Prehistoric and historic monumental funerary structures in the “Chott el Jérid” area (Southern Tunisia): the importance of photogrammetry for rapid and complete documentation in Saharan contexts

Structures funéraires préhistoriques et historiques monumentales dans la région du "Chott el Jérid" (sud de la Tunisie) : l'importance de la photogrammétrie pour une documentation rapide et complète dans les contextes sahariens

Enrico Lucci[1*], Savino di Lernia[1,2], Andrea Monaco[2], Moufida Jnen[3], Jaâfar Ben Nasr[4]

[1] Department of Ancient World Studies, Sapienza University of Rome, Italy
[2] The Archaeological Mission in the Sahara, Sapienza University of Rome, Italy
[3] Institut National du Patrimoine, Tunisia.
[4] Department of Archaeology, University of Kairouan, Tunisia

ABSTRACT. As part of the Tunisian-Italian archaeological joint mission to the Sahara, a research project (survey and excavation) has focused since 2015 on the study of the funerary archaeology of the prehistoric and historical communities of southern Tunisia. The surveyed area, located along the southern and eastern edges of Chott el Jerid (governorate of Kebili), was selected, after scrutinizing the information collected by the “Service Géographique de l’Armée Française” during the early 20th century about the funerary structures.
In this paper, we present two main archaeological funerary contexts and the methodology applied for the photogrammetric documentation of the architectural features of the structures. Then we present the post-processing of the point clouds carried out to obtain a complete data-set for the remote analysis of the excavation sequence of each tumulus. By adopting a multi-scalar approach, from GIS remote analysis to photogrammetric documentation of individual funerary structures, we have tried to optimize the chances of fieldwork activity, taking into consideration whilst so doing the contingencies due to the fluctuating socio-political situation that characterizes some countries of North Africa in recent years.
KEYWORDS. Photogrammetry; Point Clouds; Funerary archaeology; Saharan Archaeology.

Introduction

The presence of megalithic structures, specifically tumuli raised using locally available stones, characterize the desert landscape of southern Tunisia. These structures, territorial landmarks for the human groups that inhabited these regions in prehistoric and historic periods, are part of a wide cultural phenomenon, in synchronic and diachronic terms, that involves large areas of the Saharan desert (Di Lernia 2013).

From the Chott el Jerid up to the southern Tunisian borders, the region represents a pivotal point of transition between the Mediterranean and the Sahara Desert. Accordingly, it is of primary importance to understand the cultural processes and the human occupation of the different but interconnected environments during the prehistoric and historic periods. However, this area has not been subject to systematic archaeological research before, particularly as far as the funerary archaeology is concerned. Starting from the information collected by previous research (Ghaki and Paris 2013; Morgan et al. 1910; Pézard 1907; Zeil 1904; Zoughlami et al. 1985) the Tunisian-Italian archaeological joint mission (survey and excavation) has focused, since 2015, on the study of funerary archaeology of the

prehistoric and historical communities of southern Tunisia (Di Lernia et al. 2017; Ben Nasr et al. 2016).

The socio-political instability that has characterized some countries of north Africa after the Arab Spring has compelled a comprehensive review of all the fieldwork strategies. The research strategy must be planned to minimize risks. For an archaeological mission, this is reflected in a need to optimize the time and number of people employed in the field. With this in mind, the fieldwork was preceded by a careful remote analysis using a GIS platform to pinpoint the areas with greater archaeological potential, then in the field the excavation of the tumuli was performed with photogrammetry incorporated into the process as a means of rapid digital data collection. Photogrammetric documentation has proved incredibly useful in speeding up the excavation process and in obtaining a large amount of information about the architectural features of the structures. Furthermore, the post-processing of the point clouds allows one to compare and analyze the similarities and differences among the structures in order to assess the intra-site and inter-site variability.

From GIS mapping to processing photogrammetry

A density analysis of "megalithic ruins" was run on a GIS platform, using the information collected by the "*Service Géographique de l'Armée Française*" during the early 20th century (Ghaki and Paris 2013) on the funerary structures. It revealed some major concentrations, alternating with isolated and scattered monuments, in the southeast area of Douz (fig. 1). The off-line use of remote analysis permitted an overall understanding of the research area and consequently made it possible to focus only on the archaeological funerary contexts with high potentiality. The field surveys, conducted with the assistance of the local guide Hedi Bel Hadj Brahim, have provided additional information about archaeological contexts and unpublished funerary structures in the dune area south of Douz: among the most important contexts identified there is the necropolis of Ben Chroud (site 15/11). A second stage of the investigation was then planned. This involved the excavation of selected funerary structures present in the areas of Ben Chroud and Wadi Lazalim.

Considering the contingencies of the archaeological mission, the documentation of the investigated structures incorporated photogrammetry to obtain a wide dataset for the whole excavation sequence in a short time span; it employed inexpensive instruments (Chodoronek 2015; Fonstad et al. 2013; Green et al. 2014; Westoby et al. 2012). Specifically, we used photogrammetry (Structures-from-Motion) linked to archaeological contexts to collect a vast dataset regarding the architectural features.

The main sites

During the three campaigns of survey and excavation, we focused on two main sites characterized by the presence of numerous clustered tumuli: the necropolis of Ben Chroud and the funerary structures of Wadi Lazalim (fig. 1). For each site we have excavated two 'sample' structures, in order to assess the potential of the archaeological context. In both cases, the main concerns centered on the possibility of the tombs being looted and on the potential poor preservation of the skeletal elements because of environmental and geological conditions.

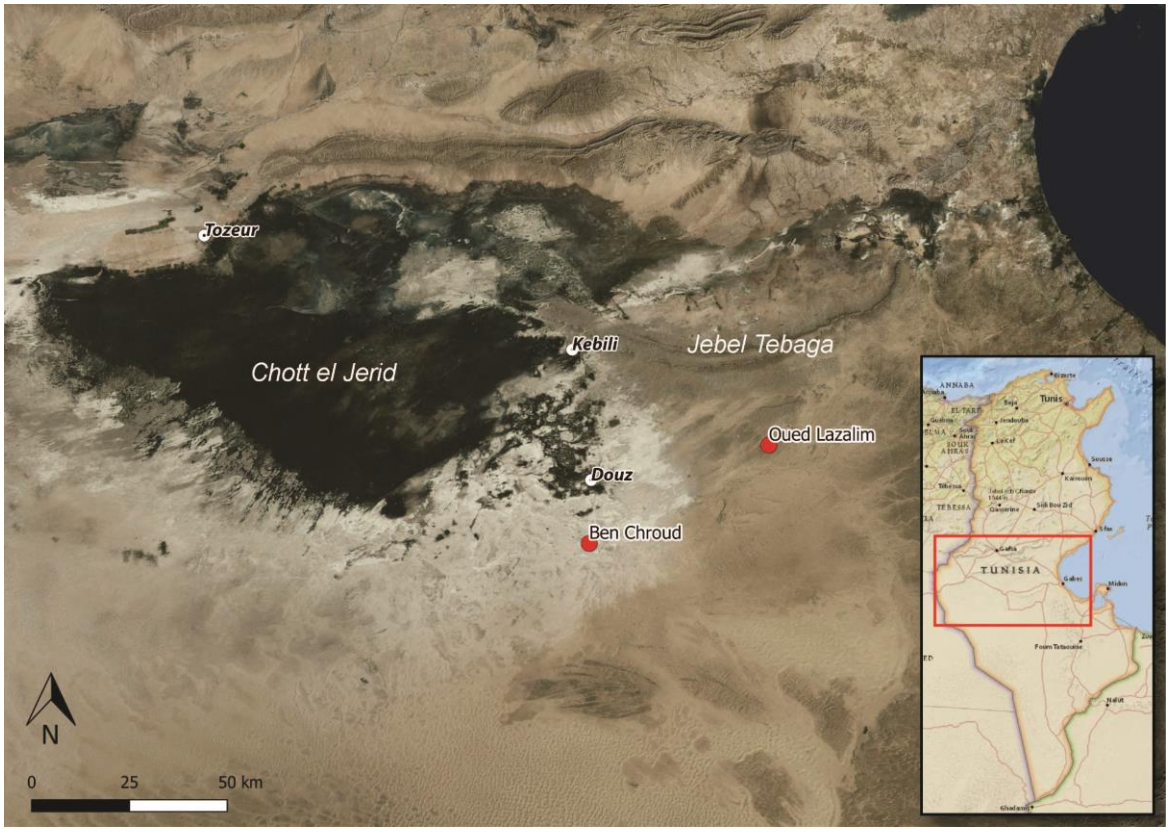

Fig.1. *Satellite map of the research area and location of the two main sites (red dots) (elaborated by E.L.)*

The necropolis of Ben Chroud

The necropolis of Ben Chroud (site 15/11) is sited at about 13 km south of Douz (N 33,338340, 9,003670 E/altitude 80 m asl) in a landscape mainly characterized by sand dunes. The fifteen tumuli that compose the necropolis are grouped in two separate clusters. The first one is constituted by tumuli T1-T6 and T15 and the second one constituted by tumuli T7-T14. Coordinates, morphology, dimensions, photographic documentation and state of preservation have been recorded for each structure. The conical tumuli, ranging from ~3 to ~10 m in diameter and of a height that never exceed 1 m, are composed from small/medium -sized stones coming from the bedrock of gypsum naturally present in the area. Ancient or recent depredations of the tombs were testified to by the alteration of the tumulus profile, especially by depressions in their top; all the structures were covered by aeolian sand.

Given the extent of the necropolis and the contingencies of the mission, two ‘sample’ structures were selected for complete excavation, with the aim first of collecting data on the architecture, the grave goods, the human remains, the chronology and then of comprehending through this something of the funerary behavior of the society that produced them.

Tumulus T3 is a conical structure of ~3 m of diameter and ~0.7 m of height; its stratigraphical sequence was composed of seven layers of stones of different sizes. The sub-rectangular burial chamber (~1.4 m in length, ~0.6 m in width and ~1m in height) was excavated into the gypsum bedrock. The only finds were three beads and a bronze ring (fig. 9 in Di Lernia et al., 2017), no skeletal elements but for a few and tiny poorly preserved bones were retrieved. For tumulus T5 (fig. 2), because of the dimension of the structures (~6 m in diameter and ~0.8 m in height), we excavated only a sample area (3x2.6 m) at the center of the tumulus, in order to optimize the excavation time. The sub-rectangular burial chamber, like that in T3, was dug down into the natural gypsum; it measured ~1.5 m in length, ~0.90m in width and 1.15 m in height from the top of the gypsum bedrock. Unlike that in T3, the T5 burial chamber expands, forming a small niche in its lower part.

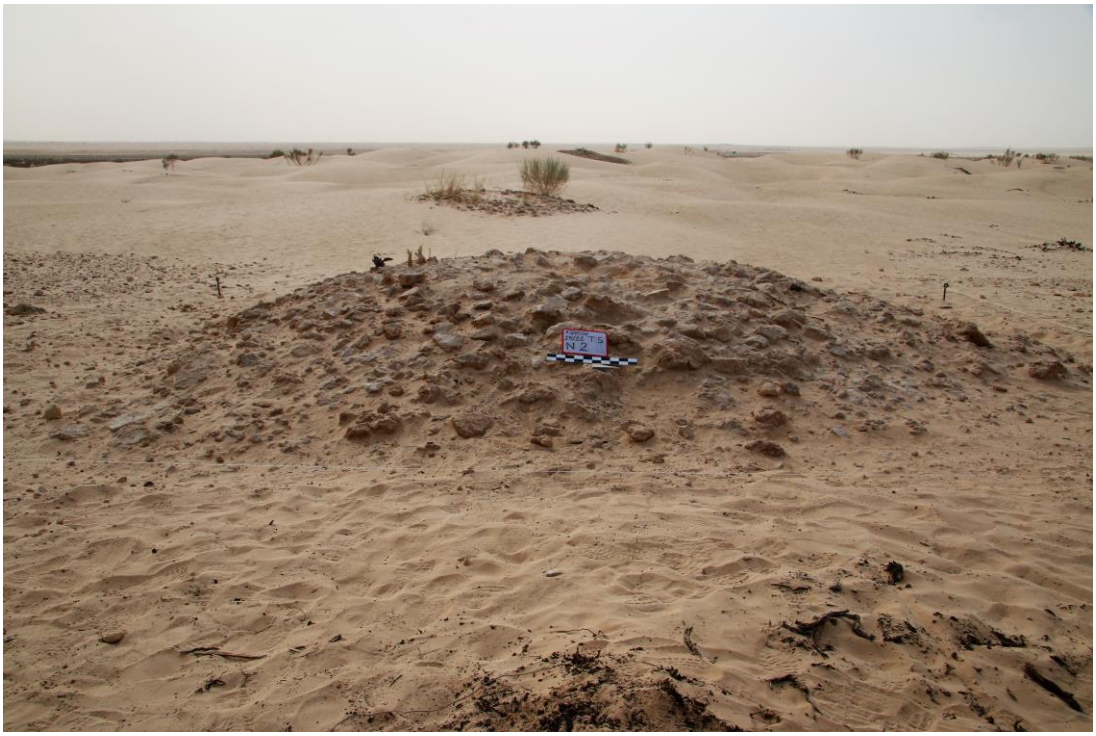

Fig.2. *Photo of the tumulus T5 of the necropolis of Ben Chroud (Tunisian-Italian photo archive)*

The funerary structures of Wadi Lazalim

The funerary structures present at Wadi Lazalim, situated in a landscape characterized by the presence of natural flint outcrops, are more scattered when compared with the necropolis of Ben Chroud. In this area we investigated two 'sample' structures, both of a conical shape and composed from small/medium-sized flint stones.

Tumulus 16/26 T1 is conical; it measures about 6 m in diameter and ~0.8 m in height. The stratigraphical sequence is composed of four layers of stones of different sizes and aeolian sand. Although the top of the gypsum layer was apparently intact and unaltered, no evidence of a burial chamber or any other type of grave was found. Hence, the function of the structure could be that of a cenotaph. Only three potsherds (of the same vessel) were retrieved during the excavation: they are attributable to the III century BC.

Tumulus 17/03 T1 measures about 10 m in diameter and reaches about 1 m in height. Unlike 16/26 T1, the burial chamber of this structure was excavated directly in the gypsum layer; the access to the chamber is of sub-rectangular shape and it measures ~1 m in length, ~0.5 m in width and ~0.9 m in height. Beyond the narrow access, the chamber expands to hold the deceased. The skeletal remains, due to the environmental and taphonomic conditions, were lacking, except for a few small fragments. Several potsherds were found during the excavation. Some of them are part of the same vessel. They allow the structure to be placed at least in the IV-V century BC.

From fieldwork raw-data to the point clouds

A complete photogrammetric survey of the main excavation sequence (before, during and at the end of the excavation) has been carried out for every investigated funerary structure; the whole picture acquisition process lasted no more than 15 minutes. The 50 or so images for each structure were acquired using a Nikon D3200 SLR camera (with NIKKOR 18-104mm lens). The camera was positioned at a height of about 3 m and activated with a remote control (fig. 3).

The images collected in the fieldwork were processed day by day to obtain the point clouds, so that we could check the reliability of the raw-data and the efficacy of documentation strategies. The main

work for the photogrammetry processing, such as creating the point clouds and the surfaces of the 3D model, were carried out using the software Agisoft Photoscan ©. However, for later elaborations (like model characterization by height and the extraction of the profile), we used the open source software Cloud-Compare (Girardeau-Montaut 2011; Oniga and Savu 2016).

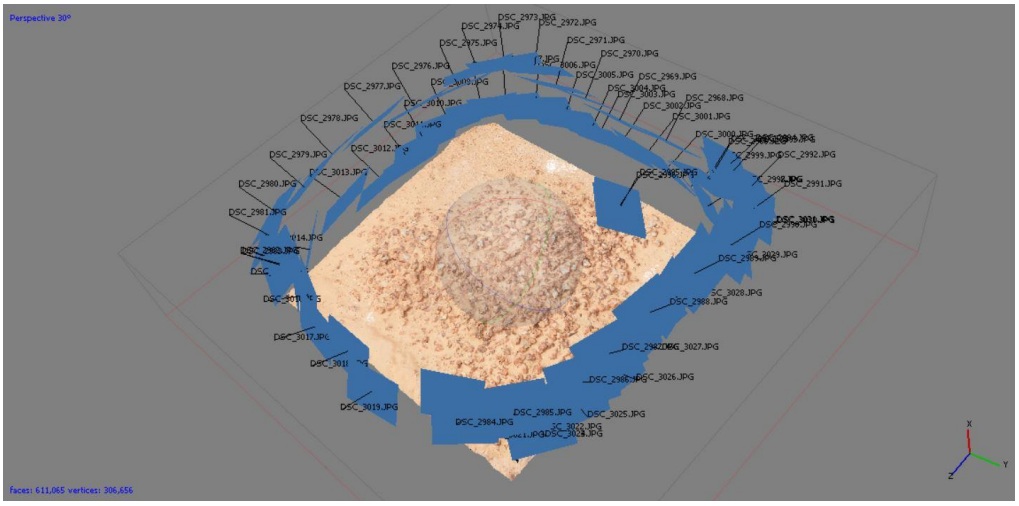

Fig.3. *An example of the image-sequence processed in Agisoft Photoscan® (elaborated by E.L)*

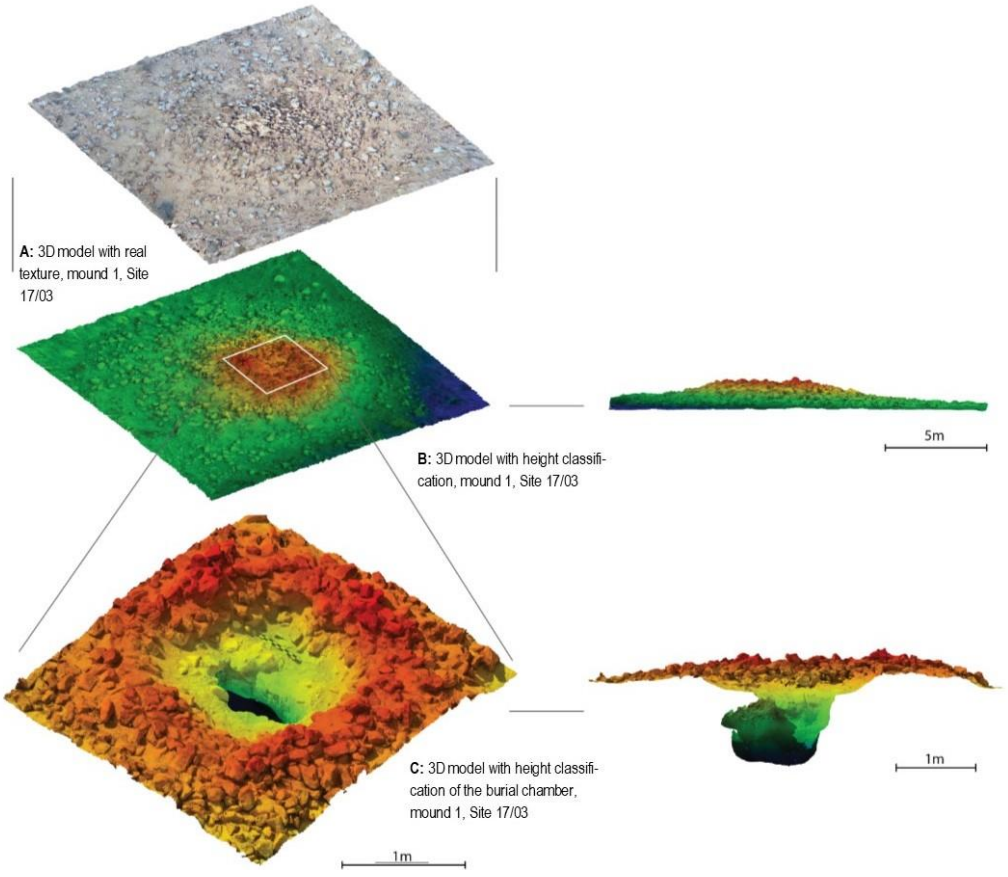

Fig.4. *3D model of the tumulus T1 of the site 17/03 (Wadi Lazalim) (elaborated by E.L)*

Two examples of the photogrammetric elaboration.

Tumulus T1 of the site 17/03 is an excellent example to show the reliability of the SfM photogrammetric method for Saharan funerary structures. Figures 4A and 4B show the 3D-model of the tumulus before the excavation, characterized by the real texture and by the gradient scalar field based on the Z axis. Figure 4C, on the other hand, illustrates the funerary structure at the end of the

excavation, with the burial chamber completely empty (point cloud elaborated with Cloud-Compare). What is most revealing is the exact rendition of the burial chamber morphology, despite the low light condition and the common problems inflicted by the desert environment (especially wind and sand).

As gaining permission for the use of drones is quite complicated because of the restrictive regulations in force in the country after the "Arab Spring", we have used the same method as tested on the single structures, this time to perform a photogrammetric survey designed to capture a spatial and morphological dataset for a wide group of tombs at Site 15/11. We obtained overall mapping of six burial tumuli (Fig. 5) set on a slightly elevated area, testing in this way the efficacy and the usefulness of this documentation method also for a large area.

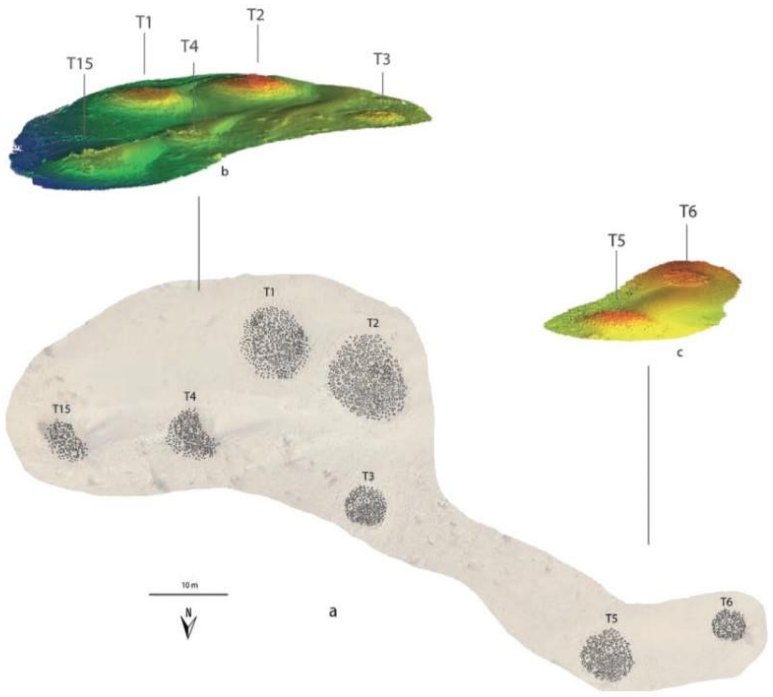

Fig.5. *Photogrammetry of the six-burial tumulus of site 15/11 (Ben Chroud) (elaborated by E.L)*

Final remarks

The Tunisian Sahara is home to a rich and remarkable cultural heritage, attributable to prehistoric and historic periods alike. In this rich framework of archaeological evidence, the monumental funerary structures, standardized in their general architectural features, are one of the most important and characteristic material culture phenomena. Nevertheless, the archaeological record lacks detailed knowledge about these monumental structures, due to the fact that few systematic archaeological researches have been carried out in the past.

With a multi-scalar approach, from the GIS remote analysis to the photogrammetric documentation of the individual archaeological structures, we have tried to optimize the time in the field to acquire a large wealth of information in a short time. This approach is extremely important in the present realities of the region, where planning of long-term archaeological fieldwork is currently difficult.

The excavated tumuli, chosen as representative of two different areas with clustered funerary monuments, show standardized architectural features (except for the absence of a burial chamber for tumulus T1 16/26): a conical shape formed by using small/medium local stones and an excavated

burial chamber taking advantage of the gypsum bedrock. Unfortunately, the environmental condition or, most likely, previous depredation, have compromised the preservation of the skeletal elements. Given the lack of organic matter (e.g., charcoal, bones, etc) It was possible to establish the chronology only on the basis of ceramic typology.

The photogrammetric documentation has been particularly reliable for the morphological data acquisition of all the excavation sequence. Worthy of note is the extraordinary achievement in the recording of the burial chamber, despite challenging conditions for image acquisition. At Site 15/11 (Ben Chroud), an extensive photogrammetric record of six tumuli set on the top of a slightly elevated area has been carried out, resulting in the acquisition of a reliable plan of the structures' features and distribution, without making use of a drone.

We then proceeded with a height characterization of the point cloud, using the open source software Cloud-Compare; this subsequent elaboration is extremely advantageous when analyzing and comparing the architectural features of the different funerary structures. This usefulness will be further enhanced, particularly when more data from other funerary sites from different areas is made available by further research.

The fieldwork and archaeological data analysis have benefited greatly from the use of remote sensing exploration and photogrammetry. Considering the small amount of time spent in acquiring the pictures during the fieldwork and the incredibly high potentiality and usability of the point cloud data and 3D-model, we can judge the use of photogrammetry as an indispensable tool, given the current contingencies of Saharan archaeological research. Obviously, remote analysis and photogrammetry can effectively support the traditional methods of work, but it is extremely important to comprehend that these tools cannot replace the fieldwork and teasing out of the relationship between material culture and archaeological landscape.

Acknowledgement

The authors would like to express their very special and heartfelt thanks to Ridha Boussoffara (Institut National du Patrimoine): who together with two of us (Jaafar Ben Nasr and Savino di Lernia), directed the three-year research program (2014-2017) in Southern Tunisia.

The authors would also like to warmly thank the Italian Embassy and the Italian Institute of Culture in Tunis, for their valuable support and help. Sincere thanks go also to the Director of the Institut National du Patrimoine and his staff for their valuable and appreciated support during the organization and execution of the work.

We extend our personal and affectionate gratitude to Hedi Bel Hadj Brahim (Artisanat du Sahara, Douz) for his friendship and invaluable support.

Emanuele Cancellieri and Matteo Dariol proffered many useful suggestions and discussions, which we happily and whole-heartedly acknowledge here.

The research has to date received funding from the Sapienza University of Rome (Grandi Scavi di Ateneo) and from the Italian Ministry of Foreign Affairs (DGSP), granted to Savino di Lernia.

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