UNIVERSITÀ DI TRENTO

IMEKO TC-4 International Conference on

METROLOGY FOR ARCHAEOLOGY AND CULTURAL HERITAGE

VIRTUAL CONFERENCE - OCTOBER 22, 24, 2020

MetroArchaeo2020

Virtual Conference

For further information, visit the website
www.metroarcheo.com

PROCEEDINGS

ATHENA SRL
Business and technology consulting

ISBN: 978-92-990084-9-2

2020 IMEKO TC-4 INTERNATIONAL CONFERENCE ON

METROLOGY FOR ARCHAEOLOGY AND CULTURAL HERITAGE

PROCEEDINGS

October 22 - 24 2020 | Virtual Conference

ISBN: 978-92-990084-9-2

MetroArchaeo 2020 Committee

GENERAL CO-CHAIRS

Pasquale Daponte, *University of Sannio, Italy*
Stefano Gialanella, *University of Trento, Italy*
Dario Petri, *University of Trento, Italy*

TECHNICAL PROGRAMME CO-CHAIRS

Michele Fedel, *University of Trento, Italy*
Annaluisa Pedrotti, *University of Trento, Italy*
Fabio Santaniello, *University of Trento, Italy*
Marco Zanatta, *University of Trento, Italy*

INTERNATIONAL PROGRAM COMMITTEE

Emma Angelini, *Politecnico di Torino, Italy*
Fabrizio Antonelli, *LAMA - LabCoMaC - Iuav University of Venice, Italy*
Lucio Calcagnile, *University of Salento, Italy*
Franco Cambi, *University of Siena, Italy*
Stefano Campana, *University of Siena, Italy*
Piergiulio Cappelletti, *University of Naples, Italy*
Luca Cappuccini, *University of Florence, Italy*
Paolo Carafa, *University of Roma La Sapienza, Italy*
Lorenzo Ciani, *University of Florence, Italy*
Juan Antonio Quirós Castillo, *Universidad del Pais Vasco, Spain*
Andrea Cataldo, *University of Salento, Italy*
Cristina Corsi, *University of Cassino and Southern Lazio, Italy*
Giuseppe Cultrone, *University of Granada, Spain*
Egidio De Benedetto, *University of Salento, Italy*
Lucio Del Corso, *University of Cassino and Southern Lazio, Italy*
Zaccaria Del Prete, *Sapienza University of Rome, Italy*
Maria Grazia D'Urso, *University of Bergamo, Italy*
Francesco Fontanella, *University of Cassino and Southern Lazio, Italy*
Venice Gouda, *National Research Centre, Egypt*
Sabrina Grassini, *Politecnico di Torino, Italy*
Francesco Lamonaca, *University of Sannio, Italy*
Marco Laracca, *University of Cassino and Southern Lazio, Italy*
Giovanni Leucci, *Istituto di Scienze del Patrimonio Culturale (ISPC-CNR), Italy*
Paolo Liverani, *University of Florence, Italy*
Carmine Lubritto, *Università degli Studi della Campania "Luigi Vanvitelli", Italy*
Marilena Maniaci, *University of Cassino and Southern Lazio, Italy*
Lara Maritan, *University of Padova, Italy*
Paola Moscati, *Istituto di Scienze del Patrimonio Culturale (ISPC-CNR), Italy*
Alessandra Pecci, *University of Barcelona, Spain*

2020 IMEKO TC-4 International Conference on
Metrology for Archaeology and Cultural Heritage
Trento, Italy, October 22-24, 2020

Preliminary data processing on the Roman Shipwreck of Grado. Archive and legacy data to create its 3D virtual model

Costa Elisa[1], Beltrame Carlo[1]

[1] *Dipartimento di Studi Umanistici, Ca' Foscari University, Dorsoduro 3484/d*
elisa.costa@unive.it, beltrame@unive.it

***Abstract* – Ca' Foscari University is working on different archaeological topics to enhance knowledge about shipwrecks through digital technologies applied on data archive and legacy data, from a wreck of a Napoleonic brick to cargos of amphoras of Byzantine and Roman period. The potential of digital technologies has allowed us to analyse and elaborate different kind of documentation, also of archive, to obtain 3D models that could be studied and visualized with innovative solution and technologies.**
The paper presents an original proposal to create a 3D virtual model on an ancient shipwreck from archival and heterogeneous data. On the Grado Roman shipwreck, we have processed the data of perspective drawings of the shipwreck and the amphoras, of measurements during the excavations, of digitalization of analogical images and of the survey of the cardboard scale model to obtain a complete virtual 3D model of the shipwreck.

I. INTRODUCTION AND STATE OF THE ART

Digital technologies are widely employed to support documentation and studies of researchers, in order to make available cultural heritage and maritime archaeology. The potential of these tools allows us to obtain 3D models from data archive and legacy data, that could be studied and visualized with innovative solution and technologies [1-3].
Ca' Foscari University is working on different archaeological topics to enhance knowledge about shipwrecks through these technologies. Usually, the excavation of a shipwreck produces a large amount of data during the excavation; some of these, called legacy data, became essentially useless, or usable only at the cost of difficult and time-consuming processes. The recovery of legacy data represents an essential requirement to avoid the loss of relevant data [4].
Analysing and elaborating different kind of documentation and legacy data, it is possible to obtain a complete virtual 3D model, in order to allow innovative archaeological research and accessibility of the Underwater Cultural Heritage to general public.

The first project of Ca' Foscari University realized on legacy data concerns the Napoleonic brick *Mercurio*; on this shipwreck, excavated from 2001 to 2011 [5] the researchers have used legacy data and have scanned the negatives of the analogical images from the old excavations, presenting a particular and original way to generate a virtual model of ancient shipwrecks from archival and heterogeneous data [4].

Another project has been realized on the Byzantine shipwreck of Cape Stoba. A cargo of amphoras has been virtually reconstructed and arranged in the original position by processing and elaborating different type of documentation realized during the seasons of excavations from 2009 to 2015 to obtain a complete model of the cargo that could be navigated following the stratigraphic excavation [6].

Towards this goal, the team has decided to analyse and processed the documentation realized, from 1990 to 2000, with almost obsolete techniques and devices of a more complex shipwreck and excavation.
On the Roman shipwreck, we have used the perspective drawings of the shipwreck and the amphoras, the measurements during the excavations, the digitalization of analogical images, the cardboard study model and we have processed all the data to obtain a complete virtual 3D model in its different phases, from excavation to reconstruction.

II. THE ROMAN SHIPWRECK OF GRADO

The wreck, which lay at a depth of 15 m, 6 miles off the coast of Grado (Gorizia), was discovered in 1986 and has undergone numerous excavation campaigns that have seen the complete recovery of the cargo and the hull (fig. 1-2).

A large part of the hull was covered by the amphoras and a section of the starboard side of the ship remained up to the height of the deck. The hull has been preserved for a length of 13 m and a width of 6 m, but the reconstructive study has shown that the boat had a total length of 16.5 m,

was 5.9 m wide in the main section and 2 m high [7-8].

Fig. 1. The hull of the shipwreck in situ (photo: Soprintendenza Archeologia, Belle Arti e Paesaggio del Friuli-Venezia Giulia).

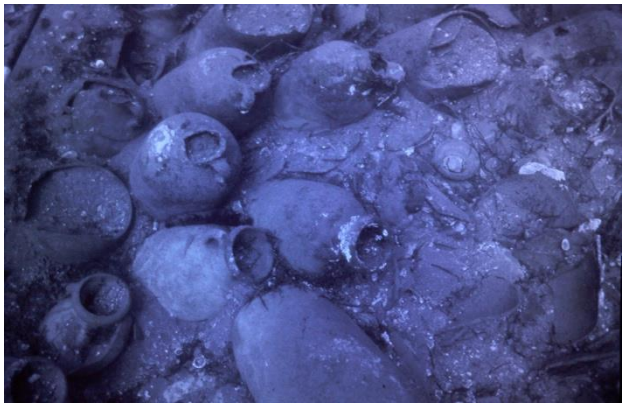

Fig. 2. A detail of the cargo of amphoras (photo: Soprintendenza Archeologia, Belle Arti e Paesaggio del Friuli-Venezia Giulia).

The meticulous study of the hull and the cargo, realized with different documentation [9], provided an opportunity to experiment the reuse of the results to three-dimensionally reconstruct the entire shipwreck and provide the possibility to allow a complete innovative visualization of an already investigated site which is not accessible anymore.

A critical aspect of the project has been represented by legacy and heterogeneous data, collected during the excavation campaigns in the '90s, when the documentation was not still finalized to create a complex digital result. The original data available of the shipwreck and the cargo consists of plans and sections, series of diacolor images for photomosaics, a cardboard model, a 2D reconstruction of the hull lines, a 3D digital model of the surveyed cardboard model.

III. DATA PROCESSING: *IN SITU* SHIPWRECK

A. The shipwreck

The 3D reconstruction of the hull *in situ* was obtained by processing the documentation of the excavation campaigns and the 1:1 scale documentation made in laboratory. The original drawings concern two maps, the first with the entire hull and the internal planks, the second with the highlighted structure of the frames (fig. 3). The recovery project, which dramatically failed, included a structure to lift the entire hull, designed on regular graphic sections of the hull.

We have used the software *Rhinoceros* for the elaboration of the 2D and 3D model. First, we have traced the 2D lines on the perspective drawings of the frames, that have been extruded, cut on different plane and joined to obtain a 3D model of every structural wooden element of the hull. Second, we have positioned them on the plan of fig. 3. These elements have been rotated complying the sections of the hull, that have been previously extrapolated and transversally placed in the correct section position extracted from the drawings of the structure (fig. 4). The external planking has been created as a unique surface projected from the bottom on the frames to maintain the perfect corresponding shape; this surface has been extruded on the measurement of the thickness of the planks and it has been subdivided into 12 planks of the port side and 19 planks of the starboard side, complying the correct shape from the drawings. The complete model of the *in situ* hull (fig. 5) was subsequently compared and adjusted with the millimetric measurements of the archaeological sections, manually realized during the excavation.

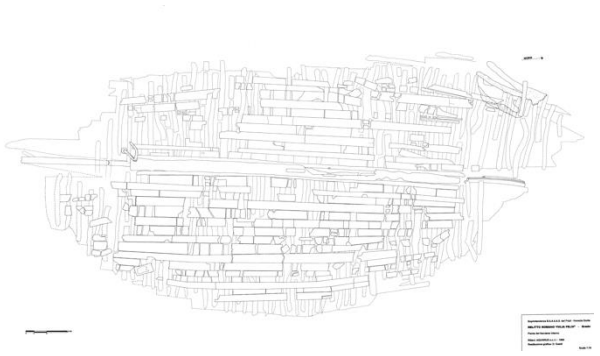

Fig. 3. Map of the shipwreck in situ (drawing: D. Gaddi)

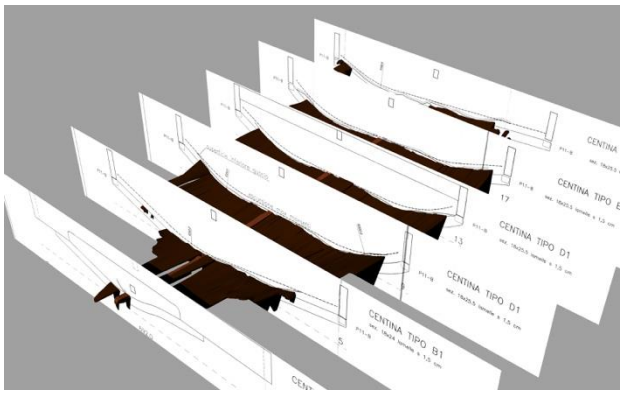

Fig. 4. Section of the structure (drawing: M. Colocci) rotated and placed on the 3D model (processed by E. Costa)

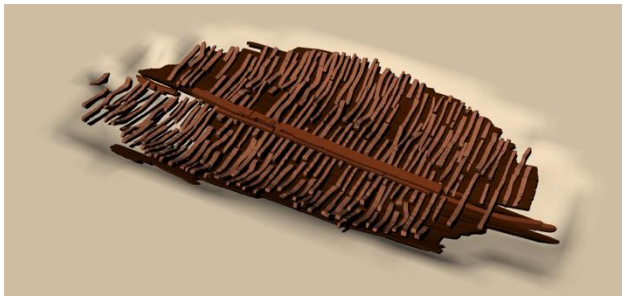

Fig. 5. Rendering of the 3D model of the hull in situ (processed by: E. Costa).

B. The cargo of amphoras

The model of the cargo of amphoras has been created on two different procedures which were subsequently compared and integrated.

The excavation phases of the cargo of amphoras have been daily documented in 1990 with a series of analogic images designed to create a simple photomosaic. This kind of legacy data could represent a problem during the elaboration of data. For example, analogical images have to be scanned obtaining a digital workspace which has to be enhanced and corrected for a better result of the alignment of the images. Furthermore, the scanned diacolor doesn't maintain the parameters of a digital images (position of principal point, focal length and distortion of the lens) that have to be employed by photogrammetric software to realize the inner orientation. A sufficient overlap has allowed us the elaboration of a 3D model with the software *Agisoft Photoscan*. The alignment of the images and the metric accuracy of the photogrammetric model have been improved with the insertion of the coordinates of the metal grid on the site which has been built with a regular grid every 1.50 m. This alignment of the images is therefore metrically correct and the check with the coordinates on the sites could be define the correctness of the entire photogrammetric model also without these parameters. We have obtained four different projects of the excavation phases, which will be useful for future projects on the dissemination of the procedures of the excavation on an underwater archaeological site with amphoras and hull. For this paper, we have decided to keep the last phase of the excavation process documented with this technique, which represents more than half of the cargo of amphoras (fig. 6).

In 1994, the cargo has been completely excavated and, before the recovery of all the amphoras, an archaeological plan of the cargo has been realized (fig. 7). The plan has been used to integrate the photogrammetric survey in its missing parts. The software *Rhinoceros* has been employed to virtually model the amphoras and to overlay and integrate the two surveys as showed in fig. 8. The two surveys perfectly correspond and, in this first work phase, we have decided to integrate only the missing amphoras: those missing from the photogrammetric model (in the middle) and those that have been excavated only in 1994 (yellow amphoras in the left corner).

To reconstruct the entire cargo, despite the photogrammetric model, we have retrieved the same analytical process of the Byzantine shipwreck studied in 2016-2019 [6], processing the 3D prototypes model of the 7 typologies with a 360° revolution of the archaeological drawings with the integrations of the handles. We have matched each model with the existing plan, positioning xy coordinates on the drawings and z coordinate accordingly to the overlapping of the amphoras and the measured vector from feet and necks (fig. 9).

Fig. 6. Photogrammetric model of the cargo of amphoras (processed by: E. Costa).

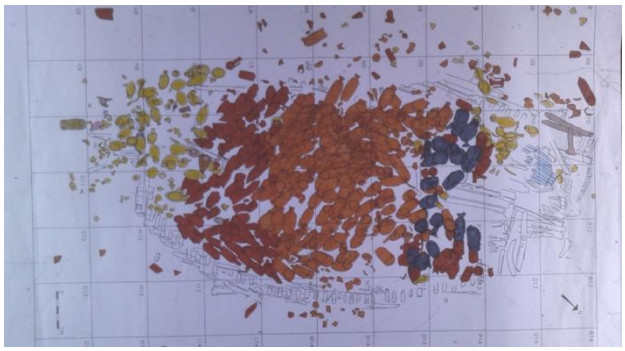

Fig. 7. Map of the cargo of amphoras (processed by: R. Auriemma)

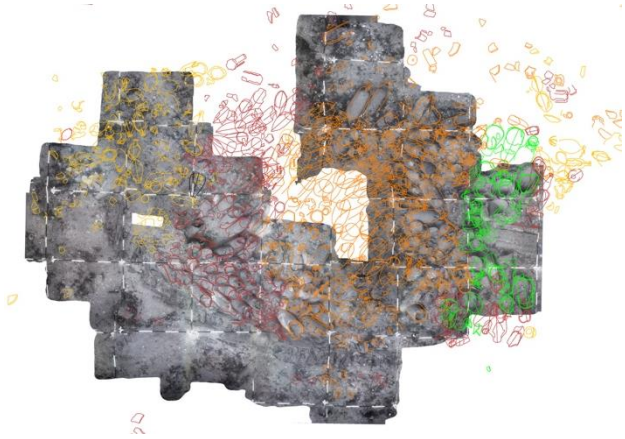

Fig. 8. The two overlapped surveys (processed by: E. Costa)

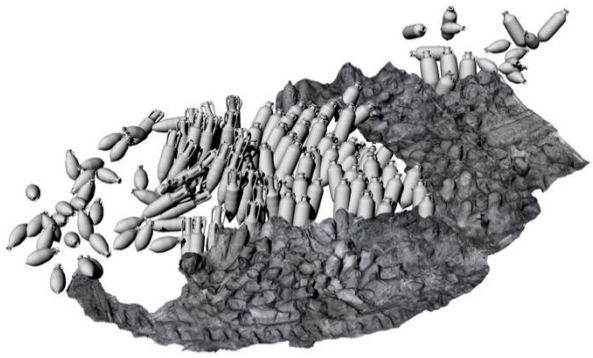

Fig. 9. Integration of the missing amphoras on the photogrammetric model (processed by: E. Costa)

IV. DATA PROCESSING: RECONSTRUCTED SHIPWRECK

A. The shipwreck

After the excavations and the recovery of the wreck after dismantling (since the one solution recovery failed), the hull lines were studied through the building of a 1:10 scale model in cardboard and plexiglass (fig. 10) [9]. This was subsequently surveyed with a measuring *Cam2 Faro Arm* obtaining a schematic geometric model of the constructive lines in correspondence with the frames and the planks. The cardboard model was also manually surveyed to create the plan and the prospect of the starboard side (fig. 11). This documentation has been integrated and compared to obtain the model of the preserved part and of the hypothetical lines of the hull.

First, we have reconstructed a surface on the sections of the hull lines and we have noticed that this didn't naturally shape, forcing us to adjust some sections to reach a correct surface at a medium solution between the measure of both surveys (fig. 12). The point cloud obtained from the new photogrammetric survey of the scale cardboard model has been used to check the correctness of the surface of the hull. Using the description of archaeological remains of the hull [10-11] and the 1:10 drawings we could projects the shapes of the planks on the surfaces and cut it in the 12 and 19 existing portion of the hull (coloured in dark green in fig. 12)

The frames have been duplicated from *in situ* model and have been rotated to perfectly match the hull.

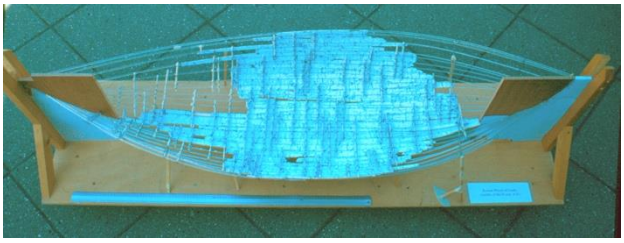

Fig. 10. Cardboard model of the shipwreck (model: C. Beltrame and D. Gaddi)

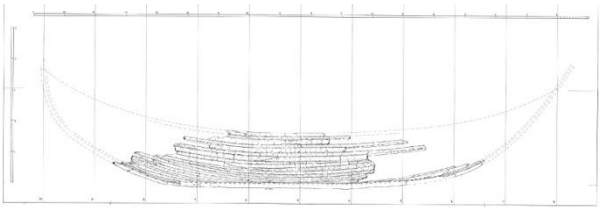

Fig. 11. Perspective drawing of reconstructed hull lines (drawing: G. Penzo).

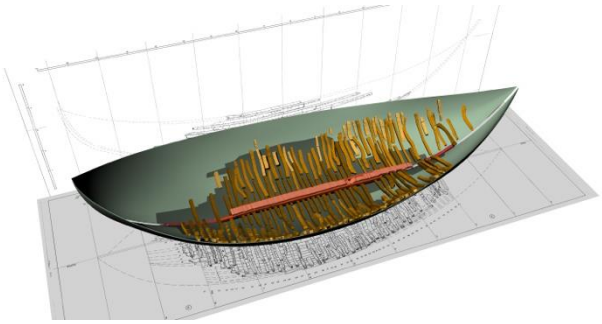

Fig. 12. 3D reconstruction of the hull lines (processed by: E. Costa).

B. The cargo of amphoras

At the moment, the work is continuing on the reconstruction of the cargo of amphoras in the stowing position, before the sinking.

Every single amphora, even those rendered in the photogrammetric survey, will be modelled and positioned on the *in situ* plan in a 3D view. Then, the amphoras will be rotated from the tilted position of the sinking to the vertical position of the original cargo and will be moved in the stowing place, in correspond of the frame and inner planking of the reconstructed hull.

V. CONCLUSION

This project is an action of the Interreg Italy-Croatia *UnderwaterMuse - Immersive Underwater Museum Experience for a wider inclusion* project, that promotes a new kind of accessibility to a wider public through a digital approach to the underwater archaeological sites of the Adriatic Sea. The main aim of our action is the development of a methodological and technological protocol for the documentation and communication of an archaeological site as a complex and multi-stratified context. The objective is therefore to transform the site into an underwater archaeological park (or eco-museum) through digital, innovative and experimental methodologies and techniques in order to disseminate the importance of the underwater cultural heritages. (non capisco le ultime due righe)

Concluding, the recovery of archive and legacy data represents an essential requirement to avoid the loss of relevant information, but, at the same time, this kind of survey and documentation presents some problems and difficulties, that could be resolved with digital technologies and innovative solution, permitting new studies and new visualization of a site not available and never exposed to the public. (forse fonderei le due ultime frasi in una perché così non è chiaro e d è ripetitivo)

REFERENCES

[1]J. Green, Legacy data in 3D: The Cape Andreas Survey (1969-1970) and Santo Antonio de Tanna Expeditions (1978-1979), in J. McCarthy, J. Benjamin, 3D Recording and Interpretation for Maritime Archaeology, p. 28-43, 2019.

[2]D. Atkinson, D. Campbell-Bell, Michael Lobb, The conservation and management of historic vessels and the utilization of 3D data for information modelling, in J. McCarthy, J. Benjamin, 3D Recording and Interpretation for Maritime Archaeology, p. 103-122, 2019.

[3]I. R. Mollema, J.F., McKinnon, Legacies of an Old Design: Reconstructing Rapid's Lines Using 3D Modelling Software, in society for Hystorical Archaoelogy, 2016.

[4]M. Secci, C. Beltrame, S. Manfio, F. Guerra, Virtual reality in maritime archaeology legacy data for a virtual diving on the shipwreck of the Mercurio (1812), Journal of Cultural Heritage, 2019, https://doi.org/10.1016/j.culher.2019.05.002.

[5]C. Beltrame, The Mercurio. Brig of the Regno Italico Sunk During the Battle of Grado (1812), Turnhout, Brepols publisher, 2019.

[6]E. Costa, The Progress of Survey Techniques in Underwater Sites: The Case Study of Cape Stoba Shipwreck, ISPRS, Volume XLII-2/W10, pp. 69-75, 2019.

[7]Auriemma R. (ed.), 1999, Operazione Iulia Felix. Dal mare al museo. Lo scavo, il recupero e il progetto di musealizzazione della nave romana rinvenuta al largo di Grado, Monfalcone, Edizioni della Laguna.

[8]Babbini L. (ed.), 1994, Operazione Iulia Felix. Dal mare al museo. Lo scavo subacqueo della nave romana rinvenuta al largo di Grado, Monfalcone, Edizioni della Laguna.

[9]Beltrame C., Auriemma, R., 2013, Lo studio ricostruttivo della nave romana di Grado, L'archeologo subacqueo, XIV, n. 3, pp. 12-20.

[10]Beltrame C., Gaddi D., 2000, Iulia Felix. Documentazione e analisi degli elementi strutturali dello scafo della nave romana di Grado (GO), Archeologia delle acque, 4, pp. 99-102.

Beltrame C., Gaddi D., 2007, Preliminary Analysis of the Hull of the Roman Ship of Grado (Gorizia, Italy), The International Journal of Nautical Archaeology 36.1, pp. 138-147.