THE ITALIAN ARCHAEOLOGICAL MISSION IN THE SUN TEMPLE OF NIUSERRA AT ABU GHURAB, EGYPT. THE USE OF COMBINED TECHNOLOGIES AND NEW PERSPECTIVES OF STUDY ON THE MONUMENT: THE TWO FIRST CAMPAIGNS

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Introduction

In January and December 2010 an Italian archaeological mission, led by R. Pirelli and A. D’Andrea, and directed in the field by M. Nuzzolo, began new investigations in the Sun Temple of Niuserra at Abu Ghurab, about 15km south of Cairo, Egypt (Fig. 1).

The archaeological survey of the site was planned in order to re-examine the temple more than one hundred years on from the discovery by the German archaeologist Ludwig Borchardt in 1898.

1 The general goals of the project, the Egyptological perspectives of the research and the results of both the technical and Egyptological investigations carried out so far, have been discussed among all the authors, each of whom has also dealt with specific sectors and questions, and has edited and signed individual paragraphs.

2 The mission was planned during M. Nuzzolo’s PhD research, and a summary of the first mission is included in the unpublished dissertation “I Templi Solari e l’Ideologia Regale nell’Antico Regno”, discussed in May 2010 at the Università degli Studi di Napoli “L’Orientale”, herafter UNO - Research Supervisor: R. Pirelli. The authors would like to thank Dr. Zahi Hawass for his crucial support on the field. The Supreme Council of Antiquities (currently Minister of State for Antiquities) was represented at the site by the inspector Mashhur Mahmoud Aziz El Din Abdel Moati, whom we wish to thank for his cooperation. The two on-field data-acquisition campaigns were granted by CISA (UNO) and the Italian Ministry of Foreign Affairs (Direzione Generale per la Promozione del Sistema paese, Ufficio VI): the responsible of this project is A. D’Andrea. We wish to thank Emanuele Brienza (archaeologist and surveyor, University of Enna Kore) for his contribution to the last data-acquisition campaign.

3 For the history of the first explorations see Borchardt 1905, 1-6; Nuzzolo 2013, 163-176.
Our investigation is actually the first fieldwork in the area since the
time of Borchardt\textsuperscript{4} and is mainly aimed at a general re-evaluation of the
archaeological data still available on the site in order to establish a new,
revised plan of the temple, also thanks to the laser scanner technologies.

*The Sun Temple of Niuserra: architectural problems and priorities* (by M.
Nuzzolo)

The sun temple of Niuserra, sixth ruler of the fifth dynasty (about
2400 BC), covers an area of about 8800 sq m and includes the following
parts (Fig. 2) (Borchardt 1905, 41):

\begin{itemize}
  \item[a.] the surrounding wall measuring about 110 × 80m;
  \item[b.] the central courtyard aligned with the main entrance;
  \item[c.] the alabaster altar in the centre of the courtyard;
  \item[d.] the corridor - originally roofed - which runs along three sides
  of the courtyard itself (northern, eastern and southern);
  \item[e.] the “storehouse” in the north-eastern side;
  \item[f.] the so-called “Big and Small Slaughterhouses” which are
  placed in the north-eastern and north-western sides respectively;
  \item[g.] the “cult complex” composed of two contiguous rooms which
  are usually named “Chapel” and “Room of the Seasons”, in
  the southern side;
  \item[h.] the “obelisk” resting on a quadrangular pedestal which is
  currently preserved up to a height of about 12.5 m.
\end{itemize}

Many parts of the complex, such as the northern side of the
enclosure wall and the “Small Slaughterhouse” are largely destroyed. The
“storehouse” is also particularly damaged, missing almost all the precious
granite and quartzite door-posts and lintels (Borchardt 1905, 41), which

\textsuperscript{4} Very recently another PhD. thesis on the sun temples was published by Susanne Voss. However detailed, her research mainly focuses on the reassessment of the published data, without including any new field-work. Therefore, from the architectural and archaeological point of view, it does not offer any new element compared to Borchardt’s analysis. She does make, instead, some interesting remarks on the general significance of sun temples as well as the reasons for their sudden building and subsequent abandonment during the fifth dynasty. See Voss 2004, 165-192, and Nuzzolo 2007, 217-247 for the discussion of some specific points of Voss’ study.
were probably plundered to be reused, as it was the case with many other Egyptian monuments of the same period. The general bad state of preservation is even more astonishing when compared with the pictures of the temple in Borchardt’s time. In most cases, we can clearly see some architectural elements of the temple which are, instead, not visible any longer nowadays.

Therefore, the main priority of our mission was first and foremost to collect as many data as possible on the temple. The work was hence divided in two phases:

1. acquisition, revision and vectorization of all the available cartographical documentation on the sun temple and the surrounding area of Abu Ghurab;
2. laser scanner campaign of the most relevant archaeological features still visible in the site.

The combination of these two phases has given us the possibility to work out a revised and updated plan of the entire structure (Fig. 3) (Nuzzolo, Pirelli 2011, 665 and pl. 41), as well as to obtain a number of archaeological and topographical data to be analysed\(^5\).

In particular, our attention was focused on the central obelisk (Fig. 4), both on account of its good state of preservation, and because it represents by far the most interesting part, although the most critical, of the whole solar complex. In fact, Borchardt reconstructs a massive and squat structure with an overall height of 56m (Fig. 5). However, as we will see further below, this reconstruction raises some doubts and has already been criticized by the present writer in other occasions (Nuzzolo, Pirelli 2011, 665-69).

The area of the “storehouse” was also taken into primary account because of its close architectural similarity with other structure from the contemporary pyramids of Abusir. This comparison could offer a good chance to get some more clues on the possible shape of the area of the sun temple storerooms, also considering that most of them are completely destroyed.

\(^5\) On the general results of these investigations, see: Nuzzolo, Pirelli 2010; idem 2011.
The Laser Scanner Campaign (by A. D’Andrea and G. Iannone)

As one of the main targets of the new investigations carried out in Abu Ghurab was to test the reconstructions provided by Borchardt at the beginning of the last century, some high resolution techniques were applied for the acquisition of the still visible structures; only by starting from a geometrical model of the existing reality it is possible to propose and check some hypothesis.

In the field of the virtual archaeology many different methodologies has been developed for the implementation of 3D model and the extraction of some geometrical features as height, width and incline or slope of the monument. A virtual model allows to dynamically simulate some possible reconstructions and to navigate in a virtual space showing all possible alternative solutions. Thanks to modern and not so much sophisticated tools it is simple to interact with the model and provide multiple views of the archaeological object; in order to reach this goal, nonetheless, the priority is starting from a reliable geometry of the monument to be reconstructed. Only through a correct geometry of the model it is possible to analyze all the archaeological information and, mainly, to highlight any possible relationship among the elements belonging to such a complex monument. In order to extract and to compare different views or possible alternative hypothesis on the reconstruction of the monument, laser scanning techniques were used to provide a solid model for the temple of Niusera. Our purpose was not to analyze the model from a mathematical point of view, that is to apply some equations or calculations to check the correctness of the reconstruction. Rather we wished to offer a solid model of the existing remains of the Sun Temple, that could be displayed and observed in a visual way.

In 2010 two different data-acquisition campaigns were carried out with the aim of surveying the Chapel and the Room of Seasons in the southern side of the temple as well as the storehouse in the north-eastern side (in January), and the area of the obelisk and the altar (in December). The data-acquisition phase was carried out by means of a phase-shift laser scanner (Zoller & Frohlich Imager 5003). For the last campaign a total

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6 The campaigns were carried out in the framework of a project, granted by the Italian Ministry of Foreign Affairs and entitled “Ricostruzione digitale mediante laser scanner 3d del tempio solare di Niusera ad Abu Gourab.”
station was used to register the shots, while in the first work only some well-pointed features of the archaeological remains were utilized to align the point-clouds.

The obelisk, which covers an area of 1.600 sq m, currently appears as a two steps structure and shows four façades which have been subdivided into three parts for the scanning process:

1. the very top of the structure;
2. the median area (the current first step of the terrace);
3. the lower part (the current ground step of the terrace).

In order to guarantee a correct alignment of the shots in the post-processing phase, it was necessary to carry out a topographical network. This grid, implemented by means of the total station, was needed to georeference the three targets placed in each shot taken with the laser scanner. Furthermore, this phase was divided in three sub-phases:

1. implementation of the topographical network by positioning four pegs around the temple - following the shape of an ideal rhombus - and one peg at the very top of the obelisk (Fig. 6). The positioning of the pegs was carried out by total station (Fig. 7). The topographical network was closed by linking the first and the last point, in order to reduce possible errors in measurement. The five pegs were cemented over and can be, thus, reused in future surveys;
2. positioning and survey of the targets (at least three for each shot) by means of total station (Fig. 8);
3. realization of the shots (Figs. 9-10): considering the area and the distance from the laser scanner to the object to be scanned, the acquisition profile chosen for the survey was medium (resolution sub-centimetre, with a distance of 10m).

While the sub-phase 1 was carried out at the beginning of the fieldwork, the sub-phase 2 and 3 were repeated whenever the shot area shifted. In total 47 shots were taken, including the basement/obelisk as well as its internal corridor.

An accurate photographic campaign was also performed for each shot, in order to register the position of the targets and to subsequently create the textures needed for a photorealistic three-dimensional model. A management system was set up to archive all acquired information and
guarantee a good level of accessibility to the archive (shots, target positioning, measurements) as well as to ensure the accuracy of the subsequent alignment and registration phase (Figs. 11-14). A numbering system for the shots, the targets and the photos has also been defined in order to allow a more precise phase of roto-translation of the shots and the final patchwork of the images and the shots.

The shots were processed according to a well consolidated method (D’Andrea 2011). Each shot was cleaned and filtered with the aim of reducing possible noise produced by the instrument. The point clouds were then registered and aligned after the total station measurements of the targets. Finally the model was converted into a solid surface by means of the so-called “mesh” procedure. The reconstruction was simplified by eliminating the duplicate points.

From the final 3D model, reconstructed assembling all shots, some graphical information have been extracted to document geometrically the monument. The sections (Figs. 15-16) have been automatically generated by choosing a precise interval which shows the still visible part of the obelisk. Different perspectives, documenting the state of conservation, have been obtained from the model (Figs.17-20); in particular from a top view (Fig. 21) has been generated a map showing the perimeter of the obelisk, the internal corridor and the collapse of the walls in the South-West corner (Fig. 22). Finally some plans, with different characterizations of the blocks used for the external and internal side of the obelisk (Fig. 23a-b), have been superimposed on the original map, given by Borchardt (Fig. 23c-d), in order to compare the reconstruction obtained from the model with the survey carried out by the German archaeologist the last century.

Furthermore, and most importantly, the model can be used to suggest the possible original shape of the temple but also to obtain a more in-depth view of the architectural layout of the monument. This is very important also to plan a project of restoration of the temple, something which seems of particularly pressing when we consider the state of preservation of the temple and the recent episodes of plundering (see further below).
Architectural analysis of the obelisk. Preliminary results (by M. Nuzzolo and P. Zanfagna)

As briefly mentioned at the beginning of this paper, the shape and original height of the obelisk, as well as the internal structure of the basement supporting it, represent the worry of the study of the monument by Borchardt, and the weak-point of his three-dimensional reconstruction.

According to him, this part of the temple was shaped as a huge, wide obelisk (20m wide and 36m high) on top of a pedestal (that we will call from now on the “basement”) in the form of a large, truncated pyramid (40m wide and 20m high). An ascending corridor must have run twice all around the basement, finally reaching the base of the actual obelisk on the eastern side (Borchardt 1905, 33-40).

Because of the severe state of disrepair of the whole building already in Borchardt’s time, his reconstruction was mainly based on the shape of the determinative employed in the contemporary tomb of the fifth dynasty priest Ty at Saqqara, where the name of the temple is determined by a two-stepped building in the form of a squat obelisk on a large basement.

Borchardt compared the ratio between the two parts of the hieroglyphic sign with the archaeological evidence still available on the site, such as, for example, the dimensions of the core masonry of the basement, the sloping of both the granite casing at the bottom of the basement (about 76°) and a limestone block probably from the obelisk (about 81°), the surface of the pedestal at the height of 20m, and the surface of the base of the obelisk, which was believed to stand in the centre of the pedestal. Taking into account all these elements, he eventually estimated the total height of the complex at 56m (Bourchardt 1905, 12, 39-40).

However, although we accept the idea that the outline of the hieroglyphic sign used to determine the name of the temple in the inscriptions must have approximated the actual shape of the obelisk⁷, we

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⁷ As Kaiser argued concerning Userkaf’s temple, the hieroglyphic sign used as determinative of the sun temples name does not seem to have been chosen by chance. There appears to have been a correspondence between the sign itself and its real model (Kaiser 1956, 108-111, and tab. 1). For an updated overview of the question (Nuzzolo 2007, 223-224, 229-230, 237 and pl. 1).
cannot expect an exact correspondence between the proportions of the real building and those of its representation.

Moreover, Borchardt himself stressed the fact that this reconstruction was highly hypothetical and the alleged height of the structure was simply a proposal: «Solche Dimensionen ergeben nämlich die nach den uns überlieferten Abbildungen versuchten Rekonstruktionen, wenn wir die gefundenen Dimensionen zugrunde legen. Natürlich muss es jedem überlassen bleiben, diesen Hohen mit uns anzunehmen oder zu verwerfen» (Bourchardt 1905, 12). Nonetheless, this reconstruction was soon largely accepted by scholars and no longer investigated in the field in the coming years.

Thanks to the laser scanner survey, and the architectural analysis of the great deal of processed data, we are now able to question many points of Bourchardt’s reconstruction, although we should not forget that all the following remarks have to be considered as preliminary hints for future investigations in the field. As a matter of fact, the bad state of preservation of this part of the complex and, especially, the impossibility to accomplish a real re-excavation of the entire structure do not allow us to definitely clarify all the debated points of the issue.

Our investigation of the basement was focused on the inner corridor which is so far the best part of the complex to get some clues on the architectural structure of the obelisk.

As we can see (Fig. 24) the visible (and hence analysed) part of inner corridor is composed of three sectors:

1. the South-North entranceway leading into the basement of the obelisk from the “Room of the Seasons”;
2. the East-West wing running on the southern side of the basement and leading from the entrance of the obelisk to the south-western corner;
3. the South-North wing running on the western side of the basement and leading from the south-western to the north-western corner.

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8 This is also the case, for example, of the hieroglyphic determinative for “mer” (pyramid) which never matches the proportions of actual pyramids in Ancient Egypt.
The three parts, as we can also see in the plan drawn by Bourchardt (1905, Bl. 6), do not have the same dimensions considering that the first wing (approximately 7.5m long), i.e. the actual entranceway to the basement, is placed about the centre of the southern side of the obelisk, thereby dividing the inner section of the southern wing in two asymmetrical parts. One of these two parts, i.e. the actual second wing of the inner corridor, measures about 15.6m. The third wing of the complex is thus the longest of the three visible and analysed sections, measuring about 24m.

Thanks to the laser scanner data and the total station measurements, we have also ascertained the different elevations of these three wings. This is very useful to try to determine the possible rise of the inner corridor and, as a consequence, of the overall height of the basement and the obelisk.

The total station measurements were taken at the beginning and the end of each wing in order to have the maximum length of the different sections of the corridor as well as to establish their respective slopes. For the first and second wings, these measurements are particularly reliable since they were taken on the original level of the pavement which is still preserved and clearly visible.

As to the first wing, we established a gradient of about 12° considering that the elevation of the room of the season, which gives access to the obelisk, is 1.18m and the level of the inner floor of the first wing, before the beginning of the second wing, is 2.82m. The drop is thus of 1.64m (in a rise of about 7.5m). According to Borchardt this first wing was composed by a ramp whose gradient and structure (steps or real ramp), however, is not specified in the text (Borchardt 1905, 33-34). Taken into account the shape and size of this part of the corridor, we can now likely assume the existence of a real stairway to bridge the slope between the entrance of the obelisk and the first landing.

As to the second wing, we can establish a gradient of about 4° with a drop of 1.73m in a rise of about 15.6m. Only the last part of this wing seems to present a slightly steeper slope (about 6°) but it might be due to the presence of a landing connecting the second and the third wing. The German scholar reconstructed this part of the inner walkway as a 4° sloping corridor, although he also did not clarify the structure of the landing (Borchardt 1905, 34). The laser scanner survey thus seems to confirm Borchardt’s reconstruction.
As to the third wing, we cannot establish a precise gradient taking into account the very bad state of preservation of the paving stones and the fact that only one of these original stones, placed in the middle of the walkway, is still completely visible nowadays. As a consequence, we could only establish that the gradient of the third wing ranged between 6° and 8°, with a drop of about 2.4m in a rise of about 24m. Borchardt reconstructed this part of the inner walkway as a 8° sloping corridor (Borchardt 1905, 34, Abb. 21), 20m long, which is thereof quite suitable with our survey. Moreover, he had the possibility to measure the level of the pavement after having carefully cleaned it from sand and debris, something which, on the contrary, was not possible to us.

However, some doubts still remains on this wing of the inner corridor: in fact, even in Borchardt’s time, nothing was visible of the last part of the third wing and the calculation of its length and slope was simply due to a comparison of the data of the paving stones of the third wing with only 3 small stones left in place on the side walls of the fourth wing). Nowadays, however, nothing is visible in situ in that point (fourth wing of the inner corridor) of the obelisk. Therefore, the original length and slope of this part of the corridor, and especially of the rest of the walkway, appear very questionable.

The analogy with the inner corridors of the contemporary pyramids is quite evident. In the case of the pyramids, however, the inner passageway was not intended to be used and walked on. Rather it was a sort of symbolic, very narrow passage connecting the burial chamber of the king with the “afterlife” represented by the stars and the sky. As a consequence, it is not entirely clear why Borchardt reconstructed the inner corridor of the sun temple as a real walkway (with a noteworthy height, as we can infer from the axonometric drawing of the temple) ( Borchardt 1905, 33, Abb. 20, and Bl. 4) also considering that it would have been quite uncomfortable for such a scope being about 1.1m large and completely unlighted.

Moreover, based on the bulk of stone still visible today in the site, it is quite difficult to figure out a structure as high and impressive as Borchardt suggests.

In this regard, it is worth noting that the core of the basement - and likely also of the obelisk - is not composed of massive blocks of limestone as in the fourth dynasty pyramids. Rather it is characterized by a system of diagonal walls radiating from the center towards the corners and flanked by
several additional branches. These walls were made of huge, roughly shaped blocks, decreasing in size as they rose, while the compartments in between were filled with sand, chips and fieldstone (Borchardt 1905, 36-38 and Abb. 20). This building system, if it actually had been 56m high, with a slope of 76° for the basement and 81° for the obelisk, as imagined by Borchardt, would have likely had great architectural problems due to the strong sliding forces at the corners as well as the slipping down of the casing. Borchardt's reconstruction appears all the more unlikely when we bear in mind that the pyramids of both Neferirkara and Niuserra are actually very damaged and should originally reach about 72m and 51.6m, with a sloping angle of 53.7° and 51.5° respectively, that is to say much less than the slope of the obelisk.

Finally, as already pointed out in another contribution, the monument as reconstructed by the German scholar is largely problematic, although not completely impossible, also from the static and engineering point of view (Nuzzolo, Pirelli 2011, 668-669).

Taking into account all these elements, it is thus much more likely to suppose that the inner corridor would have run only once around the core masonry of the basement, possibly stopping on the eastern side, in front of the central altar.

The preliminary analysis of the laser scanner elaborations and images, seems to confirm this situation. As one can see (Figs. 21-22), the inner structure of the obelisk appears as a core nucleus of masonry (with a square base of about 16m) surrounded by the walkway, and finally closed by the outer masonry of the building made of massive limestone blocks. The latter was eventually cased with granite slabs at the bottom.

From the architectural standpoint, this would mean that the real obelisk did not rest on the basement, as Borchardt says (Borchardt 1905, 40), but was mainly formed by an extension of the core masonry of the

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9 This building system, very common during the Middle Kingdom (Arnold 1991, 178 with further bibliography), was also adopted in the pyramid of Neferirkara (Borchardt 1909, 41, Abb. 9) and probably in the pyramid of Niuserra himself, although Borchardt could not determine it with certainty (Borchardt 1907, 99-120, particularly 100 and Bl. 17).

10 Measurements of the pyramids are after Lehner 1997, 17. For more details on the building techniques and the static implications of Old Kingdom architecture, see also Arnold 1991, 124-178, particularly 128-32 and Lehner 1997, 210-23.
basement itself (Fig. 25). The real basement, instead, was actually represented by the inner corridor - and the side walls forming the framework of the corridor itself - and the outer masonry.

If the actual obelisk was really made as proposed in this paper, it means that its base was shorter than what previously assumed and, accordingly, that its overall height was lower than what commonly accepted.

We wish that further analyses on the ground, as well as the completion of the three-dimensional modeling of the temple which has been carrying out by other members of the team working at Abu Ghurab, could soon provide us with new information to clarify the overall height and structure of this unique monument of the fifth dynasty.

The area of the so called “storehouses” (by R. Pirelli)

The north-eastern area of the complex is occupied by a few rests of a group of interesting architectural elements (Fig. 26), which Borchardt interpreted as a vast storehouse for the short-term storage of offerings. The complex was completed to the East by a small secondary room with a stairway leading to the roof (Borchardt 1905, 40-2).

On the base of our investigation on the site, we could ascertain that Borchardt’s reconstruction should be reconsidered, because when the sun temple was being investigated by the German mission under his direction, the exploration of the contemporary pyramid temples of Abusir was still at a preliminary stage and the two storehouses of Sahura’s temple had not yet been investigated (Borchardt 1905, 1-6; Borchardt, 1907, 1-3).

A comparison between Niuserra’s storehouses with at least the northern series of Sahura’s store-rooms however might be useful to try reconstruct the architecture of the former, although these were slightly larger (by about 15%).

The Northern storehouses of Sahura’s complex (called by Borchardt “Schatzkammern”) are arranged on either side of a central corridor, reachable by a short transversal passageway framed by a monumental granite doorway; each room, L-shaped, has a monumental entrance framed by a black granite doorway; the staircase leading upstairs - made out of a single large rectangular block - is only accessible from inside the room, on its eastern side (Nuzzolo, Pirelli, 676, fig. 6).
Although Niuserra’s warehouses are very poorly preserved, it seems evident that they had slightly different features. Borchardt reconstructed a set of ten parallel rooms, arranged on only one side (the northern one) of a long corridor whose main entrance was placed at the south-western corner of the whole complex.

According to the scanty archaeological evidence, the main gateway of the storehouses as well as the doorways of all the interior rooms were framed by quartzite door posts and lintels. These doorways, unlike those of the magazines of Sahura’s funerary temple, carried the complete royal protocol (Fig. 27).

According to Borchardt, the back wall of these rooms was equipped with at least one shelf, approximately 0.35m thick, embedded in the walls about one meter above the floor. Borchardt found a single example of such a shelf (no longer preserved nowadays) in the second room on the west, but he could not exclude the possibility that other shelves might have been fixed to the wall at different heights (Borchardt 1905, 41).

Finally in the sun temple we could not find any evidence either of the large rectangular blocks where the stairs should have been carved or of the outline of the steps in the door jambs, as in the funerary temple of Sahura.

These elements should lead us to exclude the presence of stairways in the sun-temple magazines. However, it is noteworthy that most of the staircases have also disappeared from the northern row of rooms in Sahura’s “Schatzkammern” and that out of the 20 original door posts of the sun temple, only 5 are still preserved, apart from the door post of the main gateway to the storehouse. On the other hand, in the complex of Sahura there is no trace either of shelves or royal titles on the door jambs (Nuzzolo, Pirelli 2011, 675).

By using 3D laser scanning of the actual remains of the storehouse, processed through the CAD system, one could also verify the general measurements of this part of the solar complex. It is a rectangular area measuring 58 × 8m (these measurements only refer to the inner, paved area of the “storehouse”, as we cannot take into account the thickness of the temple enclosure wall because of its poor preservation, particularly on the northern side (If we also include the outer casing of the walls we obtain a total area of about 61.9 × 13.10m). The size of the inner rooms - max. preserved - is 6.30 × 2.20m (Nuzzolo, Pirelli 2010, 229-30; idem 2011,
677). The door posts, two of which still bear traces of the bolt housing, also have different sizes and rather irregular shapes, particularly in the sides that were built into the wall. They are about 1m in length with widths varying between 56cm and 80cm. The main face is usually around 45cm wide. The actual doorway was thus 76-77cm wide. As to the number of rooms, our measurements may confirm Borchardt’s reconstruction (10 rooms in total), although there are some difficulties regarding the last two rooms. As to the tenth room, no archaeological evidence of it survives (Nuzzolo, Pirelli 2010, 229-30; idem 2011, 676-78).

In the eastern part of the store-rooms, a large stairway leading to the roof was set in a narrow, winding room: this stairway, likely to be formed of two parallel ramps (the northern one missing), is built of fine white limestone and rests on massive limestone blocks. According to Borchardt, it must have been enclosed by walls on three sides and could be reached by a narrow passageway directly from the southern corridor (Borchardt 1905, 42).

Unfortunately, the poor preservation of this sector does not allow us to confirm Borchardt’s hypothesis: the supposed room where the staircase should be placed appears nowadays as a wide, rectangular chamber, completely paved in limestone, and none of the walls reconstructed by Borchardt can be identified, even as mere traces on the floor. Further investigation of this part of the magazines should thus help to clarify its original layout, although the recent events in Egypt caused some damages to the structure (see the addendum below).

Before leaving the area of the so-called “storehouses”, it is worth recalling two of their features: the presence of a door fastening for each room and the presence of the whole royal protocol on their doorjambs. This leads us to suppose that these rooms were somehow linked to rituals directly pertaining the royal cult sphere; we hence propose to identify them as “rooms for regalia” (or “Schatzkammern” to use Borchardt's words) rather than simple storehouses.

Future Project

A crucial part of the study of the sun temples was also represented by the reassessment of the general topography of the area of Abu Ghurab. In
2012, two of the members of the mission (M. Nuzzolo and P. Zanfagna) started working on a reconsideration of the historical development of the site and the possible location of the missing sun temples. In fact, we know from the historical sources that 6 temples were built in a time span of around 60 years. However, only 2 of them have been located and archaeologically investigated so far.

Therefore, the main aim of this part of the research was to analyze the historical cartography of the site (mainly Nineteenth Century maps and the French-Egyptian topographical map of 1978) by crossing it with both satellite images (mainly Google Earth), radar images (COSMO Sky-MED) and the aerial photos of the site. This has led to interesting results as regards both the overall topography of Abu Ghurab and the location of significant archaeological evidences currently covered by the sand (Nuzzolo 2013, 163-175).

This framework of research is now also enriched by a new initiative, i.e. the ARCHEOMODE project, led by A. D’Andrea in collaboration with a multidisciplinary team\(^{11}\).

The project, which started in March 2014 and will last four years, is supported by the Canadian Space Agency (CSA) and Italian Space Agency (ASI) and is aimed at investigating the potential of the high-resolution satellite images to monitor and manage the deterioration process of archaeological structures in the area of Abu Ghurab and the Eastern Desert.

The main goal is to use high-resolution radar acquisitions to support preservation of cultural heritage sites and monuments. The on-ground activities, carried out in these two areas, are contributing to the implementation of different cartographic systems obtained through topographical surveys carried out with Total Station or GPS, and detailed architectural surveys carried out with the laser scanner.

Comparing the results of the latest on-ground archaeological activities with the remote sensing tools could contribute to improving the selective identification of surface and sub-surface features and discontinuities, and to calibrate the capability of the SAR sensor, mounted

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\(^{11}\) The team includes as co-investigators the archaeologists Irene Bragantini, Rosanna Pirelli, Andrea Manzo and Rodolfo Fattovich, from UNO and the engineer Daniele Riccio from Università degli Studi di Napoli “Federico II”.


on COSMO Sky-MED and Radarsat2 satellites, to set up a methodology for the monitoring and management of the archaeological sites in desert areas.

The project is based on demonstrative examples of two different cultural heritage sites in the desert area. They provide a large spectrum of indicators of deterioration affecting the cultural built environments and archaeological landscapes at different scales and historical resolutions. The final results provided by the remote sensing will be inserted in the existing GIS systems, which will show the detected information.

The past monitoring of the preservation of the sites is crucial not only for their management, but also for the future of archaeological research: the state of deterioration of the sites may be of critical importance when selecting the areas to be preserved for further investigation. Current practices do not allow the analysis and control of all archaeological areas in the selected countries.

The acquisition of high-resolution satellite images will provide more detailed information about present strategies of land occupation, exploitation and management. The use of satellite and radar images will be particularly fruitful to:

1. improve our knowledge of the areas from an historical and archaeological point of view, Hopefully providing the possibility to investigate in detail the overall cartography of the area by means of modern tools;
2. supply a tool to analyze the environmental risk and to check the deterioration and decay of a site, which has never been the object of an integrated project of preservation, safeguard and possibly opening to the public.

The latter aspect is particularly interesting in the case of the site of Abu Ghurab. Here, the preliminary analysis of the satellite images (Fig. 28) has already shown a critical and intense activity of digging in the desert area nearby the sun temple (mainly to the west of it) in the last seven years. This activity has clearly grown after the “Arab Spring” of 2011 and represents, regardless of its use, a serious danger for the preservation, as well as the investigation, of the site.
Conclusion

The case-study of the laser scanner survey of the sun temple of Niuserra seems to clearly demonstrate that the new technologies cannot completely replace the old, traditional archaeological and topographical methods of analysis in the field. Rather, they should work together for improving and completing each other.

However, these technologies have the undoubted advantage to be quicker and more accurate in every details. This is all the more important when we consider that - getting back to the specific case of the sun temple - the scanning process and acquisition of the whole obelisk area lasted only five working days, which is also particularly important - from the economic point of view - when we have to plan “low cost” expeditions due to financial factors with which the recent researches and missions often have to face.

Moreover, these technologies provide us with a three-dimensional model which can be used for interactive purposes as well as for the extrapolation of ortho-images, plans and sections, with the further possibility to improve our knowledge of the area to be studied with the integration of other technologies such as, for example, the remote sensing and the aerial photogrammetry.

Last but not least, they allow us to continue working on the monument long after the end of the archaeological mission. In this period of political problems and great instability, as is exactly the case of Egypt nowadays, this definitely represents an asset that cannot be underestimated.
...the Sun Temple of Niuserra at Abu Ghurab, Egypt. The Use of ... Technologies and ...
ADDENDUM

In January 2014, while the mission was not working in the site, we were informed by some tourists visiting the area of Abu Ghurab, that the sun temple had partially been plundered. In particular, as one could see (Fig. 29) the pavement of the “Room of the Season” destroyed and partially removed with the probable aim to dig underneath, while most of the stairway leading to the roof of the temple, in the North-Eastern area of the “storehouse”, dismantled and left in pieces on the ground (Fig. 30).

The central alabaster altar has also been chipped in two points, as proved by a video dating back to the beginning of the year 2013 which is still available online (https://www.youtube.com/watch?v=mgTD7ynY2gU). These injuries not only represent a serious loss for the comprehension and study of the temple and its peculiarities. They endanger the preservation of an archaeological site of the 3rd Millennium BC which has no counterpart in any other site of Egypt. The local authorities have soon proceeded to restore the altar and the pavement of the “Room of the Season”, and we hope that similar events will not be repeated any more.
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FIGURES
Fig. 1 - Google Earth view of the area of Abu Ghurab with the two known sun temples of Niuserra (A) and Userkaf (B). The area of Abusir with the main pyramids (C) of the fifth dynasty.

Fig. 2 - Plan of the sun temple of Niuserra (after Borchardt 1905: Bl. 2)
Fig. 3 - The revised plan of the sun temple of Niuserra after the laser scanner survey. (Processing by M. Nuzzolo, G. Iannone, P. Zanfagna)
Fig. 4a, b - Two pictures of the current structure of the obelisk from the north-eastern (upper) and south-eastern (lower) corners (photo M. Nuzzolo)
Fig. 5 - Reconstruction of the “obelisk” (after Borchardt 1905: Bl. 1)
Fig. 6 - The cemented peg on the top of the obelisk
…the Sun Temple of Niuserre at Abu Ghurab, Egypt. The Use of …… Technologies and …

Fig. 7 - The positioning of the cemented peg on the northern side of the obelisk by means of Total Station

Fig. 8 - The positioning of the targets by means of Total Station
Fig. 9 - 3D laser scanner data-acquisition: the western side

Fig. 10 - 3D laser scanner data-acquisition: the corridor on the southern side
…the Sun Temple of Niuserre at Abu Ghurab, Egypt. The Use of …… Technologies and …

Fig. 11 - The management system adopted for the data-acquisition: the shots carried out on the top of the obelisk with the positioning of the targets

Fig. 12 - The points cloud of the shot R1 with the photos and the measured targets used for the alignment of the shots
Fig. 13 - The management system adopted for the data-acquisition: the shots carried out to acquire the eastern side of the obelisk and the altar

Fig. 14 - The points cloud of the shot R6 with the photos and the measured targets used for the alignment of the shot
…the Sun Temple of Niuserre at Abu Ghurab, Egypt. The Use of …… Technologies and …

Fig. 15 - The 3D model of the obelisk: in different colors 10 sections West-East and 4 North-South. The sections were automatically extracted from the 3D model every 5 meters

Fig. 16 - The 10 sections WE with view from southern side

Fig. 17 - The 3D model of the obelisk from North
Fig. 18 - The 3D model of the obelisk from South

Fig. 19 - The 3D model of the obelisk from East

Fig. 20 - The 3D model of the obelisk from West
…the Sun Temple of Niuserra at Abu Ghurab, Egypt. The Use of …… Technologies and …

Fig. 21 - A top view of the 3D model of the obelisk

Fig. 22 - A plan of the obelisk extracted from the 3D model
Fig. 23a-d - Four plans of the obelisk after the laser scanner survey. In the first two elaborations (23a-b) one can see the current state of preservation of the masonry of the monument; in the following two (fig. 23c-d) the comparison with the monument at the time of Borchardt (in the background). Total station measurements of the heights and the targets of the laser scanner are marked in different colors on the plan. (Processing M. Nuzzolo, P. Zanfagna)
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Fig. 23d - (Processing M. Nuzzolo, P. Zanfagna)
…the Sun Temple of Niuserra at Abu Ghurab, Egypt. The Use of …… Technologies and …

Fig. 24 - Summary draft of the main data of the laser scanner survey concerning the inner corridor of the basement compared with the plan by Borchardt, in the centre (Processing M. Nuzzolo, P. Zanfagna)
Fig. 25 - Outline of the hypothetical shape of the obelisk and the basement overlying the laser scanner elaboration (Processing M. Nuzzolo, G. Iannone, P. Zanfagna)

Fig. 26 - Overview of the area of the so-called “storehouse” (Photo M. Nuzzolo)
…the Sun Temple of Niuserra at Abu Ghurab, Egypt. The Use of …… Technologies and …

Fig. 27 - One of the quartzite door-post of the so-called “storehouse” endowed with the royal protocol (Photo M. Nuzzolo)
Fig. 28 - Three Google Earth images of the area of Abu Ghurab in the last seven years. The area of the extensive digging in the desert is in red
Fig. 29 - The “Room of the Season” before (upper) and after (lower) the plundering of the last months. The pavement has been destroyed and partially removed (upper and centre) to dig underneath (lower)
Fig. 30 - The stairway of the “storehouse” before (upper) and after (lower) the plundering of the last months. The huge stones supporting the stairway have almost completely been removed to dig underneath.