bumpy surface	straight oblique fold (angle dimension 15,7°)	The length of the bending is too small to fix the possible curvature	Piazza d'Oro, South Pavilion: Fountain 4D
POS_03	Hadrian's Villa, Piazza d'Oro (deposit)	SEA-THIASOS	Tripartite and marked by bead-and-reel; Lesbian kyma	Smooth	concave	361	Piazza d'Oro, South Pavilion: Fountain 4A/4B/4C/4D
POS_10	Hadrian's Villa, Canopus Antiquarium	SEA-THIASOS (once reused in the Rometta Fountain)	not preserved	Turned into a slab during the modern era.	concave	954 (complete length)	Piazza d'Oro, South Pavilion: Nymphaeum
POE_01	Hadrian's Villa, Canopus Antiquarium (deposit)	SEA-THIASOS	Tripartite and marked by smooth torus; smooth Kyma	Straight with bumpy surface.	concave	1115	Piazza d'Oro, East Nymphaeum facing Tempe's Valley

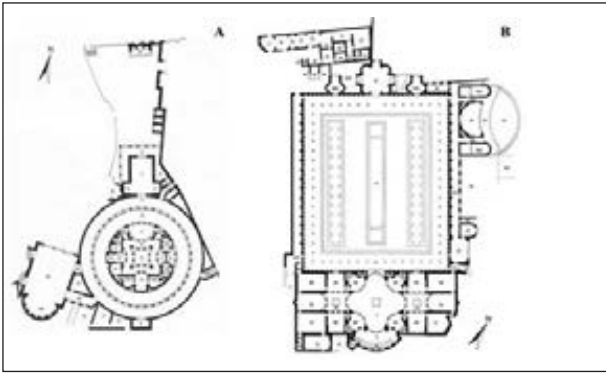


Fig. 5. A) Plan view of the Maritime Theatre. B) Plan view of Piazza d'Oro (from Guidobaldi 1994).

The database, of course, includes also bibliographical references and 3D laser scanner reliefs or at least photographs of each item, to recognize it even if there is no inventory number; there are also all the measures acquired from 3D laser scanner survey (besides the bend radius, arc of the circumference, width, etc.) or known by publications.

A very good result was achieved in the case of the south nymphaeum of Piazza d'Oro: originally, it was the end of a complex architectural design characterized by a mixtilinear central space conceivably covered by some kind of concave-convex vault, similar to the one partially preserved in another building of Hadrian's Villa, the Small Thermal Bath, and in particular in the octagonal room. The role played by this architectural complex of Piazza d'Oro is similar to the so-called Serapeum and the relation appears even clearer if we focus our attention on the global composition of the building and also to some specific aspects. Both the nymphaeum and the narrow terminal open corridor with the grotto/niche of the Serapeum are placed at the south end of a huge building characterized by the presence of fountains and waterworks, where sunlight provided to get better the scenographic effect entering from behind the walls bearing the vault of an enclosed space.

The nymphaeum to the south of the Piazza d'Oro's central hall has been analysed comparing its measures (expressed in the SI) with the ancient measuring system based on the length of roman foot, to be considered equal to cm 29.56 as well as attested by other buildings of Hadrian's age, for instance the Pantheon (for a measure equal to 29.2 cm: Cinque 2010, 19–53). The bend radius of the frieze with Sea-thiasos POS 10 is greater than the one detected at the column bases of nymphaeum, R7 (Fig. 9), because figured friezes above the niches were put along the circumference behind the capitals: in the central part of the remaining structure we can see that the upper part of the wall, above the niche, is thinner in order to receive the marble entablature with frontal frieze (Fig. 11). The distance among the column bases of the nymphaeum corresponds to the



Fig. 6. Some 3D digital models of the friezes acquired during 3D laser scanner survey.

maximum length of each frieze above the niches (Fig. 10), about 200 cm. So, we can assume that POS 10, whose length (arc of a circle) is 202, is a complete frieze, nevertheless it has been cut in ancient times for reusing: a proof is offered also by the scheme of the composition, based on an equal number of figured elements at each side of a central subject, and all are still preserved. The masonry remains (Fig. 11), although stressed by time flawing and despoliation and dispersal of the marble elements (entablature, capitals and basis), show the architectural order, as we can see, starting from the data from the survey campaign and comparing the results with the treatise on architectural design by Vitruvius and with the hypothesis formulated by E. Hansen (1960). The identified module (equal to 1+1.5 roman foot) seems to arrange the design of the whole facade according to Corinthian architectural proportions, with column over plinth (Fig. 8). The cross section of the nymphaeum also reproduces the original land placement of the building; the different height of landing levels between the inner and the outer part of the masonry indicates that the inner side of the nymphaeum was built by digging the tuff bed, to favourite the water supply of the fountains: the foot of the external wall matches with the level of the ancient water supply system, as it is shown by the holes for the passage of *fistulae* preserved in the lower part of the niches not yet restored.

The structural plan of the nymphaeum's inner concave wall (Fig. 9–10) was underlined by the decoration

Fig. 7. 3D digital model of the friezes POS 02 and POS 10 acquired during 3D laser scanner survey.

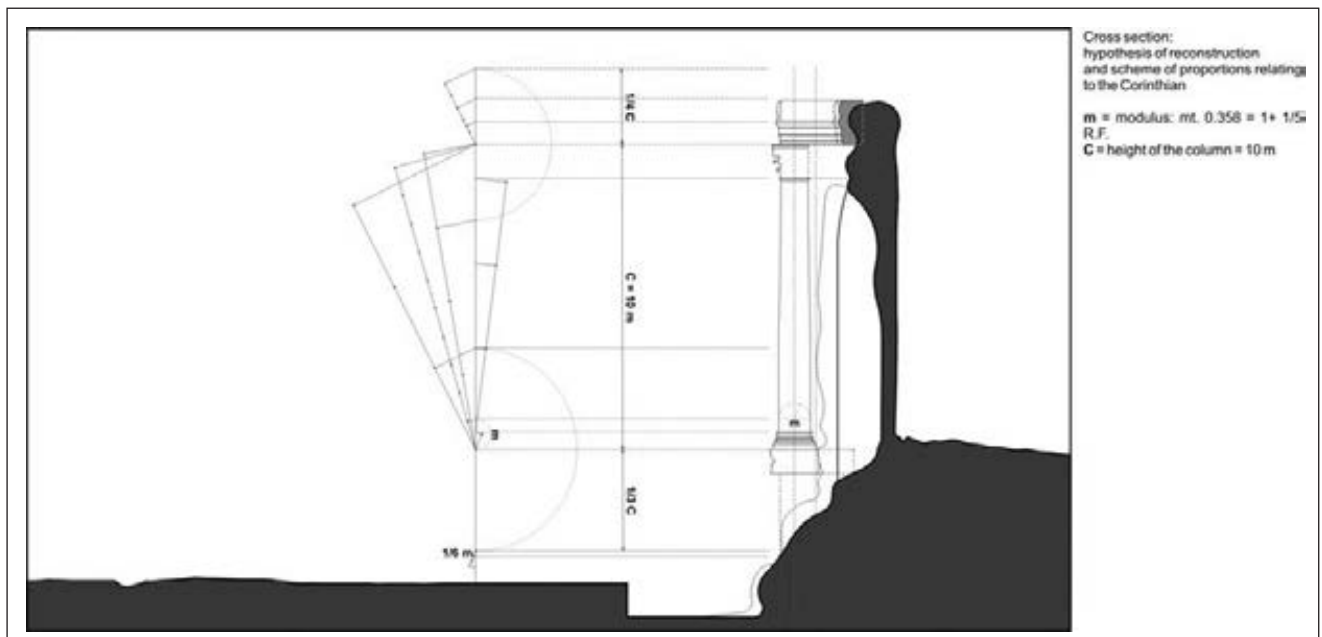
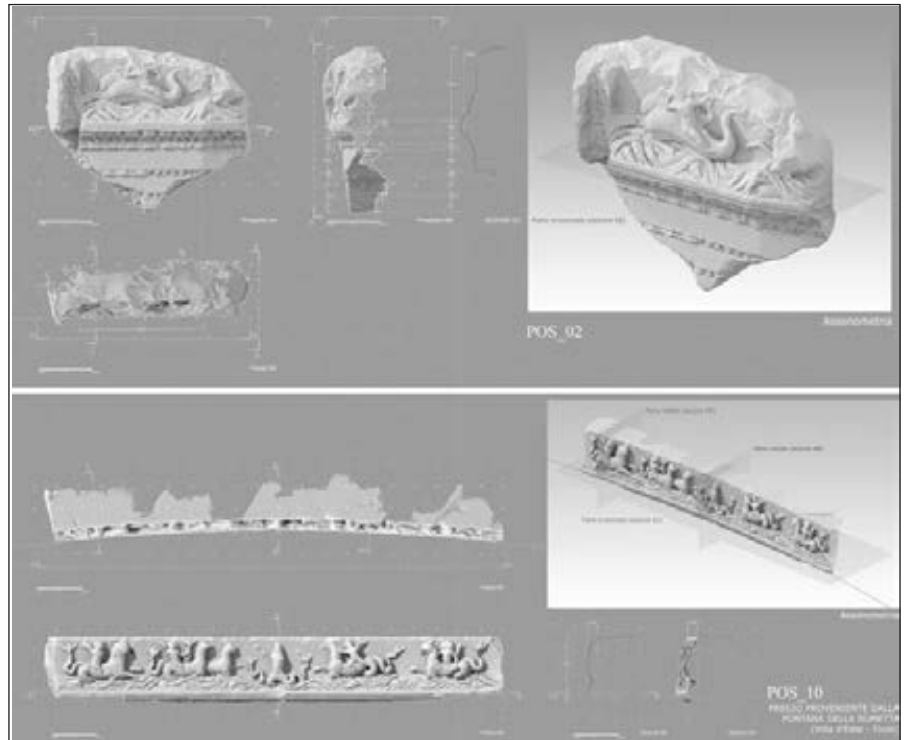


Fig. 8. Reconstruction of the architectural order starting from the data acquired during the survey campaign.

arrangement. The nymphaeum's facade, easily designed according to a linear development (Fig. 10), is wrapped along an equal length arc of circumference. The figured curved entablature was applied to the back wall, just above the niches, partially inside the masonry, and the straight one was put over the capitals. The front limit of the marble architrave fits with the circumference tangent to the column plinths between points A and B, matching with the position of the first and last plinth in front of the concave wall (Fig. 9); the length of this arc,

equal to 56 Roman feet, can be divided into 7 parts, each one 8 feet long (Fig. 10). Each section is further divided into three parts; in the central one (5 feet long) is located the niche, and each column with plinth occupies the two lateral strips (each one 1.5 feet long). The usage of full-value measures, easily divisible and manageable during the construction phase, was a habit of roman builders that simplified the transmission of information between the architect and the workers. According to the information acquired about the design