3D surveying of an eighteenth century merchantman off the Red Sea coast of Saudi Arabia

Chiara Zazzaro – Romolo Loreto – Enzo Cocca

Abstract *– In September 2015 a team of the Saudi Commission for Tourism and National Heritage and of the Università di Napoli „L'Orientale" started an underwater survey in the area comprised between Yanbu and Umm Lajj on the Red Sea coast of Saudi Arabia. The main focus of the survey was to identify the location of an 18th century merchantman wrecked at a reef to the north of Umm Lajj, off the Saudi coast. The wreckage area extends about 40 m in length and 12 m in width. Parts of the hull and of the cargo are exposed and are clearly visible. The presumed stern area is characterised by the presence of a large mound of around one thousand jars.*
Surveying methods included the use of video recording and 3D reconstruction methods. Meanwhile, handmade measurements and drawings have been used for small objects, such as single pottery artefacts and isolated elements of the hull. A 3D survey of the wreckage area has been conducted by simply using an underwater camera. The images have been processed with photogrammetric approach using the algorithm Structure-from-Motion (SfM). The resulting 3D model has been used to obtain orthorectified images which were used as a base map to extrapolate plan views and sections of the shipwreck and its cargo. The results of the Umm Lajj wreck first survey will be presented. Problems and advantages of using the 3D survey method will also be discussed.

Inhalt *– Im September 2015 startete ein Team der Saudi Commission for Tourism and National Heritage und der Università di Napoli „L'Orientale" einen Unterwassersurvey im Gebiet zwischen Yanbu und Umm Lajj an der saudi-arabischen Küste des Roten Meeres. Hauptziel war die Lokalisierung eines Frachters aus dem 18. Jh., der auf einem Riff nördlich von Umm Lajj gescheitert war. Das Wrackareal erstreckt sich über 40 mal 12 m. Teile des Rumpfes und der Ladung liegen frei und sind gut erkennbar. Die Stelle, wo das Heck vermutet wird, ist durch einen großen Hügel aus rund tausend Krügen charakterisiert.*
Die Untersuchungsmethoden umfassten Videoaufnahmen und 3D-Rekonstruktion. Unterdessen wurden Handaufmaße und Zeichnungen für kleine Objekte, z.B. einzelne Keramik-Artefakte und isolierte Rumpfteile, genutzt. Ein 3D-Survey der Wrackstelle wurde einfach mit einer Unterwasserkamera durchgeführt. Die Aufnahmen wurden in photogrammetrischem Verfahren nach dem Algorithmus Structure-from-Motion bearbeitet. Das entstandene 3D-Modell diente zur Gewinnung orthorektifizierter Bilder, die als Grundlage zur Ausarbeitung von Planansichten und Schnitten des Wracks und seiner Ladung verwendet wurden. Die Ergebnisse des ersten Umm Lajj-Surveys werden vorgestellt sowie Vor- und Nachteile der 3D-Methode diskutiert.

1. Introduction

Ancient shipwreck sites identified and studied in the Red Sea are, so far, only few. The limited knowledge of shipwreck sites is partially due to the environmental context and to the lack of suitable strategies to investigate wrecks in this specific environment. The constant growth of the coral coastline may often cause the hide of shipwrecks, the warm sea water may affect the preservation of organic materials, while better preserved shipwreck sites can be found in depths less accessible to divers.

The lack of systematic underwater research is yet another reason why very little is known about shipwreck sites in the Red Sea. Brief surveys were conducted by the Supreme Council of Antiquities of Egypt (SCA) and the Institute of Nautical Archaeology back in 1994 in the Egyptian portion of the Red Sea (Haldane [Ward] 1996) and, by the SCA again with the British Museum and the University of Southampton in 2010.

Apart from sites investigated in the Egyptian waters like the 1st cent. CE Roman shipwreck found at Fury Shoals, to the north of Ras Banas, Egypt (Blue 2013), there is also a late 4th to early 7th cent. CE wreck off the island of Black Assarca, in Eritrea, investigated in 1997 by Ralph Pedersen, and a similar wreck recently identified in the Saudi waters of the Gulf of Aqaba. Meanwhile some Roman, Byzantine and modern shipwrecks have been identified off Jeddah, in Saudi Arabia, thanks to recent surveys conducted by the Saudi Commission for Tourism and National Heritage (SCTH) in collaboration with Marburg University (Pedersen 2015).

Among the best preserved ancient shipwreck sites in the Red Sea, three date to modern period – one of which is the object of our research. The first was discovered in 1969. It was found off the coast of Sharm el Sheik (Egypt) (**Fig. 1**) (Raban 1971); the cargo included Chinese porcelain, jars and pipes and it was recognised as a large ship involved in the Ottoman trade with the East.

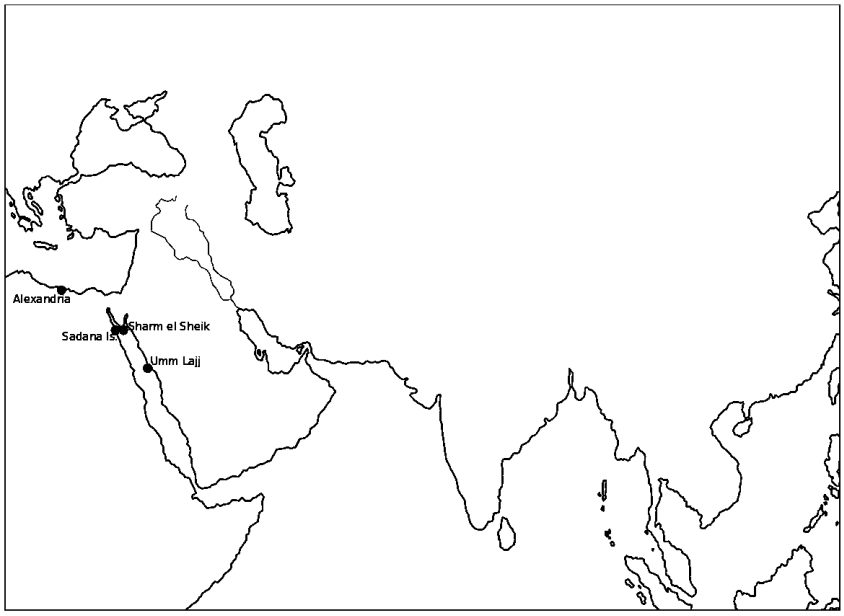

Fig. 1: General map of the Indian Ocean.

Later in 1994, a shipwreck with a similar cargo was found and systematically excavated at Sadana Island, near Safaga (Egypt) (**Fig. 1**) by the SCA and by the Institute of Nautical Archaeology (Haldane [Ward] 1996; Ward 2001). Excavations lead by Ward revealed the presence of a cargo which included Chinese porcelain, jars, pipes, coconuts, perhaps also coffee from Mocha, spices, drugs, myrrh, and incense (Ward 2001; 2002).

More recently, a group of sport divers identified – off the coast of Umm Lajj, in Saudi Arabia – a shipwreck with a cargo including Chinese porcelains and jars, similar to the Sharm el Sheik and Sadana shipwreck cargoes (**Fig. 1**).

In 2009 the Umm Lajj shipwreck was subject of a BBC documentary program „The Frankincense Trail". These earliest images demonstrated that this could have been one of those ships involved in the Ottoman trade in the Indian Ocean, like the Sharm el Sheik and Sadana wrecks. Some footage from the documentary also proves that unfortunately part of the cargo has disappeared since then.

In 2015 a team of the University of Naples „L'Orientale" was invited by the SCTH to survey – underwater – a portion of the Red Sea Saudi coast comprised between Yanbu and Umm Lajj. The first field season took place in September 2015. Given the short time available for the survey, the team decided to focus on the Umm Lajj shipwreck to the north of Umm Lajj, which is to the north of that town.

The Saudi-Italian team was composed by seven Saudi divers, mostly archaeologists form the SCTH, six crew members of the Dream Diver company, and four Italian divers: co-directors Chiara Zazzaro and Romolo Loreto, one student of the „L'Orientale" University and one underwater photographer and video recorder, Massimo Bicciato. The team was based on a live-aboard boat, equipped for underwater tourism, and rented in Jeddah, the trip to the site took a day and a half, including the overnight stop at a reef.

The Umm Lajj shipwreck was relocated by the crew members of the boat some 23 m to the east of an isolated reef. Once the shipwreck was located, the survey boat was moored in front of the reef and few metres to the west of the site. The reef extends for circa one kilometre north-south, here, circa 250 years ago, a merchant boat probably found a shelter from the north-west winds prevailing all years in this sector of the Red Sea, and subsequently wrecked, perhaps while at anchor. The shipwreck lies on a sandy sea bottom sloping from 18 to 22 m below the sea surface and is roughly west-east oriented, perpendicular to the reef, suggesting that it has been anchored or moored overnight, with the bow facing the reef.

We can only speculate about the reason why the ship wrecked: perhaps a fire on board, an accidental impact to the reef, changing of weather conditions or technical problems.

The time spent on the site was limited to only 5 days during which the team completed 12 dives, diving two to three times per day in average, in alternated groups of 4 up to 6 people each time. The average depth the divers reached was 22 m and the average temperature was of 29 degree. During this first field season the team completed the following tasks: locating and georeferencing the position of the shipwreck using control points, producing detailed photography and video recording, mapping the site using digital photogrammetry, taking basic notes and measurements of the cargo and hull, sampling the wood of visible components of the ship, for analysis, training the Saudi component of the team.

Training activities consisted in describing the main features of the shipwreck and its cargo under-

Fig. 2: General view of the Umm Lajj shipwreck hull remains.

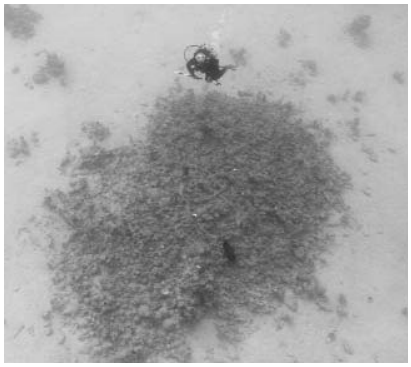

Fig. 3: The mound of qulal.

water, taking measurement and detailed notes and photographs of pottery finds, then producing technical drawings of selected finds.

2. The site

The site, including the wreck, the cargo and the artefacts around it, extends for over 40 m in length and 16 m in width including scattered parts of the cargo, particularly jars, in the area around the hull. The remains of the hull appear to be in a good state of preservation with some frames visible in the central area and some fragments emerging from the presumed stern area (**Fig. 2**). The most prominent feature at the site is a large mound of hundreds intact jars measuring 10 m in diameter and 2 m high. Almost all the jars are cemented by the calcium carbonate, naturally secreted by coral (**Fig. 3**).

2.1 The cargo

The part of the cargo that the team could observe emerging from the sea bottom, also included: several fragments of large ceramic con-

Fig. 4: A fragment of a large storage jar

Fig. 5: Chinese porcelain cups.

Fig. 6: Fragments of coconut husks.

.ig. 7: An Ottoman type of pipe.

tainers, Chinese porcelain, glass bottles, coconuts and pipes.

In the central area, corresponding perhaps to amidship, the team noticed a prevalent concentration of large storage jars – none of them entirely preserved – of the type called *zyla* (**Fig. 4**). These vessels were most likely used to store water for the crew and/or cereals and seeds. Fragments of some large basins were also noted in the same area.

On the port bow quarter board side a concentration of blue and white Chinese porcelain cups was seen (**Fig. 5**). The cups are decorated with flowers and plants, the absence of human figures and animals may reflect the intention to respect the Islamic religious precepts of the destination markets, as suggested by Ward (2000).

A coconut husk and a pipe of Ottoman type were also found in the same area (**Fig. 6**). The pipe suggests that some of the crew members could have been Turkish or from a region under Ottoman influence (**Fig. 7**). While the coconut husks certainly comes from the eastern Indian Ocean area and reminds us the fact that part of the cargo may have been organic and therefore not straightforward identifiable without using proper methods of investigation.

Fig. 8: Detail of the qulal.

A fragment of a green glass bottle was found towards the bow area. This is comparable to the bottom of a type of square green bottles found in the Sadana shipwreck.

The large mound of concrete jars is positioned to the south-east end of the shipwreck, in the presumed stern area. These highly decorated jars are identified as *qulal*, a type of jars usually bearing a filter, widespread in Egypt and Arabia, and used for liquids (**Fig. 8**). The team counted circa one thousand jars and identified at least nine different shapes bearing various types of moulded decorations and incised geometric patters which will be analysed in detail in the future field season.

2.2 The hull

The overall structure of the hull is massive: the maximum length of the visible remains of the hull is 36 m, while the visible part of the width is 9 m, suggesting a ship measuring at least 40 m.

The parts of the hull emerging from the sandy bottom mainly include frames and stringers. All those elements look massive comparing to contemporary ship frames. In fact, among those that have been measured, the team recorded an average width of 18 cm in width and 20 cm in depth. These elements are spaced circa 41-42 cm center to center. The frames are nailed to the hull with square or rectangular iron nails. The nails examined on one of the frames are spaced 20/31/10 cm and they are 1.5 × 1/1.5 × 1.5 cm in size.

Five wood samples were taken from the visible frames and stringers. Wood analysis conducted by Rainer Garisch revealed that four elements, most likely frames, are pine (*Pinus* sp.). The only longitudinal element is oak (*Quercus* sp., deciduous).

2.3 Preliminary analysis

The shipwreck and its cargo recall very much the Sharm el Sheik and the Sadana shipwrecks. Both of these wrecks were dated on the basis of the cargo, and particularly on the basis of an inscription on a copper cooking basin, at Sadana, to the second half of the 18th century.

Few direct comparisons can be made with the Sharm el-Sheikh wreck because of scarce published information: the length of the visible remains of the hull seem to be similar, so as the system of joint, which includes the use of nails, and the estimated quantity and typology of *qulal* jars.

A comparison of the spacing of the Sadana frames with the measured frame spacings on the Umm Lajj wreck reveals that these latter are slightly lower, 41-42 cm against the 47-52 cm for the Sadana shipwreck. Frame dimensions are also smaller: 22 × 26 cm for Sadana compared with 18 × 20 cm for Umm Lajj. The system of joining frames to the planking using iron nails is the same in the three shipwrecks. The estimated length of the Sadana is 50 m, while Umm Lajj could be 40-45 m. The estimated capacity of the Sadana shipwreck was 900 tons, while for the Umm Lajj is not possible to estimate yet.

Like the Sadana and the Sharm el Sheik shipwrecks, the Umm Lajj may also have been a merchant ship dating to the 18th century, sailing up to the north of the Red Sea, carrying local and exotic products from the Far East perhaps, as suggested by historical sources, in exchange of red dye cochineal, paper, food and fabrics, bullion from Europe. The final destination of these ships and their cargo was most likely Egypt and the Alexandria markets. (Ward 2001). Like the two Egyptian wrecks, the Umm Lajj wreck represents some of the last evidence of the Egyptian-Arabian trade circuit in the Red Sea before the interference of Napoleon. In this period the Mediterranean – Red Sea connection, which also included the important coffee trade, was monopolised by the Ottoman Empire.

Just as with the other two shipwrecks, it is so far difficult to understand what was the aspect of the ship and where it has been built and in which boatbuilding tradition it fits. Iconography suggests that various types of ships sailed up and down the Red Sea at that time. So as historical sources attest both the existence of shipyards in Suez and of ships of Indian construction in the area (Ward 2001).

The identification of the wood suggests that it was built in the northern part of the Red Sea, where species such as pine and oak were more easily available, through the Ottomans.

The Sadana and the Sharm el Sheik shipwrecks, both seem to suggest a local and, so far, unique type of construction, perhaps more similar to the Mediterranean tradition than to that of the Indian Ocean, although we have to take into account that very little is known about boat construction in this area at that time.

3. The 3D survey and data management

A 3D survey of the wreckage area has been conducted using an underwater camera. The images have been processed by Enzo Cocca with the Structure-from-Motion (SfM) method for the 3D processing (Cocca 2014). The resulting 3D model was the starting point for extrapolating an orthorectified image to be used as a topographic base map for drawing plan views and sections of the wreck and its cargo.

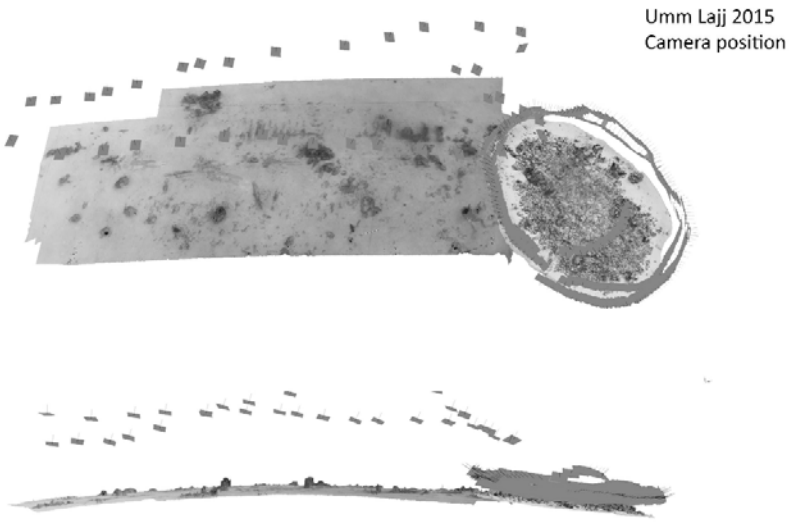

Fig. 9: Survey drawing of the shipwreck site.

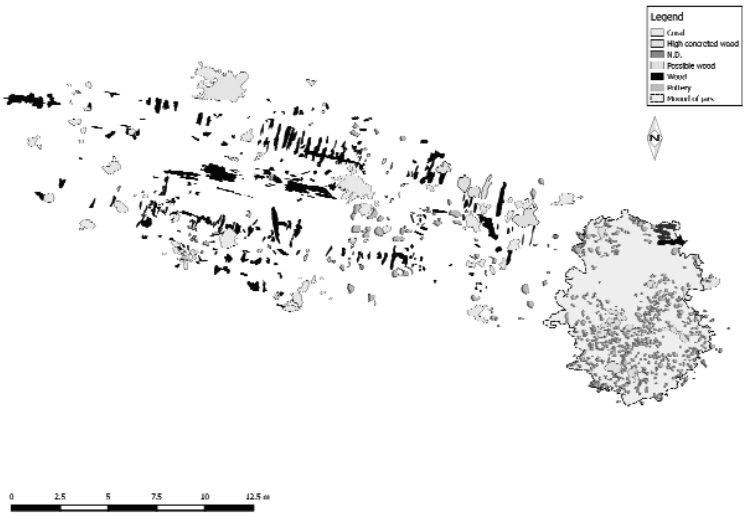

Fig. 10: The orthorectified image and the digital elevation model showing camera positions.

The topographic map runs on the Qgis GIS programme. The software used for processing images and for the 3D reconstruction was PhotoScan Pro (version 1.2.4) of Agisoft. Topographic data are linked to a spatial DBMS especially created in Postgres/Postigs (version 9.3/2.0).

The management and the exchange of archaeological data, both alphanumeric and geometric, among other members of the project are administered on a Web Platform of the University of Naples „L'Orientale".

The images were taken with a Canon EOS 500D with a fixed focal lens length of 17 mm and 12 mm with a resolution per frame of 4752 × 3168 pixel. The total number of processed images for the 3D reconstruction of the wreck in question are 313, 105 of which were used for the reconstruction of the wreck and 217 for the reconstruction of the jar mound. The average height of filming from the seabed is of 3.86 m. The produced orthophoto resolution is 1.4 mm per pixel. The image overlay is about 80% (**Fig. 9**). The points cloud extrapolated for the 3D reconstruction are 23.843.651 millions. In order to extrapolate the point cloud, a depth filtering, aggressive type, was used. The mesh produced by the point cloud consists of 4.522.655 million of faces and 2.264.983 million of vertices.

The 3D final product was georeferenced using nine control points (GCP) in the geographical system WGS84. The average error (RMS) of georeferencing is 0.86 cm, 0.40 cm of which are on the x-y axis and 0.77 on the z, these errors are due to the use of the manual GPS.

A digital elevation model (DEM) was also produced for the reconstruction of the bathymetry with a resolution of 5.6 mm per pixel (**Fig. 10**). The DEM reveals that the seabed, along with the investigated area, slopes NW-SE and N-S, with a vertical drop of about 2.50 m, 18.60 m at the bow and 21.30 m to the east of the mound of jars.

4. Conclusions

During this field season the team managed to map the whole area accomplishing the tasks expected for this first visit to the site. In the overall the 3D photogrammetry has been an efficacious, fast and accurate tool for these aims. One of the disadvantages has been that it took long time to process data and to select the better set of photographs suitable for the photogrammetry.

Problems encountered by using this technology were due both to human mistakes and also to the nature of the site. In terms of human mistakes we had a couple of divers' figures appearing in the final general orthophoto; this was due to a lack of sufficient coordination during the diving time. The resolution of the top area of the qulal mound in the orthophoto was affected by the lack of a sufficient number of images, a fact which prevented us from distinguishing every single jar and completing the drawing of the whole mound. In order to improve the visibility of the jars for the orthophoto to allow a study of them, in the next field season jars will be cleaned from the organic deposit on their surface and the number of photographs to be taken will be increased.

Problems due to the nature of the site are: the presence of coral growing both on the pottery and on the wood, particularly on some emerging frames, and the presence of numerous fishes moving around.

The Umm Lajj shipwreck has a great potential both for conducting a long term scientific investigation and underwater excavation training for local archaeologists and students. The cargo, and the ship in itself, can be of great impact in the development of the local maritime cultural heritage. Large part of the cargo and of the wreck is still well preserved. All these data could lead, in the future, to an hypothetical reconstruction of a so far unknown type of ship.

Bibliography

Blue, L. 2013: The Red Sea, in: A. Catsambis – B. Ford – D.L. Hamilton (eds.), The Oxford Handbook of Maritime Archaeology (Oxford) 495-512.

Cocca, E. 2014: Kojtepa 2013. The Use of 3D for the Drawings of Excavation: A Methodological Approach. Newsletter di Archeologia CISA 5, 1-20.

Haldane [Ward], C. 1996: Archaeology in the Red Sea. Topoi 6/2, 853-868.

Raban, A. 1971: The shipwreck off Sharm-el-Sheikh. Archaeology 24.2, 146-155.

Ward, C. 2000: The Sadana Islands Shipwreck. The Red Sea in Global Trade. Saudi Aramco world 51.6, 14-21.

Ward, C. 2001: The Sadana Island Shipwreck: An Eighteen-Century AD Merchantman off the Red Sea Coast of Egypt. World Archaeology 32.3, 368-382.

Ward, C. 2002: The Sadana Island Shipwreck, in: U. Baram – L. Carroll (eds.), A Historical Archaeology of the Ottoman Empire. Breaking New Ground (New York, Boston, etc.) 185-202.

Pedersen, R.K. 2015: A Preliminary Report on a Coastal and Underwater Survey in the Area of Jeddah, Saudi Arabia. American Journal of Archaeology 119.1, 125-136.

Credits of figures

Fig. 1: Drawing by Salvatore Colella; Figs. 2-8: Photos UNO-SCTH Project/Massimo Bicciato; Fig. 9: Elaboration by Enzo Cocca; Fig. 10: Drawing by Enzo Cocca and Salvatore Colella.

Addresses

all three authors:

University of Naples „L'Orientale"
Department of Asia Africa and Mediterranean
Piazza S. Domenico Maggiore, 12
I – 80134 Napoli

Chiara Zazzaro
Mobile +39 3407882233
czazzaro@unior.it

Romolo Loreto
rloreto@unior.it

Enzo Cocca
enzo.ccc@gmail.com