Fig. 1 The sun temple of Nyuserre: view of the remains of the "pedestal building" from the south-east (photo M. Nuzzolo)

Sun temple of Nyuserre in Abu Ghurab: Report of the 2017 season

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In January 2010, an Italian mission from University of Naples "L'Orientale" started a new archaeological investigation of the sun temple of Nyuserre in Abu Ghurab (fig. 1). During earlier campaigns, we realized that the plan drawn by Ludwig Borchardt (1905: Bl. 1) in 1898–1901 contained some inaccuracies and, most importantly, that his axonometric drawing and three-dimensional reconstruction of the main part of the temple's architecture, namely the so-called obelisk, was not convincing (Nuzzolo – Pirelli 2011: 664–679; D'Andrea *et al.* 2014: 48–98). Therefore, the aim of the mission is to produce an updated plan of the temple as well as a new proposal for a three-dimensional reconstruction of the obelisk's structure. Documentation works continued by the fifth season last year, lasting from 4th November to 30th November 2017 and including also a topographical survey of the area located south of the sun temple, which had never been systematically explored (Nuzzolo – Zanfagna 2017: 110–123).

The works in the 2017 season were focused on three areas of the sun temple:

1. the structure of the so-called obelisk;
2. the limestone blocks lying in the south-western corner of the obelisk;
3. the area of the alabaster altar.

For each of these three areas, we not only carried out a complete cleaning and documentation by means of traditional hand re-drawing, but also proceeded with a systematic laser scanner campaign. Laser scanner technology had been used in previous campaigns, but in both 2010 and 2014, we had used a type of laser scanner that did not provide

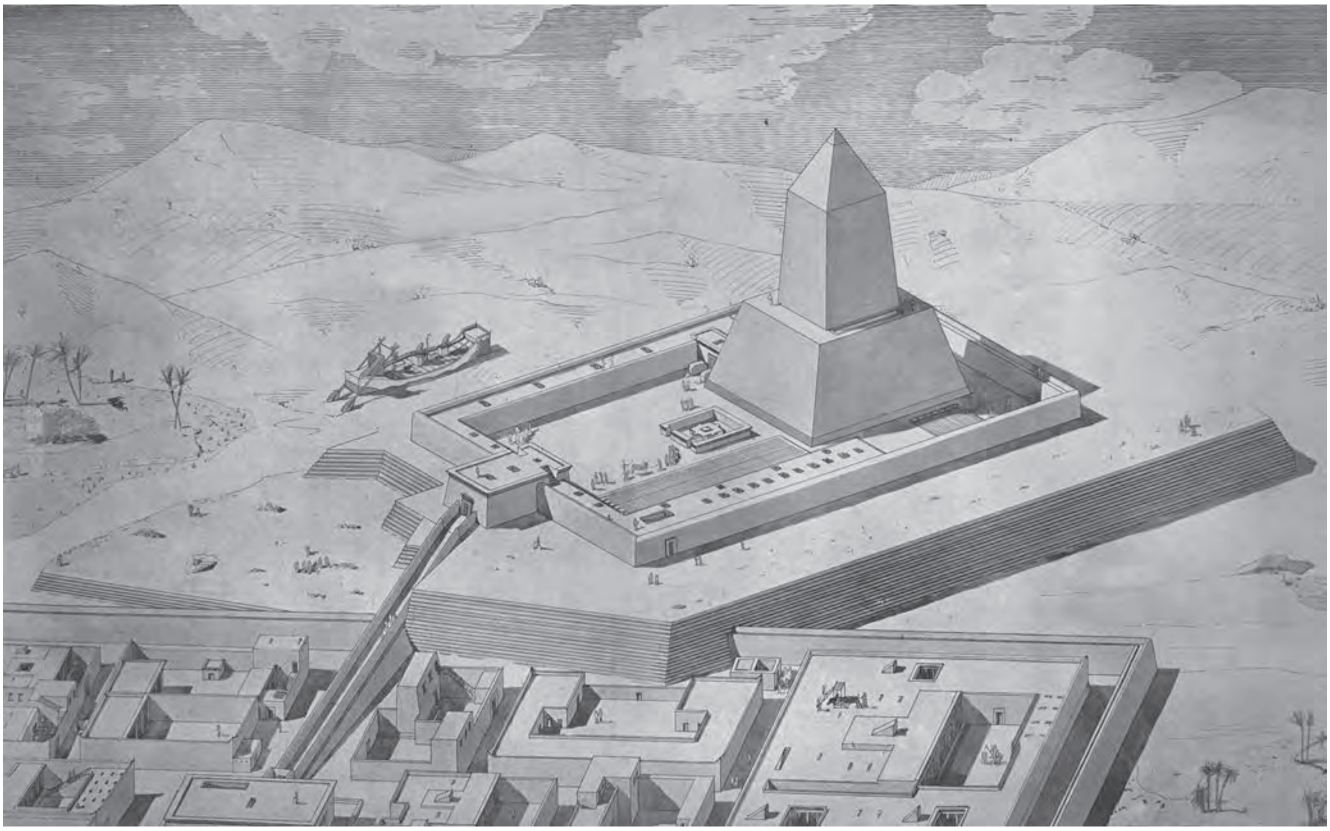


Fig. 2 Three-dimensional reconstruction of the sun temple of Nyuserre (after Borchardt 1905: Bl. 1)

us with the colour features of the analysed structures (D'Andrea *et al.* 2014: 48–98). This year, to the contrary, we used a new system of laser scanning which also gave us the colour indications and textures. To further implement our documentation procedure and the final reconstruction, we also accomplished a systematic photogrammetric campaign of all major architectural components of the above-mentioned areas, notably the core masonry of the obelisk and the most significant blocks of fine limestone and granite (many of them with hieroglyphic inscriptions) that are scattered all around the obelisk and the altar. This workflow has given us the possibility to combine two different methods of documentation and analysis of the archaeological dataset and, most importantly, has finally allowed us to re-create a 3D model of the temple's structures by means of a new methodological process of acquisition and management of archaeological and 3D data, so-called Building Information Modelling (BIM). This new technological/methodological approach, which is currently underdeveloped in archaeology and even less used in Egyptology, allows scholars not only to use archaeological data in terms of 3D modelling and reconstruction but also to produce categories of environmental and technological objects and sub-systems which represent the 3D semantic of the acquired model (see below for more details).

Obelisk structure (Massimiliano Nuzzolo – Rosanna Pirelli – Patrizia Zanfagna)

As is widely known, Borchardt imagined the main cult symbol of the temple, *i.e.* the obelisk, as a structure composed of two parts (see fig. 2): a base, 40 m per side and 20 m high, featured as the trunk of a pyramid with a slope of *ca.* 76°, which we will call the "pedestal building"; and the obelisk itself, 20 m per side and 36 m high, featured as a large and tall (somehow disproportionate) structure sloping at an angle of 81°. The whole building, according to his reconstruction, was 56 m high (Borchardt 1905: 33–40).

The shape of the obelisk is actually an important question not only in terms of pure architecture but also in terms of symbolism and cult. This is even more significant when we consider that the obelisk in the sun temple of Nyuserre is the only one that is still partially preserved and visible. A complete reconsideration and architectural analysis of the obelisk of Nyuserre's sun temple is thus of extreme importance not only for the history of the sun temple of Nyuserre but also for the understanding of sun temples in general. Consequently, our investigation has tried to reassess all data available in the field concerning the obelisk.

The starting point for our analysis during the first campaigns was the main assumption of Borchardt's reconstruction. Reading his publication carefully, it can be noted that his reconstruction of the whole building was not based on specific archaeological evidence, but rather on the shape of the determinative used in the contemporary tomb of the Fifth Dynasty priest Ty at Saqqara. There, the name of the temple is determined by a two-stepped building in the form of a squat obelisk on a large base. Borchardt compared the ratio between the two parts of the hieroglyphic sign (*ca.* 1/3 for the base and 2/3 for the obelisk) with the archaeological evidence still available at the site – *e.g.* the dimensions of the core masonry of the "pedestal building", the slope of the granite casing at the bottom of the "pedestal building" (*i.e.* 76°), the hypothetical surface of the "pedestal building" at a height of 20 m, and the surface of the alleged base of the obelisk, which was believed to have stood in the centre of the pedestal – and estimated the overall height of the complex at 56 m.

As noticed in other contributions (Nuzzolo – Pirelli 2011: 665–669; Nuzzolo 2018: 169–170), this theoretical assumption is mistaken. While we accept the idea that the shape of the hieroglyphic sign used to determine the name of the temple in the inscriptions must have approximately resembled the actual silhouette of the obelisk, an exact correspondence between the proportions of the real building and those of its hieroglyphic representation certainly cannot be expected. It would be like saying that the hieroglyphic sign for the pyramid, *mr*, is equal to the real pyramid represented in the specific inscription, a suggestion that is clearly untenable.

Borchardt's reconstruction is not sound from an archaeological standpoint, either. Nowadays, the "pedestal building" is only partially preserved (see fig. 3). The core masonry of this structure is characterized by a system of diagonal walls radiating from the centre towards the four corners and flanked by several additional branches (figs. 4a, b). These walls were made of large blocks of rough, yellowish limestone decreasing in size as they rose, while the compartments between them were filled with sand and fieldstone (Borchardt 1905: 36–38 and Abb. 20).[1] These limestone blocks certainly came from local quarries and were also used for the Abusir pyramids core masonry (Verner 2005: 533–535 and fig. 1). The outer part of the structure was finally cased with fine white limestone from Tura, as well as (at the very bottom) with one layer of red granite from Aswan (Borchardt 1905: 37 and Abb. 25). Although most of the granite casing is gone, some blocks remain *in situ* on the eastern side (and partially on the northern and southern sides), giving us the idea of its original form. The limestone casing is more preserved but, except for one block that is still *in situ* on the eastern side (see fig. 3), the rest is scattered all around the obelisk, with a major concentration in the north-eastern and south-western corners. The top of the present ruins of the entire structure (see fig. 1) measures *ca.* 12.5 m (*ca.* 25 cubits); this is about a half of the height suggested by Borchardt for the "pedestal building" alone, *i.e.* 20 m, and about four and a half times less than what he proposed for the overall structure, *i.e.* 56 m (see Nuzzolo – Pirelli 2011: 666–668, and fig. 1 therein).

The inside of the "pedestal building" is characterized by a corridor that allowed the king and/or the priests to reach the top of the base and carry out solar rituals at the bottom of the actual obelisk. To support his thesis of a 20 m high "pedestal building", Borchardt imagined that this corridor would have run twice around the core of the structure (fig. 2). Once again, however, when we analyse the architectural and archaeological evidence, there is no reason to share this view. In fact, both in Borchardt's time and today, nothing is visible of this inner corridor starting from the northern side onwards (see fig. 3), and even its slope cannot (and could not even in Borchardt's time) be exactly determined (Borchardt 1905: 34; see also D'Andrea *et al.* 2014: 65–67). Rather, based on what we can see today, it seems that the corridor may have ended up on the northern side, thereby leading the visitor to reach the top of the "pedestal building" in its north-eastern corner, namely in front of the alabaster altar in the central courtyard (Nuzzolo 2018: 171–173).

The 3D model produced by the laser scanning campaign of the currently preserved structure is also interesting in this sense, for it exhibits the different

Fig. 3 The current remains of the "pedestal building" viewed from the north-east (photo M. Nuzzolo)

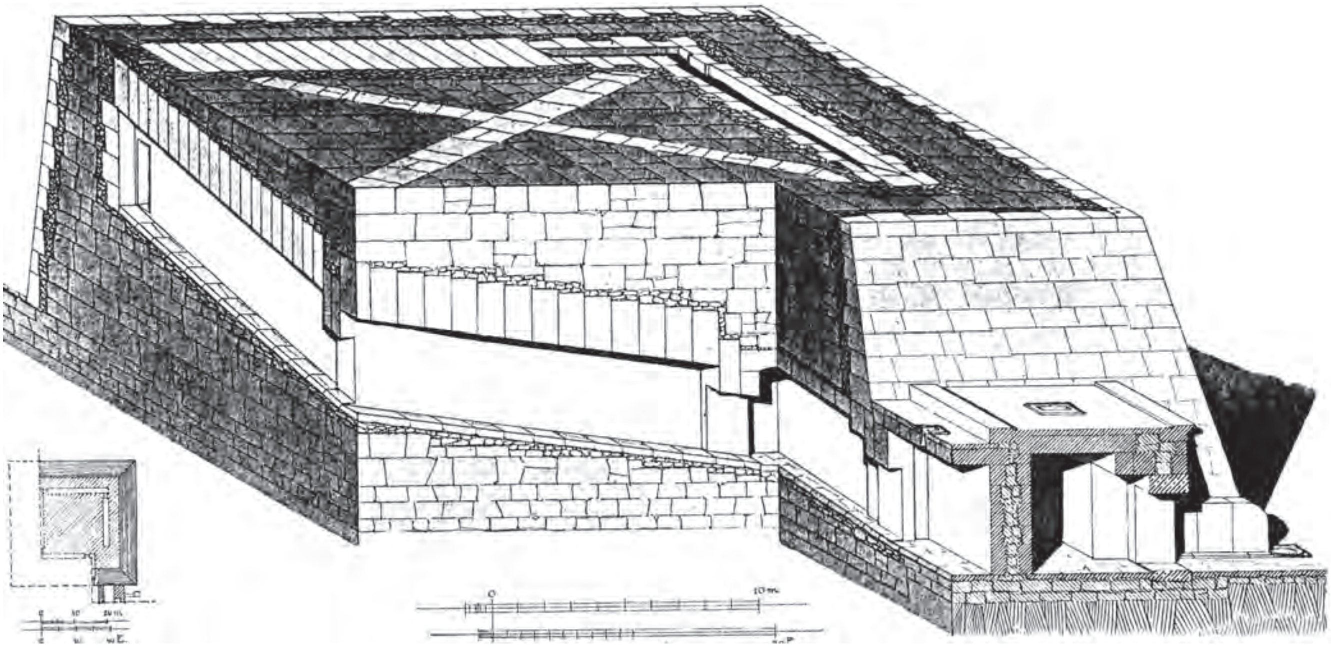


Fig. 4a Isometric reconstruction of the "pedestal building" of the obelisk (after Borchardt 1905: Abb. 20)

elevations of the specific parts of both the core and the outer masonry of the "pedestal building" (fig. 12 in colour plates). Based on this model, we could elaborate several plans and sections to stress the different features of the architecture of the building. This 3D view of the core masonry, both in elevation and plan, evidently shows that the whole northern and eastern parts are missing and the current elevation of both sides is practically the same as the one of the final part of the inner corridor in the north--western corner (Nuzzolo 2018: 172). The analysis of the 3D model also shows that, out of the four diagonal walls radiating from the centre to the corners, only the south--eastern one is still preserved and visible today, whereas very small portions of the other corner walls are visible and preserved. Finally, the analysis of the 3D model also evidences that the northern side of the obelisk is much more damaged than the eastern one, exhibiting a kind of trench in its central part. This may indicate that some sort of a structure (the final part of the inner corridor?) may have been originally situated here and later completely dismantled for reuse of the construction material, giving rise to the current state of disrepair.

The most problematic part of Borchardt's reconstruction, however, is represented by the shape and size of the obelisk itself. As a matter of fact, when we look at Borchardt's publication, we can see that his reconstruction is based on a single block – made of fine white limestone, according to his description (Borchardt 1905: 40, Abb. 28) – of which he provided only a very small drawing, based on which we can calculate its dimensions at about 40 × 80 cm. The block is said to have shown a double slope, *i.e.* 90° at the base and about 81° on the upper part. It is also not specified by Borchardt if the block was found on the "pedestal building" or on the ground of the central courtyard.

During our 2017 fieldwork, we carried out a complete cleaning of the four sides of the "pedestal building", both at the level of the bottom courses, and on the top area of the current ruins, and we could verify that there is no block corresponding to the one described by Borchardt. Nevertheless, we have to bear in mind that on top of the current ruins there are indeed some blocks which are not made of the rough and yellowish limestone which characterizes the core masonry, but rather of a finer quality whitish limestone. These blocks on top of the current ruins are larger than the rest of the blocks of the core masonry placed immediately below them, as is clearly visible in fig. 12 in colour plates. These top blocks might

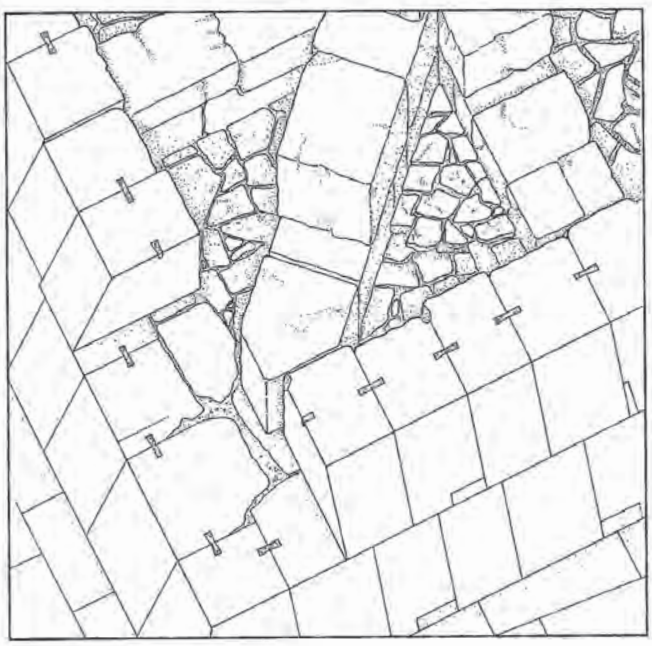


Fig. 4b Scheme of the building technique of the core masonry of the "pedestal building" (adapted after Arnold 1991: fig. 4.109). Differently from Arnold's scheme, which refers to the pyramid of Sesostris I, the blocks of the "pedestal building" are not adjoining one another by means of dovetail cramps but simply juxtaposed

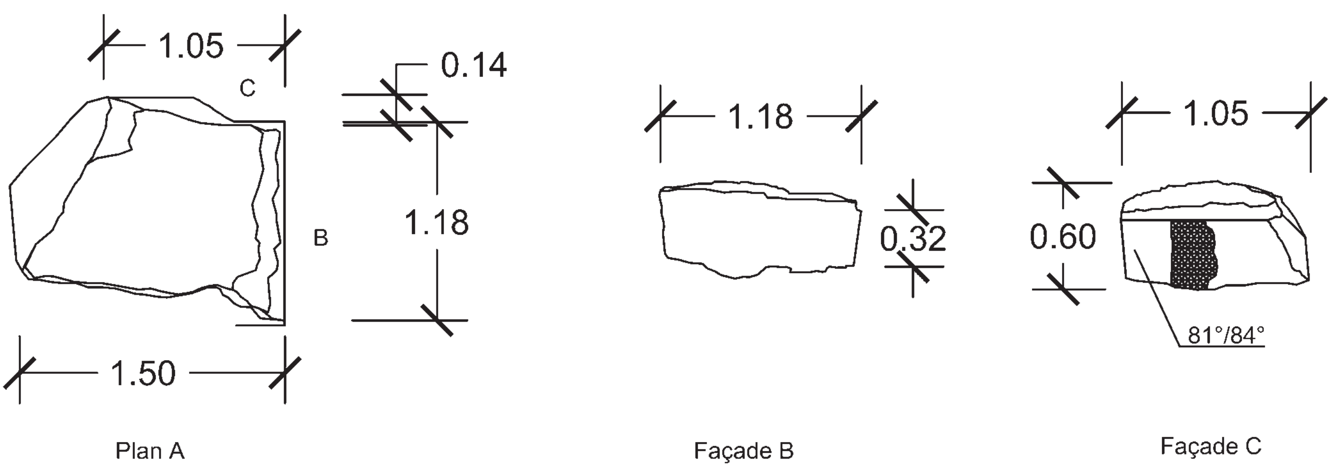


Fig. 5 Two different views and a drawing of white limestone blocks situated on the top of the "pedestal building" (photo M. Nuzzolo; drawing P. Zanfagna)

thus indeed have been part of the obelisk, but we have to consider, for the sake of completeness, that none of them are polished, and only one of them (fig. 5) presents a side which, although partially damaged, seems to have a slope (of about 81°–84°) compatible with the one described by Borchardt for the obelisk's blocks. Whether these blocks might have belonged to the core of the obelisk or to its casing cannot be established with certainty in the current state of our knowledge, although the inclination of the one just described would seem to indicate that we are dealing with a casing block. Whatever the case, it goes without saying that if these blocks do really belong to the obelisk, Borchardt's reconstruction of the "pedestal building" as a 20 m structure does immediately fail.

In conclusion, there is no concrete architectural or archaeological element to support Borchardt's reconstruction of the huge obelisk of the sun temple of Nyuserre. To the contrary, all hitherto available elements would seem to indicate that the whole monument was characterized by much smaller dimensions. More specifically, the features (position, dimensions and material) of the top blocks of the current ruins as well as the characteristics of the inner corridor would seem to indicate that the dimensions and height of the "pedestal building" were not very different from what we can see today. Consequently, the obelisk on top of the "pedestal building", while certainly being a considerable and soaring structure composed of high quality limestone blocks, was probably smaller and shorter than is usually assumed. This is even more plausible when we consider that the state of preservation (and the height) of the whole building that we face nowadays is not very different from the situation in Borchardt's time, as we can see in the historical pictures of the excavations. It is therefore not really clear why Borchardt imagined such a huge structure.

Although we can evidently dismiss Borchardt's reconstruction, we do not have, at the moment, enough archaeological data to ascertain what the obelisk looked like. In fact, even if we imagine that the block described by Borchardt did exist and has been simply lost, and even if we associate that block with the ones that we have identified on the top of the current ruins, we would not be able in any way to define with certainty either the shape or the final size of this obelisk.

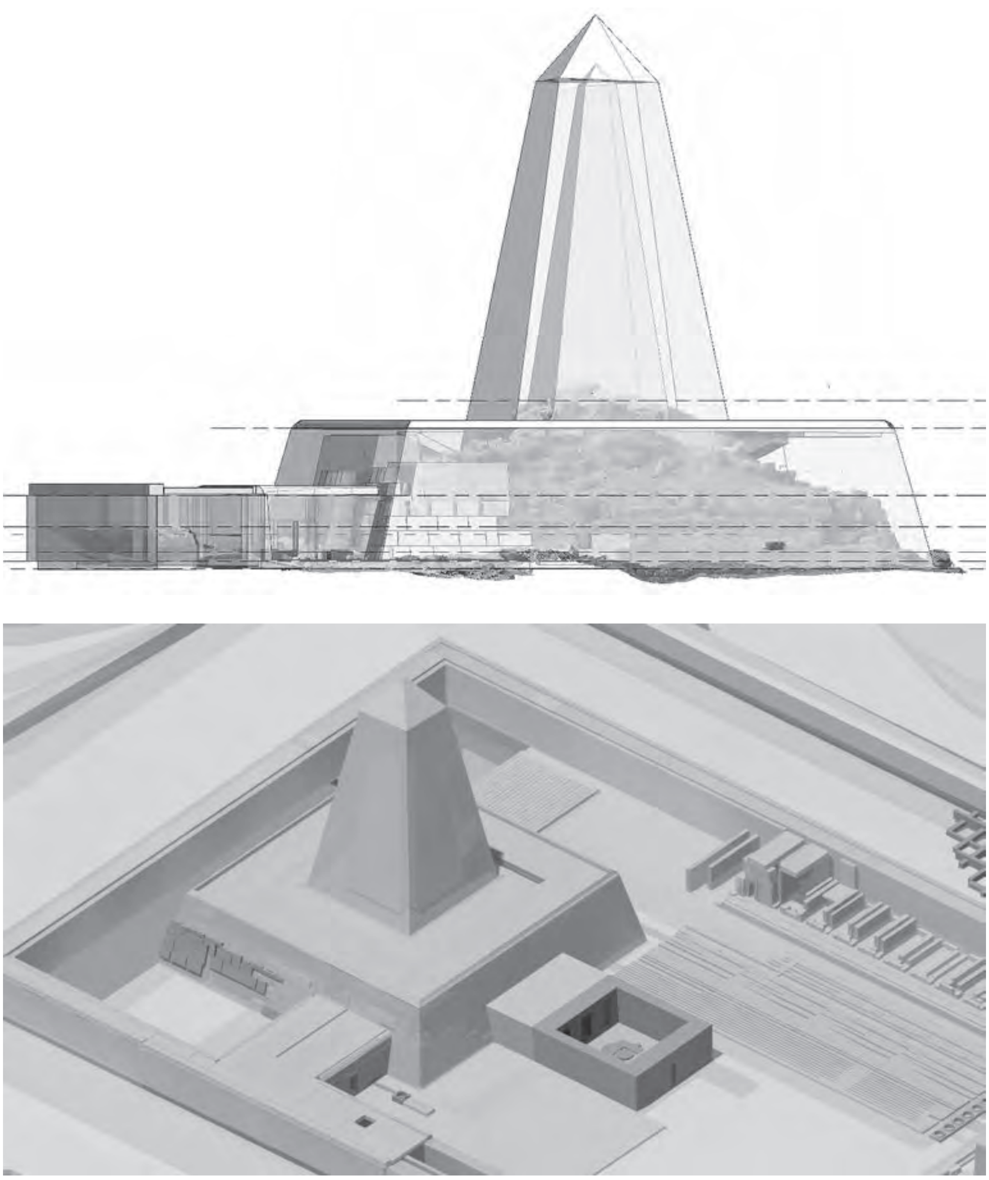


Fig. 6 Isometric view and three-dimensional reconstruction of the obelisk of Nyuserre's sun temple according to the reassessment of archaeological data. The model also shows the new interpretation of the altar area with the two possible hypotheses for the chapels' plan depicted in different tones of grey (elaboration in BIM by P. Zanfagna)

Fig. 7a General view of the south-western corner of the obelisk with an accumulation of limestone blocks from the casing of the "pedestal building" (photo M. Nuzzolo)

Fig. 7b A detailed view of three of the limestone blocks from the area (photo M. Nuzzolo)

What we can do at the moment is simply try and figure out a suitable solution that may correspond to all available pieces of archaeological and historical knowledge. The first such piece is that the obelisk should be approximately twice the height of the "pedestal building", so as to have a balanced proportion of the overall figure; this is also what we can see in the hieroglyphic representations of the sign. Considering that, as has been said, the height of the currently preserved ruins (*ca.* 12.5 m) does not seem to be very different from the original height of the "pedestal building", we may conclude that the obelisk on top should have measured about 20 to 25 m in height. This puts the overall height of the structure ("pedestal building" + + obelisk) at approximately 30–35 m (see also Nuzzolo 2018: 174–175, and fig. 6 here). The dimension of the obelisk's base is also a complicated issue and cannot be calculated with certainty, although it could not exceed 20 m, which is the size of the central core of the structure on which the obelisk, as stated also by Borchardt, must have stood (see also fig. 12 in colour plates). The last piece of information to be recalled here is that that the construction of a structure – 20 cubits (*ca.* 10 m) long and wide, height unrecorded – is mentioned in the consecration inscriptions found in the valley temple of Nyuserre's sun temple in relation to the upper temple (Kees 1928: Bl. 29, no. 451). According to Helck, the building in question was in fact the obelisk, because it is the only part of the upper temple that could fit these measurements (Helck 1977: 61) Although no direct association of this inscription with the obelisk can be proved, since the inscription is fragmentary and not explicitly referring to any part of the temple, it can be easily noted that these measurements would fit the available archaeological evidence quite well and further demonstrate that the obelisk was a much more slender and proportioned structure than assumed by Borchardt.[2]

Naturally, the reconstruction of the obelisk proposed in the present article still has to be considered provisional, given the above considerations on the limited nature of the available archaeological data, and it will certainly be the aim of future investigations in the field to try to better clarify the issue of the obelisk's shape and measurements. However, even with due caution based on the above-mentioned reservations, in view of the current state of our knowledge, this reconstruction certainly fits the archaeological and historical evidence better and is, therefore, more reliable than Borchardt's one.

Limestone blocks in the south-western corner of the obelisk (Massimiliano Nuzzolo – Patrizia Zanfagna)

An extremely interesting area of the sun temple is the south-western corner of the obelisk (fig. 7a). This area is actually characterized by a concentration of limestone blocks of considerable dimensions. The position, measurements and shape of these blocks, as well as the fact that they all exhibit a polished façade with a slope of about 76° immediately indicate that they were part of the original casing of the "pedestal building". This was

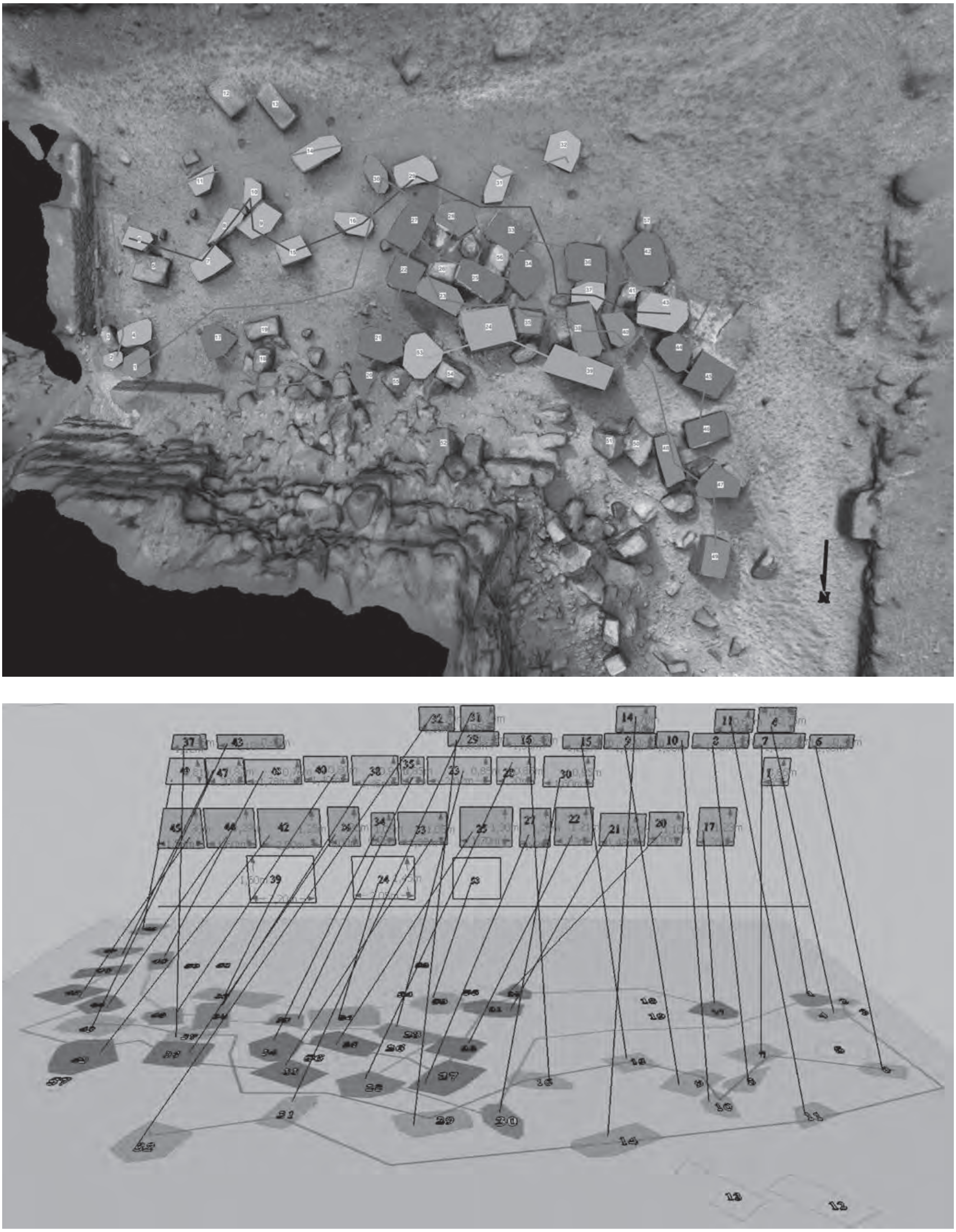


Fig. 8a Two images of the south-western corner of the "pedestal building" with a structural analysis and categorization of the limestone blocks in plan and section (elaboration in BIM by P. Zanfagna, based on laser scanner and photogrammetric data)

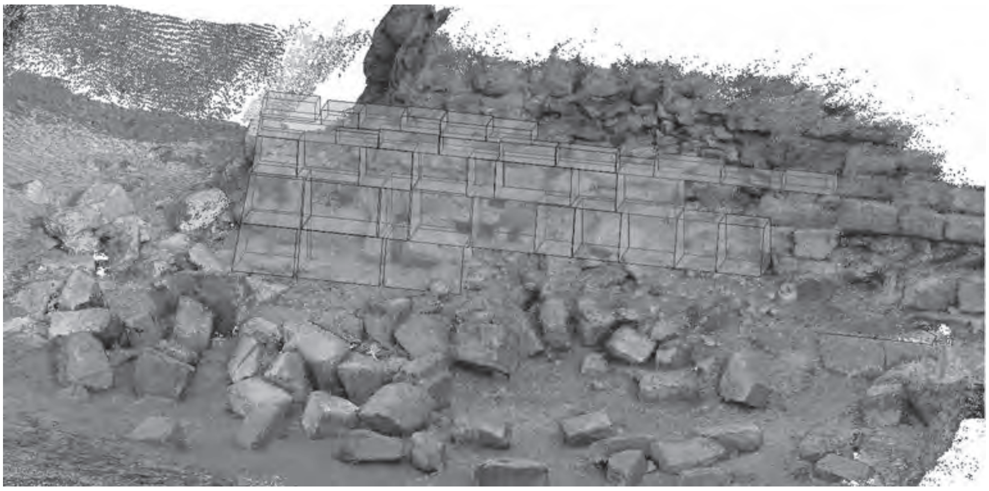


Fig. 8b Schematic reconstruction of the south-western corner of the "pedestal building" (elaboration in BIM by P. Zanfagna, based on laser scanner and photogrammetric data)

certainly also Borchardt's idea; he did not explain this area in detail, possibly taking for granted that the blocks had originally composed the bottom layers of the structure's casing.[3]

In the 2017 campaign, however, we decided to analyse and draw these blocks one by one in order to verify if their current location on the ground and their dimensional features could give us some new clues on their original position and on the dynamics of their fall. This process was assisted by photogrammetry and the potentiality of 3D reconstruction and modelling provided by the above-mentioned BIM (see below for further details).

The basic assumption of our fieldwork is that this considerable concentration of fine white limestone blocks in this area of the temple is rather anomalous. In fact, the reuse of the stones has definitely been more intense on the other sides of the obelisk. This is especially visible on the northern side of the basement, where no good quality limestone block is left today. On the eastern side, too, only a few blocks of fine white limestone remain, and they are usually the corner blocks of the casing, which were probably not easily reusable for further building purposes. The concentration of fine limestone blocks in the south-western corner may thus indicate either a later phase of dismantling of this area of the temple, less systematic than the previous phases probably dated to periods immediately after the temple's abandonment,[4] or the occurrence of a natural event (earthquake?), which provoked the fall of the blocks when the temple had already been completely abandoned. The latter hypothesis seems to be corroborated at first glance also by the position of several blocks placed one above the other in a rather unnatural position for having been dismantled intentionally (see fig. 7b).

The area in question measuring about 20 × 28 m is characterized by the presence of approximately 40 blocks of fine white limestone lying on the ground, which have been all analysed and drawn. Two types of blocks have been distinguished.[5]

1. corner blocks, namely blocks with a quadrangular base and a trapezoidal shape, which are polished on two sides;
2. casing blocks, namely blocks with a rectangular plan and a trapezoidal shape, which are polished only on one side.

In addition to these fine white limestone blocks, several blocks of rough yellowish limestone can also be found in the same area, all belonging to the core masonry and usually smaller than the limestone blocks of the casing.

Each block has been documented (photographed and drawn), georeferenced and finally imported in the GIS environment, where it has been linked to a database containing both geometric (length, width, height) and positional (corner or side block) features. Based on comparison with the other casing blocks preserved all around the obelisk and the dimensional features of *in situ* blocks of the core masonry, which are all characterized by great regularity and modularity, as typical of Fifth Dynasty architecture (see Arnold 1991: 164–176), all the blocks fallen in the south-western corner have finally been categorized into five types according to their measurements (see fig. 8a):[6]

- Class A: 3 blocks (database codes 24, 39, 53) with a height between 160 and 145 cm;
- Class B: 13 blocks (database codes 17, 20–22, 25, 27, 33–34, 36, 42, 44–46) with a height between 130 and 105 cm;
- Class C: 10 blocks (database codes 1, 23, 28, 30, 35, 38, 40, 47–49) with a height between 95 and 80 cm;
- Class D: 6 blocks (database codes 2, 4, 11, 14, 31–32) with a height between 78 and 67 cm;
- Class E: 10 blocks (database codes 6–10, 15–16, 29, 37, 43) with a height between 48 and 40 cm.

An important aspect of the categorization of the blocks and the understanding of their original position has been represented by the mutual interrelation among them – *i.e.* the proximity and/or distance from one another according to their dimensional class – as well as by their position with respect to the "pedestal building". The analysis of this interrelation clearly evidences that larger blocks (classes A–B) are closer to the "pedestal building" compared to smaller blocks (classes D–E). The former blocks must thus have formed the lowest courses of the original casing, whereas the latter blocks must have belonged to the highest ones. This consideration, in turn, would seem to indicate that the blocks did not descend as the result of intentional dismantling one by one, but rather that they fell down at the same time, in consequence of a natural event.

Fig. 9 A visitor graffito found on one of the limestone blocks of the south-western corner of the "pedestal building" (photo M. Nuzzolo)

Based on their current position on the ground, it also seems that blocks from classes C–E were originally placed on the casing as "headers and stretchers", something which evidently causes that class C is followed by class E and then by class D (see figs. 8a, b), thereby breaking the logical sequence of blocks regularly decreasing in size as they rose.[7]

We have analysed the possible fall trajectory and spatial spread of the collapsing blocks in order to understand if this natural event might have been an earthquake. This analysis — using a specific earthquake simulation and reconstruction software included in the above-mentioned BIM — has evidenced the dynamics of the blocks displacements such as slipping, rolling over, free fall or rebounding that eventually resulted in the current position of the blocks and in their being often located upside down with respect to their original position, determined naturally on the basis of their sloping façade.

As the last step of this analysis, we have reconstructed the original aspect of these five courses of the casing of the "pedestal building". When remounted in their original position, they give us a total height of about 5.10 m, plus the bottom granite course of about 1.2 m.

In this regard, it might be of some interest to note that all these granite blocks of the casing of the south-western corner are actually missing. Only three blocks are currently *in situ* next to the wall of the "Room of the Seasons", thus not pertaining to the area here in account. This is quite strange when we consider that, given the dynamics described above for the fall of the limestone blocks, the granite blocks of the casing should be situated close to the "pedestal building". Therefore, we can assume that these granite blocks were removed from their original position after their fall to be reused somewhere else (another monument?), whereas the limestone blocks were not, or at least not systematically. This reuse of large-size stones, such as the granite ones, seems to be confirmed also by the fact that the biggest blocks of limestone, especially those from the bottom course, were more systemically stripped away compared to smaller limestone blocks of the other courses.

Last but not least, it is worth noting that fifteen more blocks – also made of fine white limestone and evidently belonging to the casing (block nos. 3, 5, 12–13, 18–19, 26, 41, 50–52, 54–57 in fig. 8a) – have also been included in our analysis (and in the database) but are not listed in the above-mentioned five classes of blocks for they do not match any of them. Except for a few blocks, which are nowadays broken and cannot be categorized in any of the above-mentioned classes, the rest of the blocks probably belonged to other (higher) courses of the casing, on which, regrettably, we do not have enough architectural data at the moment to establish any category.

In conclusion, all the above considerations on the blocks (position, dimensions, features) as well as the analysis of their falling dynamics seem to clearly indicate that the natural event which provoked the falling of the blocks must have been an earthquake. The dating of this event is, of course, another matter, not easy to establish at the moment. The only secure chronological element is that the event should have occurred before the Ramesside period. In fact, on one of the casing blocks of this area (see block no. 36 in fig. 8a, and fig. 9) we were able to identify a so far unknown visitor graffito, written in hieratic and mentioning a visit to the temple by the scribe Kiky (*sš Kyky jw*).[8] The palaeography of the inscription indicates a Nineteenth Dynasty dating, a hypothesis which seems to be further corroborated by recent archaeological discoveries in South Saqqara.[9] Although the graffito is inscribed on the polished (outer) side of the block, it is very unlikely that the inscription was made when the block was still in the casing. The block belonged to the upper parts of the casing and it would have been illogical (and also very uncomfortable) to leave the inscription there when the bottom courses of the casing were more suitable for the purpose.[10]

As for the dating of the seismic event, one should also recall Arnold's notes on the position of the blocks found by Borchardt during the excavations of Sahure's temple (see Borchardt 1910: 105–106, figs. 42–43), especially the fragments of the originally monolithic granite columns and architraves. According to Arnold, their position would indicate that they were not smashed down by stone

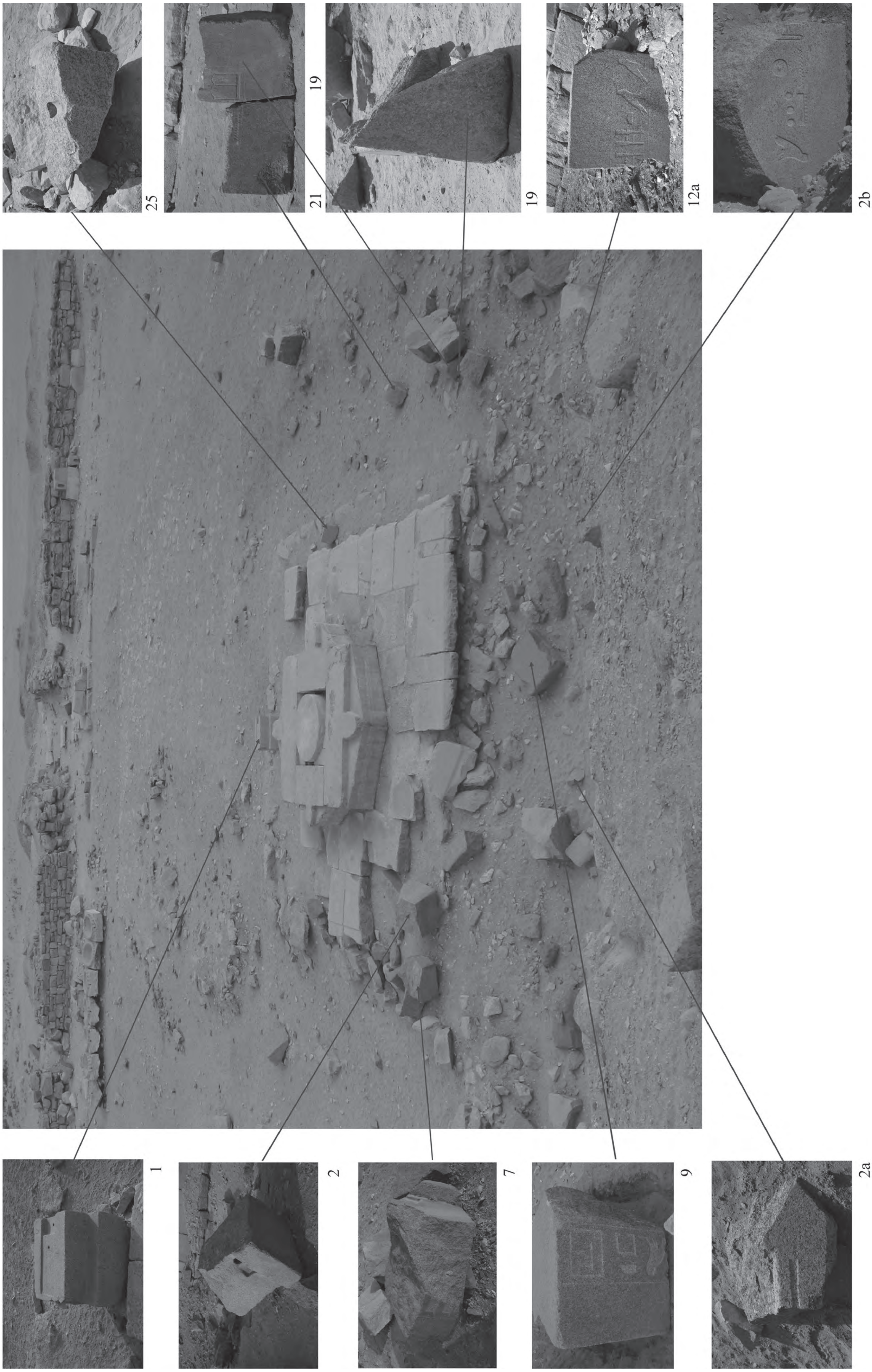


Fig. 10 The central alabaster altar viewed from the top of the obelisk with all the granite blocks still visible on the site. At both sides, detailed pictures of blocks engraved with hieroglyphic inscriptions. Some of these blocks (nos. 2, 7, 9, 25) also show a slot for the door hinge (photo M. Nuzzolo)

robbers but rather fell down in one piece, probably as a consequence of a seismic event (Arnold 2010: 10). Unfortunately, the date of the event cannot be determined in the case of Sahure's temple, either. In fact, Borchardt observed that Greek visitors' graffiti had been scratched into the monument while it was still standing (Borchardt 1910: 106). This would indicate a very late date for such a seismic event,[11] but we have to recall that these graffiti (few in number) were engraved only on some blocks of the so-called "Sakhmet sanctuary" and not in the rest of the collapsed structure of the pyramid temple.

Whatever the case, all the archaeological elements analysed so far not only indicate that the sun temple of Nyuserre underwent several phases of dismantling and reuse of stones (which we are now able to reconstruct in more detail) but also that a natural event affected the area of the Memphite necropolis between the end of the Old Kingdom and the late New Kingdom. This chronological horizon, although quite wide, is a piece of information not to be underrated in terms of the history of seismicity in ancient Egypt, taking into consideration that our knowledge of the natural catastrophes/events which affected the Memphite area in antiquity is extremely scarce.[12]

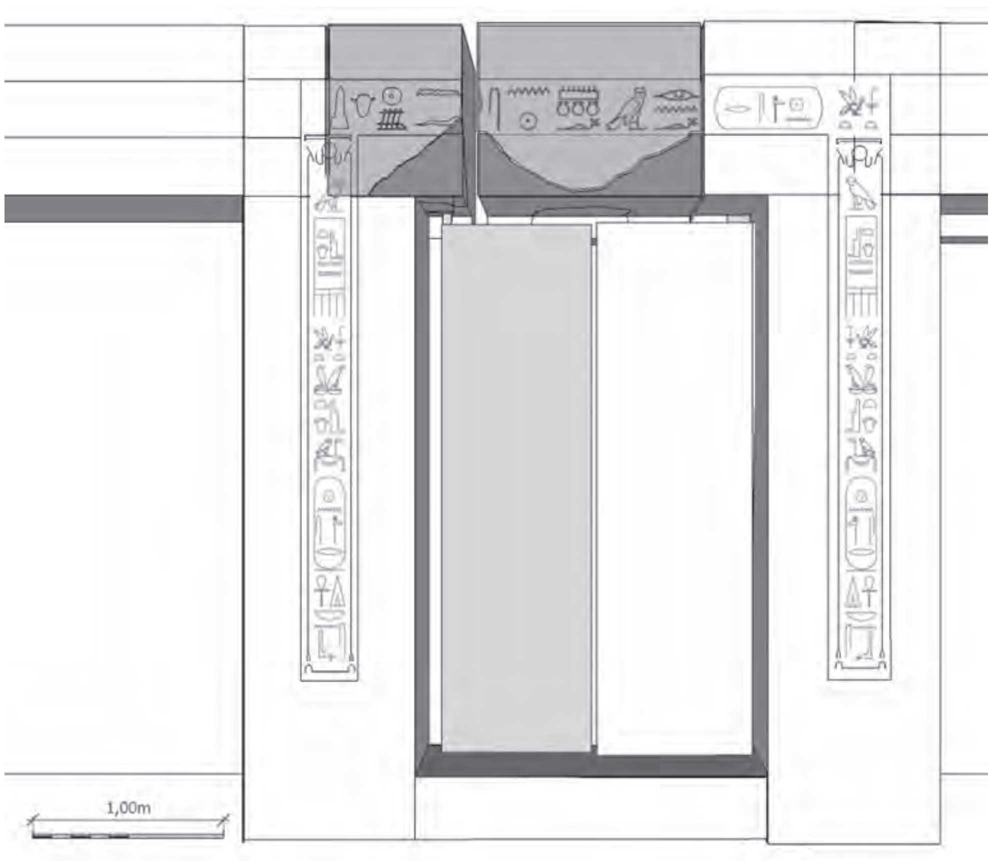
Alabaster altar area (Massimiliano Nuzzolo – Rosanna Pirelli – Patrizia Zanfagna)

The alabaster altar in the centre of the courtyard is certainly one of the most impressive architectural features of the sun temple of Nyuserre. A quite neglected aspect of this area, however, is represented by the presence of several granite blocks, some with hieroglyphic inscriptions, which are scattered all around the altar. Borchardt called them "Architektureteile ohne sichere Bestimmung", since he was not able to define with certainty where the blocks had originally come from. He did not provide any drawing or sketch of these blocks but only a brief description (and hieroglyphic transcription) of the main inscriptions engraved on them, reaching the conclusion that they had once been part of two official inscriptions commemorating the foundation of the temple and the celebration of the king's Sed festival (see Borchardt 1905: 54–56).

In the previous campaigns, we had concentrated our attention on the study of the epigraphic features of these blocks, which were all drawn and catalogued. During the last campaign, we continued the documentation of this area with the aim of attaining an architectural reconstruction of the blocks (their original 3D aspect) and their original location.[13]

The first element to be considered is the number of the blocks. During our campaigns we have ascertained that there are at least five granite blocks with slots for door hinges, not three as Borchardt says (blocks nos. 2, 5, 7, 9, 25 in fig. 10).[14] Although it is very damaged today at the bottom, block no. 12a was probably also equipped with a hole for a door hinge; this can be inferred – based on comparison with block no. 2 – from the presence of the *pt* (sky) sign below the main hieroglyphic text. The reading of Borchardt's publication gives the impression that he only considered the three pieces (blocks nos. 2, 7, 9 in fig. 10) that were almost entirely preserved and bore hieroglyphic inscriptions. Indeed, two of them (blocks nos. 7 and 9) might have belonged to a single doorway, because their inscriptions can somehow be joined (Borchardt 1905: 54),

Fig. 11 Sketch and reconstruction of the doorway formed by two of the inscribed blocks (nos. 2+2b) found around the altar (CAD elaboration by M. Nuzzolo, P. Zanfagna)



whereas block no. 2 can be joined with block no. 2b so as to form a second portal (see fig. 11). These two portals, both with two leaves, formed two official inscriptions of the consecration of the temple, as stated also by Borchardt. However, the two minor pieces (blocks nos. 5 and 25 in fig. 10), which he did not consider at all,[15] undoubtedly demonstrate that there was at least one more (third) granite doorway in the temple,[16] whose location remains uncertain.

Another block (no. 1 in fig. 10), currently located on the eastern side of the altar, also likely belonged to a doorway. Borchardt imagined that this block may have served to hold some cultic items or statues once located in front of the altar (Borchardt 1905: 45–46, and Bl. 1), a hypothesis that we also shared at the beginning of our fieldwork in the sun temple (Nuzzolo – Pirelli 2011: 672–673, fig. 4). The comparison with other pyramids (especially Sahure, see Borchardt 1910: 58–60), however, seems to indicate that the block here in account should have been part of a doorpost. Moreover, this block cannot join any of the above-mentioned granite blocks because of its large size. Block no. 1 thus had to belong to a different (fourth) granite portal.

The second element to be taken into account is the original location of all these blocks and, consequently, of the doorways they belonged to. Borchardt did not pay much attention to this issue and proposed that they could have been placed at the main entrance of the temple, at the obelisk's entrance, or even that they might have been the doorways to either the "Rooms of the Seasons" or the "Chapel" (see fig. 12).[17]

Borchardt, however, did evidently not try to reconstruct the original size (especially the width) of these portals based on their hieroglyphic inscription. In fact, some of the blocks in account here, notably blocks nos. 2 and 2b (see fig. 11), are characterized by a hieroglyphic inscription which, when recomposed, gives a doorway with an inner width (including the space for the door leaves) of about 150–160 cm.[18] These dimensions do not correspond to any of the doorways in the sun temple, whose dimensions – always visible, at least in the foundation – are smaller (see fig. 12).

One, of course, may still object that at least the other granite blocks found around the altar may have belonged to other portals (*e.g.* those suggested by Borchardt). When addressing this issue, however, we should consider more carefully, in the present writers' opinion, the position of all these blocks with respect to the temple's plan.

Borchardt maintained that the area of the altar was used, for a long and undefinable period, as a sort of "workshop area" for cutting and reusing granite blocks that came from all over the temple. This is why he somehow took it for granted that all these blocks had not been originally situated where he found them. However, one may wonder why these heavy blocks should have been moved from the "Chapel", the "Room of the Seasons" or anywhere else to the narrow area between the altar and the obelisk when the entire central courtyard of the temple, and especially its southern part, was completely free and definitely more suitable for such kind of activities (*i.e.* stone cutting and reusing).[19]

To the contrary, when we carefully observe the position of all the granite blocks in the entire temple, we can see that most of them are usually not far from their original location (see fig. 12). The few preserved blocks from the bottom of the casing of the obelisk's "pedestal building" are all broken but still very close to their original position, a situation that can be observed on at least three sides (northern, southern and eastern). Two big blocks clearly belonging to the doorways of the "Room of the Seasons" are still lying at the entrance of this room. Two more huge and rounded blocks, which Borchardt identified as part of two uninscribed stelae placed at the entrance of the "Chapel", also remain in their assumed original position (see Nuzzolo 2018: 175–176).

The above-mentioned observations on the position of granite blocks all over the temple seem also confirmed by the position of quartzite fragments. Nowadays, all quartzite fragments present in the temple (in fact quite a considerable number) are concentrated along the southern side of the storehouse, whose doorways were all made of quartzite. It is thus more than logical to conclude that these fragments were once part of the door frames of the storerooms, as confirmed also by their inscriptions, which perfectly match those still situated *in situ* (see also Nuzzolo 2018: 177). These quartzite fragments thus remain not far from their original positions, although, due to their small sizes, they might have been very easily moved anywhere else in the temple.

Therefore, in the case of the altar area, too, the situation may not be as confusing as it seems: rather than from other areas of the temple, the granite blocks may come from the same area where they are situated nowadays, *i.e.* from the western side of the altar.

If the core of this theory is correct, it is not unlikely to imagine that there were some rooms/spaces for the cult statues in the area to the west of the altar. These rooms were equipped with granite doorways whose remains are the fragmentary blocks with inscription that we are discussing here.

In this regard, it is also worth noting that nowadays this area (*i.e.* the space between the altar and the obelisk) not only lacks the foundation platform – which is still visible underneath the altar – but is also dug out as to form a quite deep trench (see figs. 10 and 12).[20] There is thus no feature, even at the foundation level, which could give us useful information concerning the ground plan of this area. What we can note here is that statue-chapels in pyramid temples (*e.g.* Sahure or Unas) have also been regularly and severely damaged by the almost complete removal of the pavement. This pavement was usually made of precious construction stones, notably alabaster (see Borchardt 1910: 54–55, and Bl. 16; Labrousse – Lauer – Leclant 1977: 46, and fig. 32), and there is indeed a considerable accumulation of alabaster fragments also in this area (*i.e.* the space between the altar and the obelisk) of the sun temple.

Last but not least, the presence of chapels/shrines for the cult statues in this area of the sun temple seems to be corroborated also by a more theoretical argument, namely the complete lack of a suitable and proper space for the cult statues in the entire sun temple. In fact, neither the "Chapel" nor the "Room of the Seasons" are suitable spaces for such a cult device, being devoid of any statue

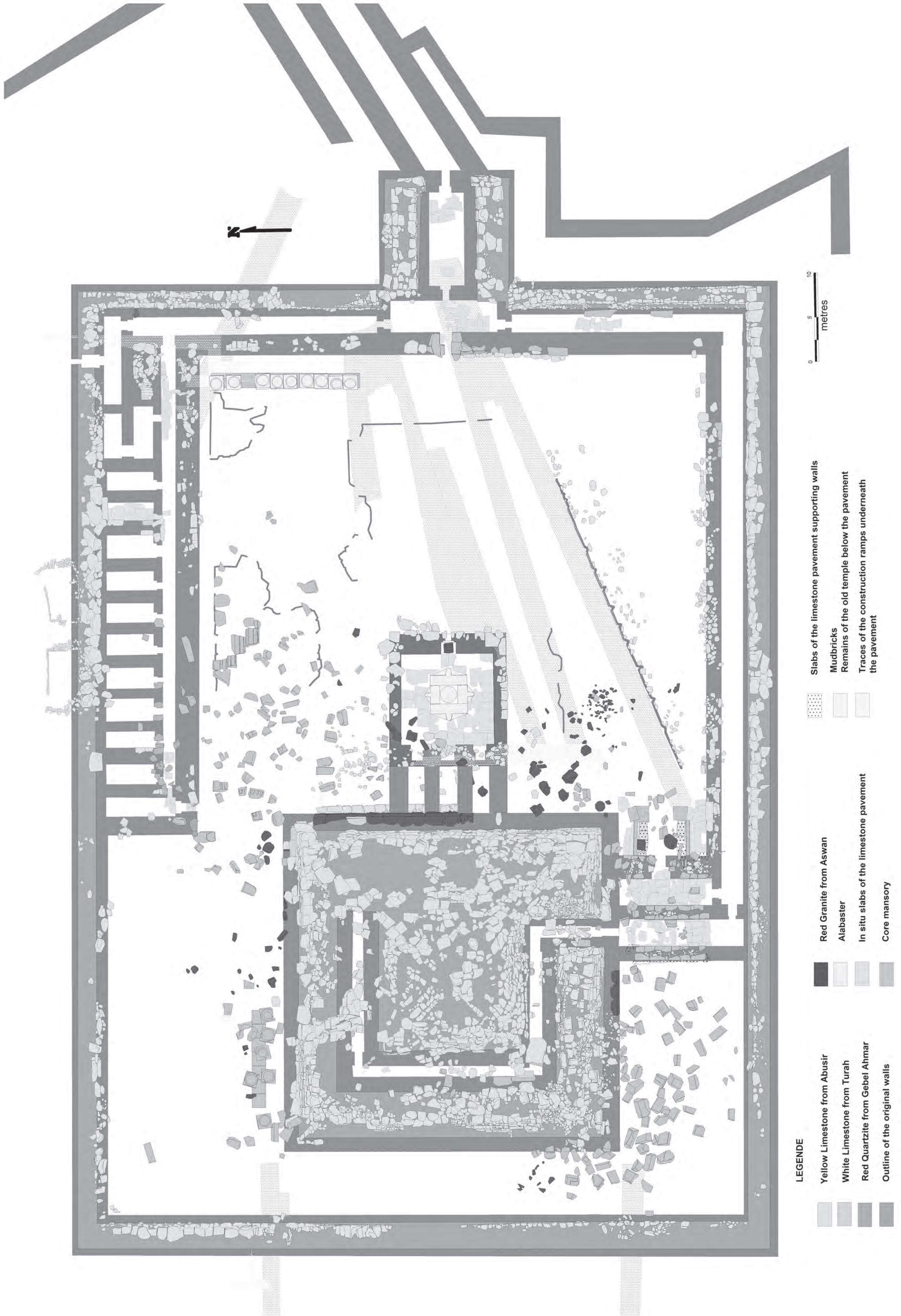


Fig. 12 General plan of the sun temple with the reconstruction of the original layout overlapped on the current pieces of archaeological evidence (drawing M. Nuzzolo, P. Zanfagna)

recesses. On the other hand, it is inconceivable that a sun temple – a pivotal monument for the cult of the sun god – would not have a more standard place for the cult of the statues, especially when we consider that the temple was modelled after the pyramid temples, which all have a specific space dedicated to the cult statues (Nuzzolo 2018: 179–180).

Whether these rooms for the cult statues were proper chapels or small shrines is difficult to say at the moment, lacking precise archaeological elements. Nor is it possible to ascertain the number of these spaces/rooms for the statues, although the first logical conclusion (see fig. 6) is to hypothesize that they were three, respectively dedicated to Re, Hathor and the king, on account of the strong connection of the solar cult with the king's cult and the figure of Hathor, as also testified by the titles of priestly personnel serving in the sun temples (Nuzzolo 2007: 241–247, pls. 1–2).[21]

What we may note at the moment is that the granite casing of the "pedestal building" of the obelisk is partially still preserved on the eastern side and does not seem to show any traces of adjoining walls.[22] This would suggest that the spaces for the statues, whatever their number, were built as small shrines rather than proper rooms/chapels, thereby featuring a situation not so different from the sun temple of Userkaf, where Herbert Ricke (1965: 14, 20–24, and pl. 14) indeed found two small, freestanding shrines between the altar and the obelisk. These data are not fully conclusive, however, as there are rare examples of walls of chapels directly adjoining the sloping surface of the pyramid without any masonry connection.[23] This might be not so strange in the case of the sun temple if we consider that the casing blocks of the obelisk are set in an almost vertical position (76°). This would have evidently facilitated the addition/adjoining of masonry (*i.e.* the one of the shrines/chapels) to the body of the obelisk. Additionally, we should also note that except for some granite blocks of the first course of the casing, the other courses of the casing, made of limestone, are completely missing, making it impossible to reconstruct whether there were joins or imprints of pertinent joining masonry.

These considerations eventually lead us not to rule out either of the possibilities (free-standing versus adjoining chapels).

In conclusion, the analysis of all the available archaeological and cultic-religious elements would suggest that, contrarily to Borchardt's reconstruction, the area between the obelisk and the altar was not shaped as an empty space. Rather it seems to have been characterized by the presence of structures (chapels/shrines) for the cult of the statues, although, due to the current state of disrepair of the area, we are unable to provide more information concerning its development in elevation and plan (the precise number of rooms; free-standing or adjoining chapels/shrines).

Topographical activity: From total station to GIS (Emanuele Brienza)

Differently from the previous campaigns, when topographical works had been carried out mostly inside the sun temple, the topographical activities of the 2017 mission have also included the rest of the solar complex (the causeway and the valley temple) as well as a wider survey of the area of Abu Ghurab.[24] The main scope of the mission was, in fact, not only to complete the topographical work in the solar complex but also to contribute to the definition of a broader topography of the site, which can be then compared and joined with the long-lasting topographical work carried out by the Czech colleagues in the contiguous site of Abusir.

The first topographical work in the sun temple was carried out by the mission during its first campaign in 2010. The target of that work was to set up, for the first time in the history of the site, a topographical network which could serve both the future works in the solar complex and the survey of the whole Abu Ghurab area. The first step of the 2010 mission was to check the plan made by Borchardt (the only one hitherto available of the sun temple) in order to verify its accuracy and identify any discrepancies with visible archaeological evidence. This examination was made by total station, measuring the main general orientation, position and volume of the preserved structures and comparing them, one by one, with Borchardt's plan (for results of this work, see Nuzzolo – Pirelli 2011: 664–669).

Methodologically, we set up a new topographical network based on fiduciary points physically represented by topographical pegs fixed on the ground, choosing the best reciprocal visibility control-points without risking damage to ancient remains. The network was based on a closed traverse set up around the obelisk (where a forthcoming laser-scanner survey was planned) and composed of five benchmarks: four on each side of the enclosure wall of the sacred area, and one on the top of the "pedestal building".[25] In this way, each peg was an ideal triangle vertex defined from (at least) three control points. In order to obtain the maximum accuracy of each benchmark position, we calculated the average square deviation of multiple measurements (fig. 13).

Concerning the elevations, it was impossible to assign absolute sea level values: national geographic benchmarks were not visible in the surrounding area, and the use of global navigation satellite system/digital global positioning system (GNSS/DGPS) tools was not allowed for military reasons. We thus selected the solar disk of the alabaster altar located in the central courtyard of the temple as the main elevation reference point, assigning to it a 2 m conventional height value. At the end of the work, we had 157 detail points measured all over the upper temple of the solar complex (fig. 13). Finally, to support the laser scanner survey activity, we measured the position of 123 targets, taken from the known stations but also adding new station points located by resection from existing benchmarks (D'Andrea *et al.* 2014: 61–62).[26]

Unfortunately, all the benchmarks in the upper temple were removed at an unknown moment between 2012 and 2013, when the mission could not work due to political instability in Egypt (D'Andrea *et al.* 2014: 76). Therefore, in 2017, we had to set up a new topographical network to accomplish our topographical survey of the area outside the upper temple of the sun complex. New benchmarks (S1–3), with a three control points reciprocal visibility, were thus positioned in the upper temple on the eastern, northern and southern sides of the enclosure wall (fig. 14). From these stations, we have measured several detail points for a new architectural framework of the solar complex as well as several points to support the detailed photogrammetry survey (see the next paragraph) still to be completed inside the temple area. Subsequently, by resection with two pegs of the upper temple (S1, near the entrance, and S2, on the north enclosure wall) we have positioned four new station points (S4–7) in the valley area. This enabled us to measure all the pieces of archaeological evidence belonging to sun temple, namely the remains of the causeway, the visible structures of the terrace walls supporting the temple on its northern side, and the valley temple's structures. When the work ended, we had a total of seven station points set up and 301 detail points measured, giving a precise location to all pieces of archaeological evidence and supporting the photogrammetry activity as well as, in the post-processing phase, the implementation of a 3D BIM model of the temple.

The new topographical work has been linked to the previous surveys by identifying ten points of the new topography with ten corresponding points taken during the 2010 mission. This phase of the work is pivotal to connect the documentation work (laser scanner) carried out in 2010 and 2014 with the one (photogrammetry) done in 2017 as well as to finally obtain the best fitting of the resulting points clouds.

Finally, this topographical work in the sun temple has also been used as a starting point for a wider exploration of the Abu Ghurab area south of Nyuserre's solar complex. In fact, as suggested in a recent paper, the comparison of data provided by satellite remote sensing (both radar images and Google Earth imagery) with the historical cartography of the site of Abu Ghurab seems to indicate that half-way between the sun temples of Nyuserre and Userkaf, in the valley area, there might be archaeological structures unexplored so far (Nuzzolo – Zanfagna 2017: 114–117). The analysis of the isohypses and elevation gains of the entire Abu Ghurab site evidently shows that the valley area here in account is higher than the rest of the area contiguous to the vegetation, and we can particularly note the presence of a huge tell (located to the north of the valley temple of Userkaf) which extended over 600 m^2 (see fig. 15: tell with an elevation of 28.6 m). In this area and in the area upstream, we have therefore measured six points with the twofold aim of investigating the overall spatial relationship of this area with that of Nyuserre's sun temple and comparing the latter's archaeological structures with the area in account in terms of orientation and elevation (fig. 15).

During the data elaboration process that followed on--site activities, we have georeferenced all surveyed data in the WGS8-UTM36N geographical system, predisposing a new GIS-base map, which will be implemented using proper

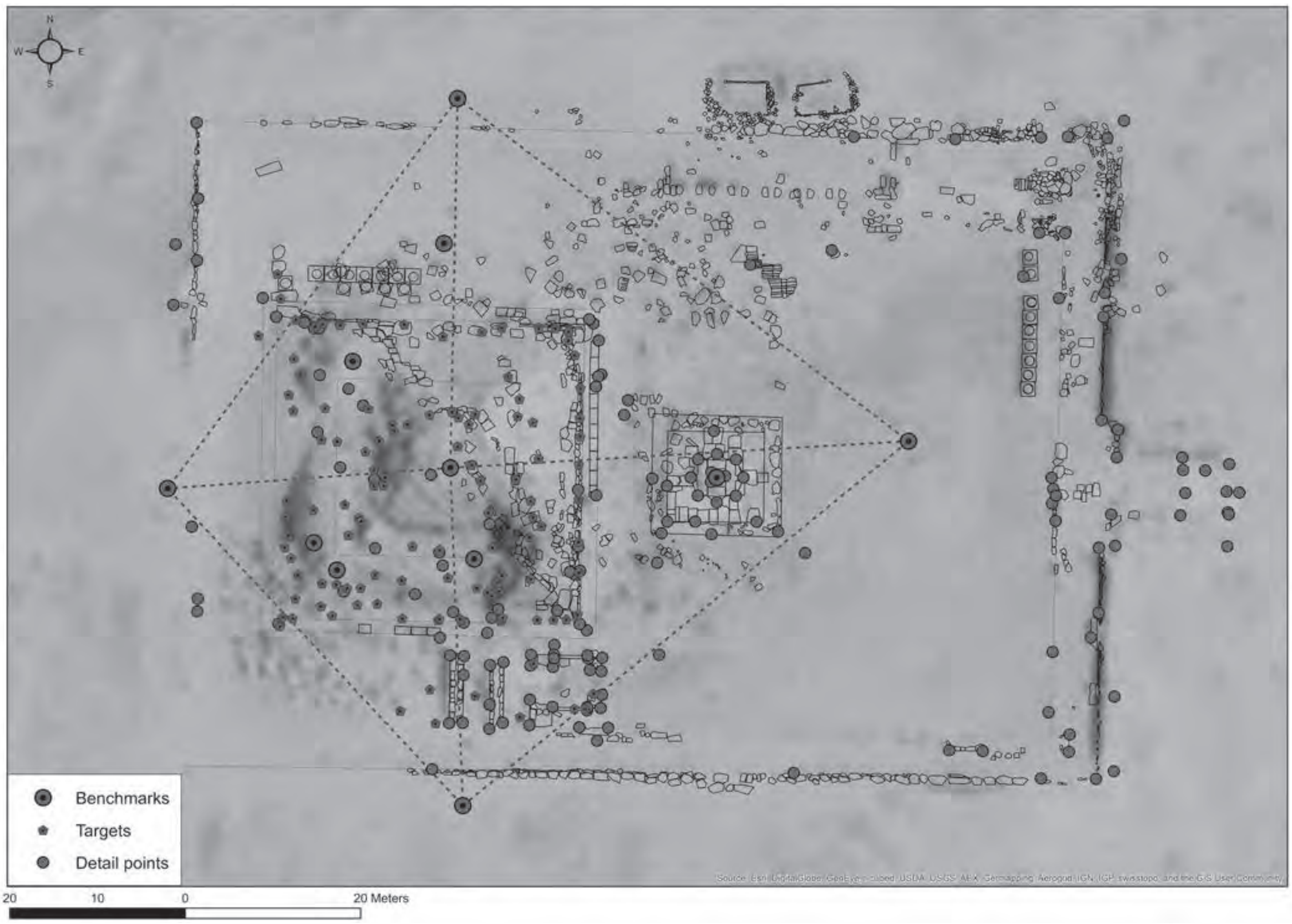


Fig. 13 The 2010 topographical survey of the sun temple overlaid on a Google Earth image and the temple's plan elaborated by P. Zanfagna after post-processing of the 2010 laser scanner data (elaboration by E. Brienza)

Fig. 14 The 2017 topographical survey of the sun temple overlaid on a Google Earth image and the 2014 laser scanner point cloud elaborated by A. D'Andrea (elaboration by E. Brienza)

measurements devices during the next archaeological campaigns. This map is composed of several layers which include, besides purely archaeological data analysed in the field, the vectorization of the general map of the area made by French and Egyptian institutions Egyptian Ministry of Housing and Reconstruction (EMHR 1978, sheet 21, scale 1:5000), the vectorization of the published plans of monuments in the area,[27] and several satellite images of different types (radar, panchromatic) and resolutions (see also Nuzzolo – Zanfagna 2017: 110–123).

The post-processing of all data resulting from the topographical survey of Abu Ghurab will eventually provide us with a digital elevation model of the site, which is to be further used for future work in the field but is also crucial as preliminary phase on the way to the accomplishment of a proper geophysical and geomagnetic survey – scheduled for the next campaigns – which only can give us more clear information on the real presence of archaeological evidence in this area of the site.

3D data-acquisition campaigns (Andrea D'Andrea – Angela Bosco – Mohamed Osman)

As specified in the introduction, one of the aims of the 2017 campaign was to complete 3D data acquisition in the entire temple of Nyuserre. In the previous campaigns, restricted to the inner part of the temple, more than 100 scans were acquired by means of two different laser scanners, namely Imager 5003 by Zoller & Froilich in 2010 and FARO Focus X3d 130 in 2014.

The main difference between the two campaigns was not only in the areas of the temple concerned, but also, and fundamentally, in the characteristics of the laser scanner technology used for the work. The laser scanner used in 2010 could not acquire colour data: for this reason, some photos of the same areas which had been scanned were also taken by means of a digital camera and then superimposed on the final 3D model in order to achieve a much more realistic rendering (D'Andrea *et al.* 2014: 61–63). The 2014 survey was carried out using a new laser scanner mounting a high--resolution digital camera, which already incorporated the colour functions (Bosco *et al.* 2018: 355). These acquisitions were very useful in the effort not only to reconstruct the shape of the temple but also to figure out the final texture of the different buildings in order to provide a completely realistic 3D model of the sanctuary. Moreover, while in 2010, all the scans were processed, registered and aligned based on targets measured by means of total station, the 2014 scans were aligned automatically using the scan-to-scan function of the software Scene, which enables accurate and precise final registration in a millimetre precision without positioning and measuring the targets using total station.

In 2014, 56 scans were taken all over the temple, with a particular concentration in three main areas, which

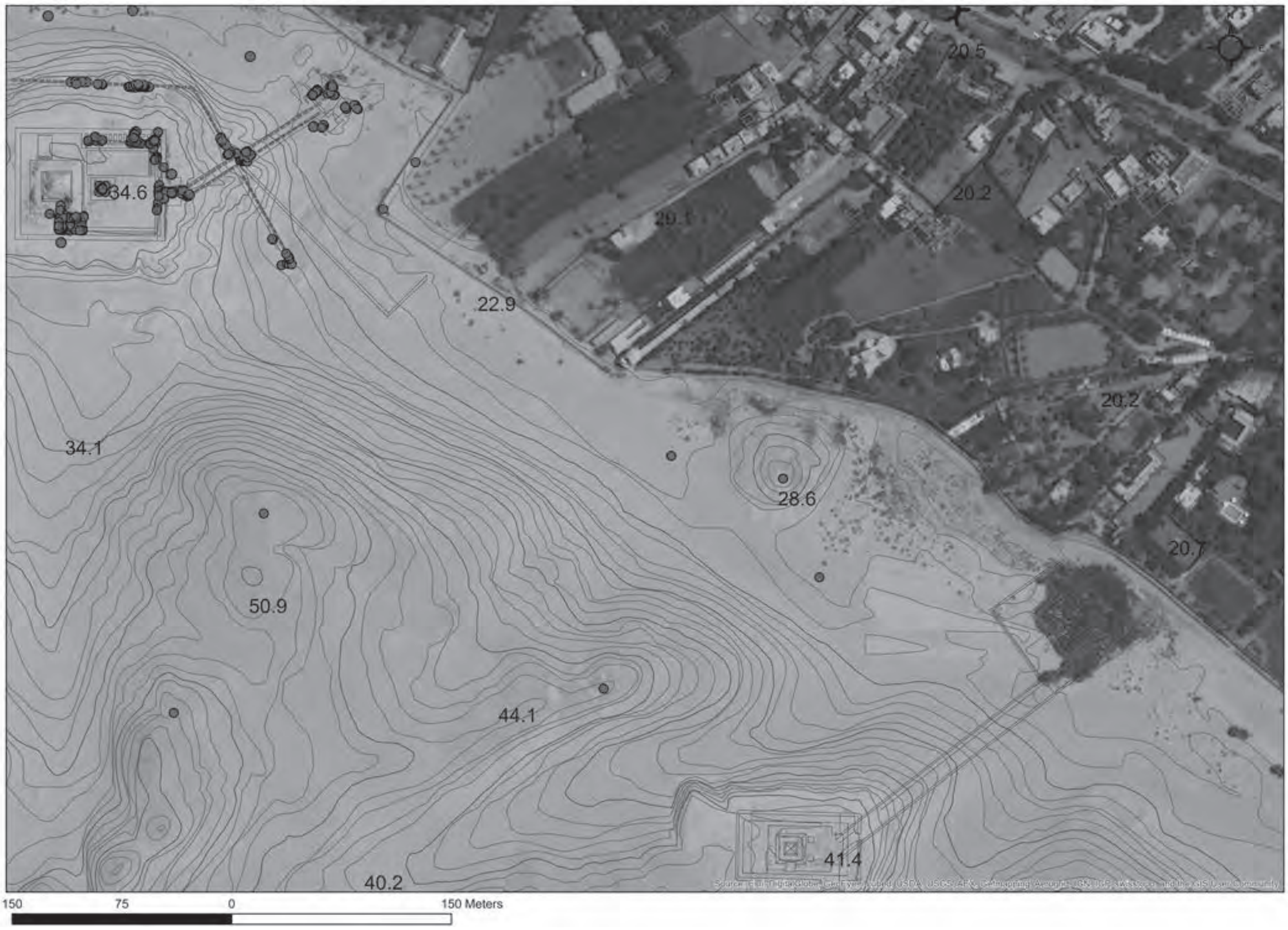


Fig. 15 The 2017 topographical survey of the Abu Ghurab area overlaid with a Google Earth image and the French-Egyptian 1978 photogrammetric map (EMHR 1978, sheet 21, scale 1:5000; elaboration by E. Brienza)

required more detailed scanning given their architectural features:

- the obelisk (or more precisely the "pedestal building", see above);
- the altar and the area around it, where several inscribed blocks of granite are still visible and partially readable on the ground;
- the entire enclosure walls of the monument and the main doorway of the temple, with particular attention paid to the analysis of the blocks of the structure lying outside the enclosure wall.

The 2014 laser scanner campaign was also accompanied by an extensive, image-based photogrammetric campaign. This approach is based on a wide dataset of photos taken according to specific parameters and processed by the SFM (structure from motion) algorithm. This algorithm makes it possible to reconstruct a 3D model of an item based simply on photos acquired while moving the camera around the object. This technique is not only very fast but also gives the possibility to produce coloured meshes, which can support the final analysis of the model and its architectural features. Furthermore, the integration of data coming from the two techniques (laser scanner and photogrammetry) makes it possible to generate an accurate 3D model of the given object/monument in terms of geometry, architectural shape and building materials.

The 2014 photogrammetric campaign was limited to some critical areas of the temple, which were fundamental for the reconstruction of the entire monument:

- the main gate of the temple;
- the area of the so-called "slaughterhouse", and especially its alabaster basins;
- the collapsed blocks lying at the bottom of the obelisk in its south-western corner.

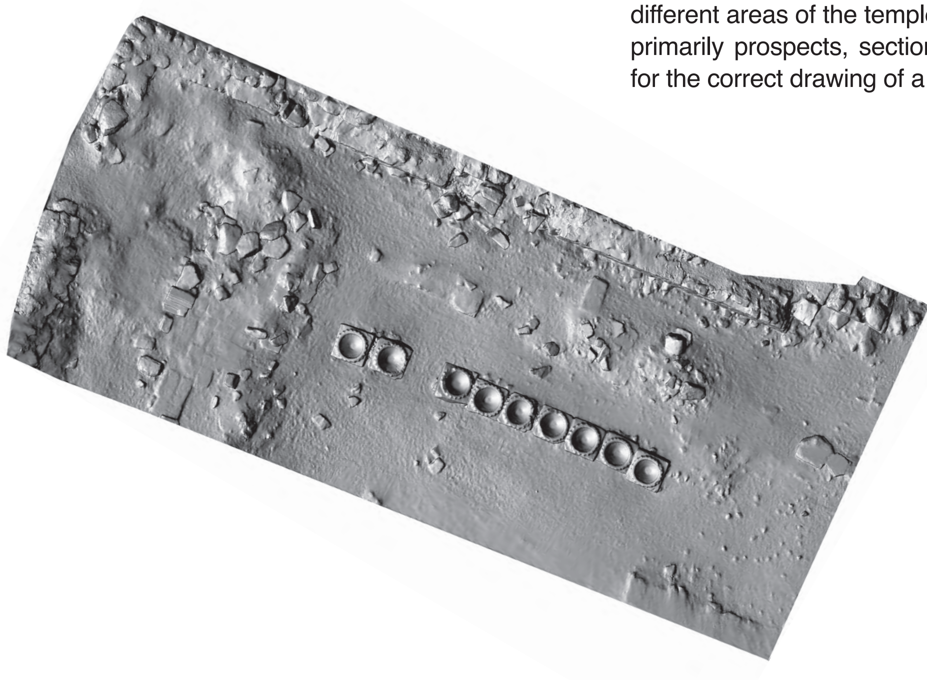
The model generated by scans acquired by the laser scanner has been used as a virtual grid from which it has been possible to extract whatever point to geo-reference the models obtained by photogrammetry. In this way, all the point clouds and meshes were combined and integrated in a single 3D replica. Different plans, sections and other graphical information have been extracted from the resulting reconstruction to support the analysis of the monument.

In 2017, we continued the acquisition by photogrammetry to complete the missing parts not photographed in the previous campaign and obtain a more complete 3D model, especially as regards the area of the obelisk, which given its huge dimensions deserved a specific set of photogrammetry and post-processing. Additionally, individual pieces which presented specific features to be recorded in detail (*e.g.* all inscribed blocks, whenever possible) were photographed, texturized and then recreated in CAD as independent 3D pieces/models. These replicas can then be easily

Fig. 16 Orthophoto of the alabaster altar, based on photogrammetric data (elaboration by A. D'Andrea, A. Bosco)

moved and rotated either to re-create single components of the architectural structures or to simulate possible reconstruction of the parts that are no longer visible. Most importantly, and for the first time, we used the above-mentioned technology to document also archaeological evidence situated outside the temple, namely the remains of the huge terrace structures still partially visible on the northern and eastern sides, the few remaining slabs of the causeway pavement, and the remains of the valley temple. Here, in particular, our documentation work was made more complicated by the presence of dense vegetation as well as by the high level of groundwater, which still surfaces in some areas, especially during the fall.

The whole data acquisition process in 2017 has been carried out by means of the "Osmo system DJI" with a Sony X3 sensor, which uses a gimbal to keep the camera flat in order to avoid shake and blur. This technology has also been combined and integrated with data acquisition carried out by means of two very high-resolution cameras (Nikon 5300D and Nikon D750). By the end of the fieldwork, we obtained more than 2,000 shots of the entire temple which produced different texturized point clouds and meshes. All these 3D data have then been integrated in a digital replica acquired during the previous campaign, with the aim of creating a complete model of Nyuserre sun temple. This 3D base can be used to extract not only ortho-photos of the different areas of the temple (see figs. 16–17) but also and primarily prospects, sections and plans which are pivotal for the correct drawing of a new temple plan (fig. 12).



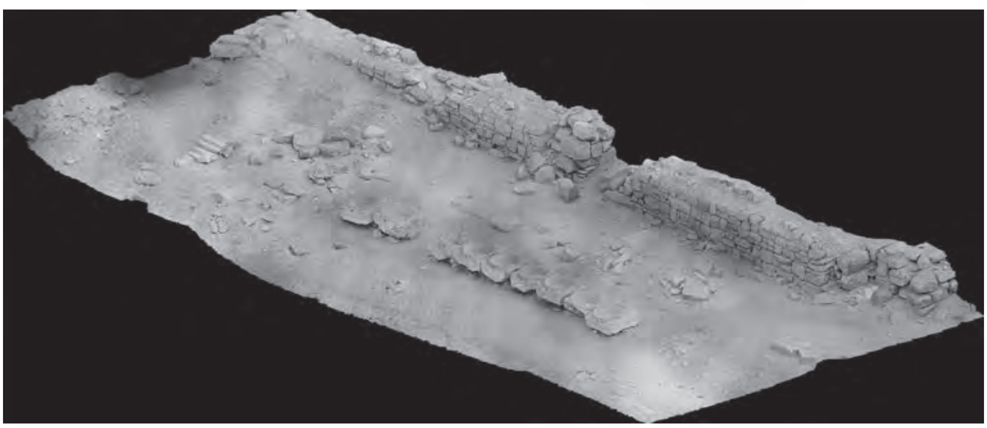


Fig. 17 Hill-shade basic analysis of the area of the alabaster basins, based on photogrammetric data (elaboration by M. Osman)

The final step in this part of the mission, whose post-processing phase still continues, is to elaborate the missing part of the digital replica using CAD modelling techniques in order to hypothesize the original shape and volumes of the temple. In order to manage and integrate all the archaeological, architectural and laser scanning data acquired so far, we started the implementation of a specific application by means of a new approach, the above-mentioned Building Information Modelling (BIM). This approach, introduced in the following two paragraphs, is based on a process involving the management of the digital representations of the physical and functional features of the buildings, considered as objects composed of different elements, each with its specific geometry, attributes and relationships.

Building Information Modelling (BIM) technology (P. Zanfagna, A. D'Andrea)

"Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle, defined as existing from earliest conception to demolition." (http://www.nationalbimstandard.org/faqs. Accessed on 11th October 2018).

As clearly pointed out by the above definition, Building Information Modelling (BIM) is not just a graphical software for 3D modelling, but rather a new conceptual approach to the design, collection, sharing and management of different datasets, as well as a new methodological process of modelling architectural data. We have analysed the main characteristics of this new technology in detail in a very recent article (Bosco *et al.* 2018: 359–360). Given the scope of the present article, it will be worth recalling some of its main aspects here.

BIM has been employed in modern civil engineering to integrate the needs of the designers with the world of the building companies and industries. From this point of view, BIM has been implemented to facilitate the design and management of new buildings by creating a digital environment accessible by different stakeholders. Notwithstanding these original features, BIM has been applied also to the management of historical buildings, up to the point that some scholars have even introduced the definition of Historical Building Information Modelling (HBIM) to describe an approach focused on the conservation and virtual reconstruction of ancient buildings (Murphy – McGovern – Pavia 2009: 311–313).

Even if BIM was not originally created for built heritage, the need to share and combine into a unique system several categories of data, such as the state of preservation, the description of single architectural elements, information about spatial organization of the buildings, the use or reuse of spaces and objects or the classification of objects, has encouraged different scholars to apply this new approach to cultural heritage. The main task of BIM is therefore to manage different datasets relating to a building during its complete life-cycle, by also including spatial and alphanumerical data (Tobiaš 2016: 28–29). In other words, BIM is a combination of standard GIS databases with a 3D environment, as it interrelates 3D alphanumerical and spatial data of the architecture of a building with 2D geometric features of all its components, finally intertwining all of them into a GIS system.

One of the main potentialities of BIM is the possibility to freely share 3D data from various sources, providing experts with access to the same model. By means of BIM, each user can access, analyse and modify whatever part of the model by participating – actively, and not only receptively – in the same project. BIM thus encourages the various actors to collaborate, without obliging them to acquire a new language.

It is also worth noting that, contrary to the CAD approach/methodology, BIM 3D modelling is based on parametric elements representing all physical and functional properties of whatever architectural object with its spatial relationships. The model is thus described through a formal representation highlighting concepts and categories, which is usually called "a library" (Murphy – McGovern – Pavia 2011: 97–99). While the libraries of parametric elements can be easily implemented and shared in modern civil engineering, in the field of HBIM there are not yet libraries suitable for 3D reconstruction. In fact, while in the field of built heritage, the architectural elements are frequently well preserved and the creation of categories of objects is a quite simple task, in the archaeological context, the structures are very often poorly preserved and only partially visible or strongly restored/modified compared to their original shape. This lack of shared libraries is probably the main reason why the application of BIM to archaeological monuments and sites has been very rare so far (Garagnani 2012: 297–302). Moreover, in the Egyptological context and particularly as concerns the Old Kingdom, the application of BIM is made even more complicated by the almost complete lack of well-preserved structures that might serve as sample buildings/architectures to create the basic libraries. As a result of these factors, BIM is practically unknown in Egyptology, with very few exceptions (see Kawae *et al.* 2016: 3–11).

BIM model of the sun temple of Nyuserre (Patrizia Zanfagna – Andrea D'Andrea)

Based on the above-mentioned remarks on the use and purpose of BIM, it is immediately clear that the first and foremost task in our project dealing with the sun temple of Nyuserre is the creation of a specific library of technological elements adopted during the construction of the monument (see Bosco *et al.* 2018: 361).

As BIM deals with environmental and technological systems, the first step was the analysis of the architectural model in order to facilitate the composition and decomposition of all elements on various levels of detail. The temple of Nyuserre has been completely surveyed during the campaigns carried out in 2014–2015 and, especially, the last 2017 season. Much architectural information about the building system and the typologies of masonry was extracted from the 3D model created after these surveys. All blocks of the temple were individually analysed in order to highlight the design and the building function of the different structures in which these blocks were employed. This preliminary work made it possible to correctly formalize the whole complex according to the UNI 8290-1981 classification set-up for building systems:

PART ∩ COMPONENT ∩ SUB-SYSTEM ∩ ELEMENTARY SYSTEM ∩ SYSTEM

SYSTEM = whole solar temple;
ELEMENTARY SYSTEM = individual classes of technological units which composed the temple (structure system, closing, internal and external partitioning, *etc.*);
SUB-SYSTEM = technological units of each elementary system (foundation, horizontal or vertical partitioning);
COMPONENT = classes of basic technical elements (architraves, door jambs, pavement, internal and external walls, core masonry and casing stones, *etc.*);
PART = each element identifiable as a component (blocks, slabs, *etc.*).

An important aspect of the BIM approach is that while in the past campaigns, 3D data were mainly used to extract 2D sections and maps useful to document the shape of the monument and its state of preservation, now, thanks to BIM, it is possible to set up a wider workflow allowing the creation of spatial and geometrical 3D objects enriched by a formalized description. The first step of this new project was to import the scans into a BIM. To clean and merge all scans in a single point cloud, all 3D data were imported into Autodesk® Recap®. The processed point cloud was then imported into the software BIM Revit® by Autodesk®. As Revit uses a different language to describe the technological system, one of the main tasks was to convert the categories of data based on the UNI standard into conceptual groups readable from Revit. This is the final result:

UNI	Revit
System	Family
Sub-System	Type
Component	Instance

A methodological aspect that we have to bear in mind is that BIM has been developed to design new buildings starting from well-known architectural elements. This approach must be reversed in the case of the Nyuserre's temple and more generally in all HBIM applications, for we cannot but start from the evidence visible in the ground to achieve the reconstruction of a prototype of the monument. Of course, a fundamental step of this modelling is to exactly localize the original position of all architectural elements that are analysed in our model, especially those which are currently no longer *in situ*. In fact, an incorrect interpretation of the original function/position of the individual blocks may affect the whole system, leading to the failure of the proposed final modelling. Therefore, the confrontation with similar contemporary monuments – *e.g.* the pyramid temples as compared to the sun temple of Nyuserre – is pivotal, as the technological system used in one monument was evidently not very different from the others. The result is a simulation laboratory where it is possible to recreate the different phases of the construction process, from single blocks to the entire building, with the final advantage of continuous sharing, and thus also criticizing, of the results of the work with all other users.

Some categories of architectural elements corresponding to different components of the technological

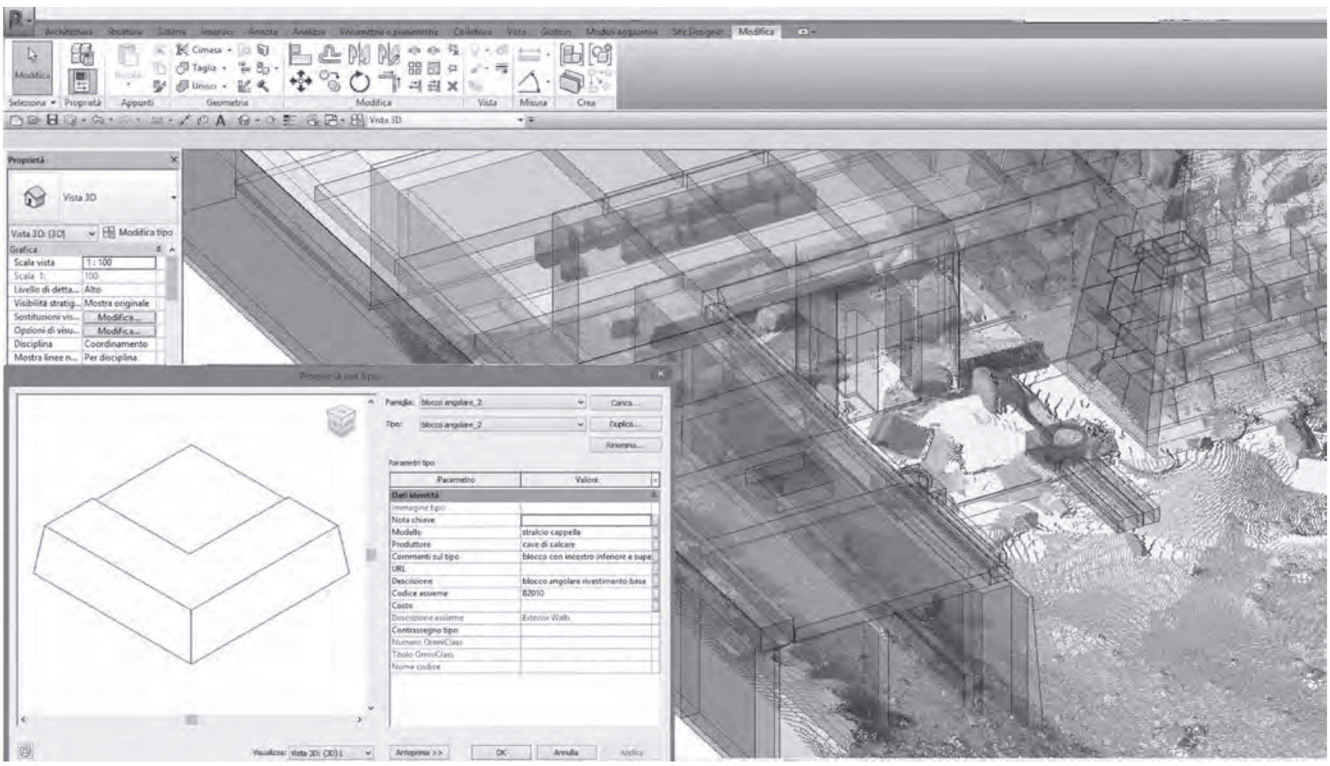


Fig. 18 An example of "types": an angular block and its description (elaboration in BIM by P. Zanfagna)

and constructive system have been extracted from the analysis of the conceptual model. These semantic parts contribute to the formal and physical representation of the 3D reconstruction of the monument. Based on the 3D survey, different 3D geometrical objects have been created and associated with a description including code, material, dimension, provenance and current location (fig. 18). Each element of the sub-system has thus been analysed and correctly assigned to a specific category. Revit allows to create a taxonomy within the architectural model including families, types and single instances (see Bosco *et al.* 2018: 362).

As Revit has been designed for the engineering industry, a fundamental step of the project implementation was the creation of new parametric libraries which included a detailed description of all archaeological artefacts. Thanks to this formalized organization of data, called ABACI in Revit, BIM allows to associate physical instances with graphical, photographical and archival information. The database can then be easily queried and the geometrical objects visualised. In this way, BIM works as 3D GIS.

The conceptual design of Revit also allows the user to analyse all components and create classes or entities of standard volumes, which can be integrated in the model. These entities can be progressively converted into virtual building materials, and detailed architectural elements (walls, roofs, pavements, *etc.*) can be created on the basis of their volumetric families. In this way, one can also easily calculate the amount of building materials necessary for the construction of each part or sub-system of the temple, and evaluate what is missing and/or what has been destroyed.

This reconstruction of the monument and its overlapping with the remaining structure can also contribute to the understanding of the original architectural structure of some of the temple's components (fig. 19) as well as to the clarification of some phenomena and/or dynamics of the collapse or movement of the individual blocks, which are very useful for the final reconstruction of the monument. As we have seen above, this is extremely important for the obelisk, whose original shape has not yet been clarified and has been the main target of the past campaigns.

Finally, by assigning correct geographical coordinates to the model, it is possible to contextualize and visualize the monument in its natural landscape. This approach is particularly useful not only to generate correct shadows in the animation but also to deepen our view of the spatial significance of the monument in terms of landscape phenomenology (orientation of the monument and its astronomical implications, visibility in the landscape, interrelation with other monuments of the time, accessibility from the surrounding areas, relation with the location of natural sources, *etc.*).

Material culture of the sun temple. A brief archaeological survey of the upper temple (Jaromír Krejčí)

One of the problematic issues connected with the sun temple of Nyuserre is represented by our lack of knowledge of the material culture of this important monument. Unfortunately, Borchardt did not pay attention to finds such as pottery, stone and copper implements, as he was focused on the evaluation of the temple's architecture and the relief decoration. No evidence of a documentation of such finds has been found even in the available archive material. Perhaps we can attribute this *lacuna* in the documentation to the fact that the research in Abu Ghurab

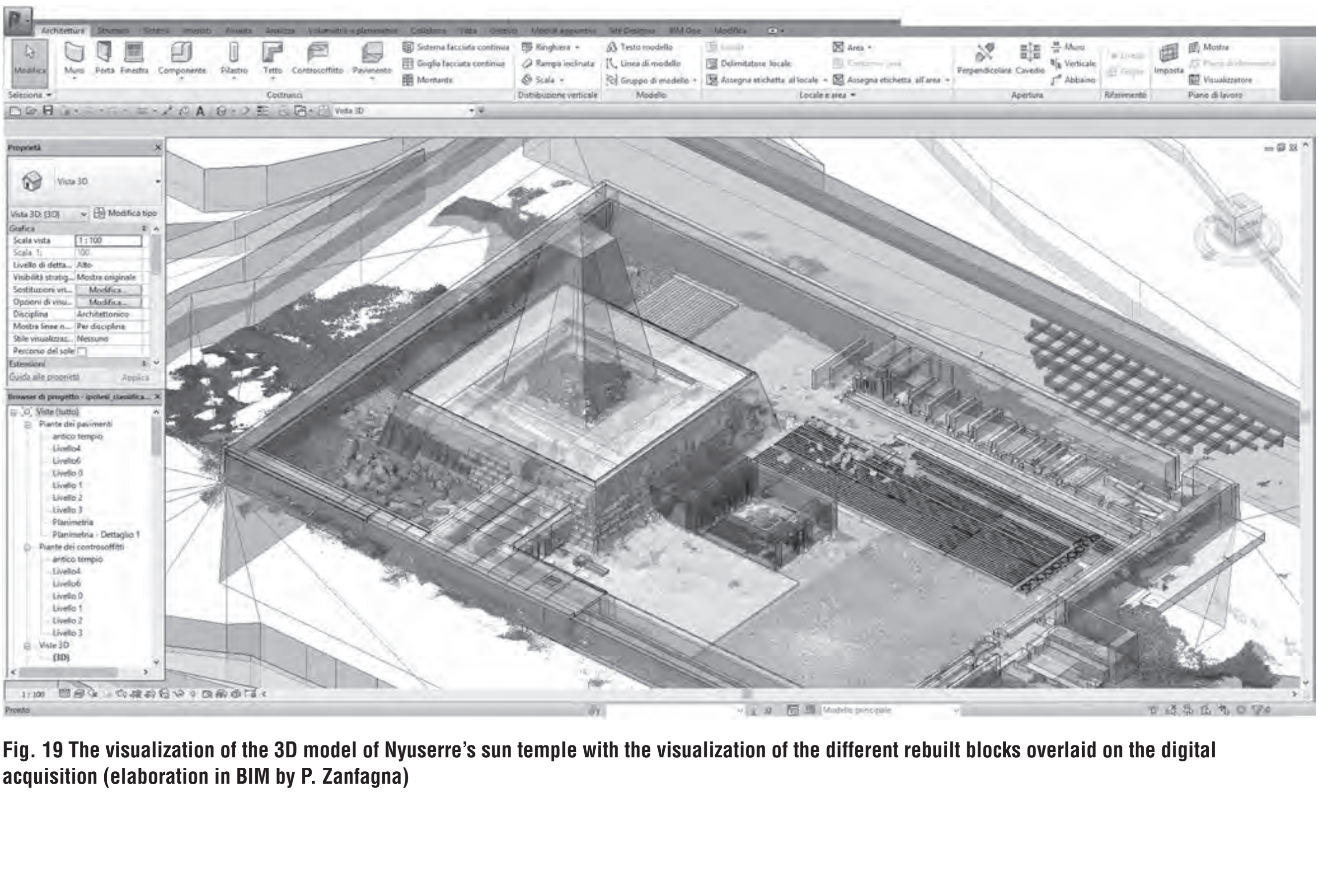


Fig. 19 The visualization of the 3D model of Nyuserre's sun temple with the visualization of the different rebuilt blocks overlaid on the digital acquisition (elaboration in BIM by P. Zanfagna)

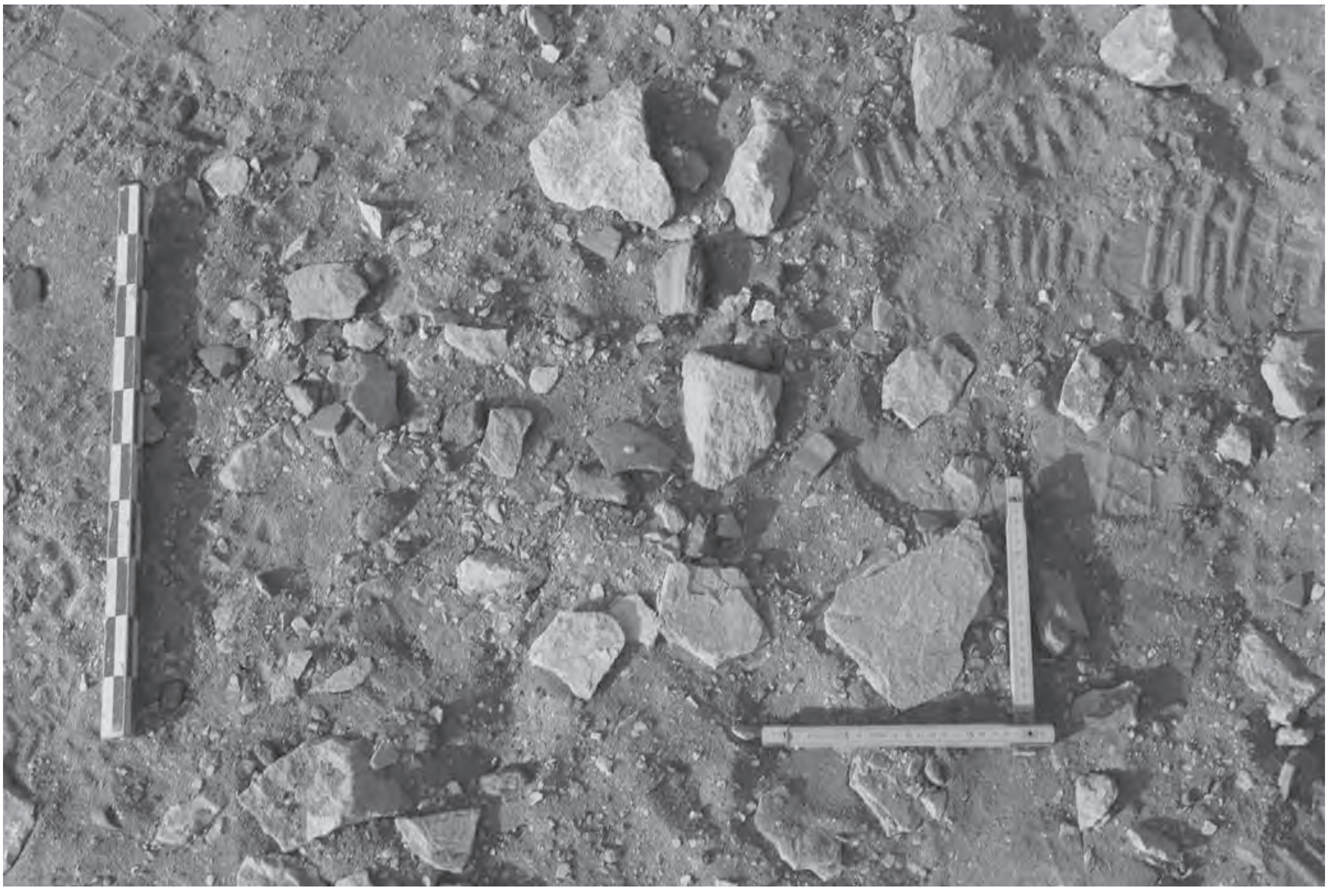


Fig. 20 Cluster of pottery sherds located in the north-eastern corner of the open courtyard in the upper temple of Nyuserre's solar complex, close to the alabaster basins of the so-called "slaughterhouse" (photo J. Krejčí)

was one of Borchardt's first fieldworks in Egypt. The lack of information about the material culture of Nyuserre's sun temple becomes more evident when compared with the approach of the Swiss-German Expedition directed by Ricke, which worked in the nearby sun temple of Userkaf less than sixty years later. Pottery and some of the other types of finds from the temple were processed in the report monograph on a level appropriate to the time of issuing (see the various contributions in Ricke 1969).

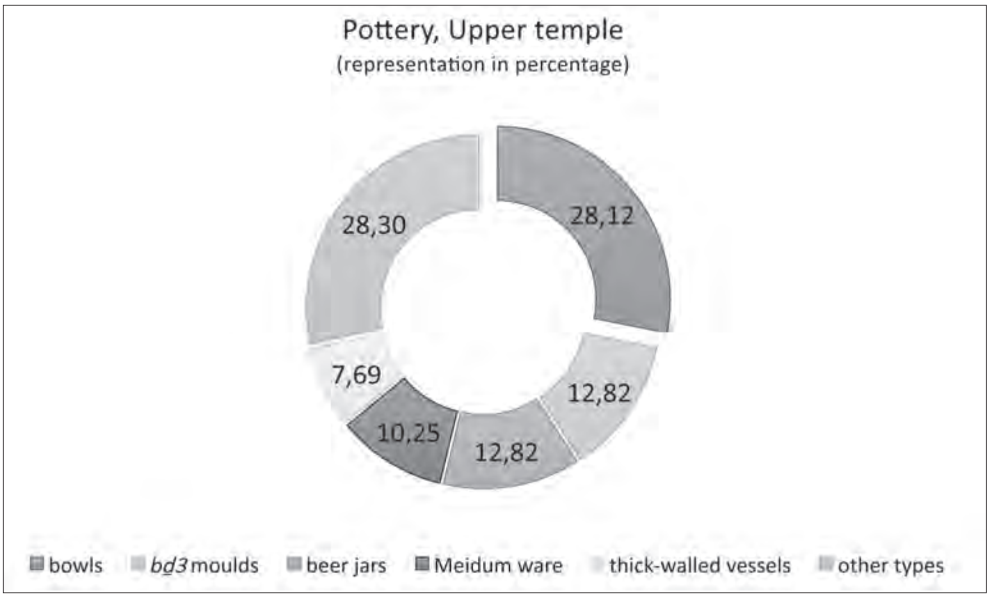
However, a glimpse at the area of the upper temple of Nyuserre's solar complex and the massive dumps left by Borchardt all around it as well as around the valley temple clearly show that the material culture of the temple was rich (see fig. 20). The first archaeological survey in the area was carried out in November 2017. Although a vast majority of artefacts was taken away during Borchardt's excavation of the upper temple, it was still possible to document fragments of ceramics and stone, especially flint implements. Results of this very simple investigation can contribute to the dating of cultic activities in the temple, the mapping of its ritual landscape and the planning of future fieldwork and research in the sun temple area.

Methodologically, this investigation was a surface survey during which diagnostic pottery fragments and flint implements were documented on the spot. Given that about 120 years had elapsed from Borchardt's excavation of the upper temple, the find positions of the objects had fundamentally changed, both horizontally and vertically. Therefore, their approximate location was recorded and the sherds or stone implements were photographed in their actual find spots. Sketch and photographing documentation of these objects was also taken on the spot. Altogether, 39 diagnostic sherds and 23 stone implements were documented.

Because the documentation options were limited due to the form of the survey, only the basic analysis of the found sherds will be presented here. The highest number of documented diagnostic sherds (84.17%) is represented by material datable to the Old Kingdom, with all probability the second half of the Fifth or the beginning of the Sixth Dynasties. The sherds datable to later periods (Twentieth and Twenty-First Dynasty, Third Intermediate Period, late Roman and Arabic/Coptic Periods) comprise 15.83% of the set. As for the shapes, the most documented were bowls with 28.12%, followed by *bḏꜣ* forms with 12.82% and beer jars with the same percentage (see fig. 21). Four sherds of Meidum ware were documented, comprising 10.25% of the assemblage. The rate of thick-wall pottery is rather low, only 7.69%, and there were also found a fragment of an open-formed vessel, a thin-wall fragment and other not-recognizable rims of vessels (chart 1).

As regards the spatial distribution of the sherds, the most interesting is a cluster of Roman and Coptic pottery sherds in the north-eastern part of the upper temple, where Borchardt unearthed but then dismantled undocumented mud brick masonry of apparently secondary (settlement?) function (Borchardt 1905: 74). As the number of these late-dated pottery sherds is rather high, it is improbable that

Chart 1 Graphic of the pottery finds in the upper temple of Nyuserre's solar complex



they were brought to this place from another part of the temple. Nevertheless, sherds dated to the Old Kingdom were also found among these late-dated sherds.

It is worth noting that no diagnostic sherd was documented in the western sector of the upper temple, *i.e.* in the area west of the so-called "Room of the Seasons", and on the northern side of the "pedestal building". While this is not very surprising for the former area, which was lacking cultic function, it is much more so for the northern side of the "pedestal building". In this area is situated the so-called "small slaughterhouse", which was completely cleaned by Borchardt and must have had a real cultic function. For the sake of completeness, it must be noted, however, that the westernmost part of the courtyard around the "pedestal building" is still covered by a massive accumulation of sand and debris unexplored by Borchardt and presumably containing archaeological finds. Moreover, no indicative pottery sherd or stone implement was found when surveying the surface of this debris. Whatever the case, the concentration of diagnostic sherds in the eastern sector of the upper temple clearly demonstrates, as could be expected, that major part of the cultic activities concentrated there.

As to pottery forms, they are usually quite similar to those documented in central Abusir (Bárta 2006: 289–324; Arias 2014: 71–260); it is interesting to note that no miniature forms have been detected until now, not only in the area of the temple itself but also on the dumps made during Borchardt's excavation.

Beside pottery fragments, the survey also focused on the documentation of stone implements (for comparison, see Svoboda 2006: 502–518). In this respect, the largest group of finds was represented by flint splinters with retouches – probably used as scratchers – comprising 43.47% of the analysed items; the second largest group were borers (17.39%), followed by 2 small retouched blades (8.69%), 1 burnisher, 1 flint core and a quartzite hammer (4.35% each). The results are, as in the case of pottery finds, deeply influenced by the fact that the surveyed area has been open for many decades and many phenomena (visitors, degradation of masonry, blowing of sand, weather, *etc.*) certainly disturbed the original finding situation, notwithstanding the fact that the area was archaeologically explored and the results of this work were not documented in their entirety.

Unfortunately, the form of the stone implements does not allow us to propose more precise dating. The finding of a quartz hammer in the area between the altar platform and the "pedestal building" can probably be connected with activities associated with the destruction of the temple. The main cluster of stone finds is located in the central open courtyard of the upper temple, at the main eastern entrance of the temple, and in the area south of the alabaster altar.

This very brief and simple survey shows that this type of documentation work is much needed, and its accomplishment not only in the dumps left by Borchardt all around the upper temple but also in other sectors of the solar complex (the causeway, the valley temple and the surrounding areas) represents a great challenge for the coming future. This investigation can not only improve our understanding of the material culture associated with the running of the sun temple but also our knowledge of its function, architectural form and building development and their individual components, as well as of the sun temple's interconnection with the overall ritual landscape of the area of Abu Ghurab and Abusir.

Conclusion and perspectives (Massimiliano Nuzzolo)

The investigation of the sun temple of Nyuserre started in 2010 with a precise objective, namely to check the accuracy of the plan and architectural drawing and reconstruction that had been made by Borchardt more than a century earlier. After five campaigns of archaeological, architectural and topographical investigation of the sanctuary, along with an extensive acquisition of data by means of diversified technology of photogrammetry and laser scanning, we have now an almost complete plan of the temple as well as a new 3D model.

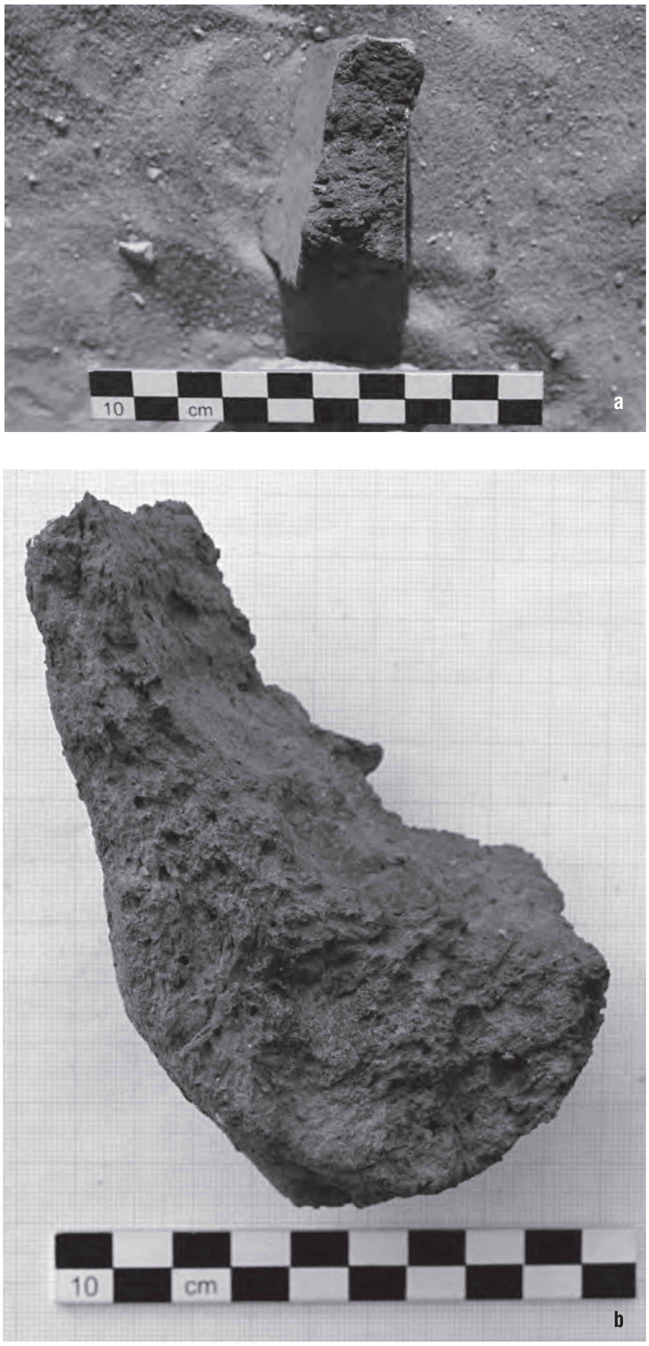


Fig. 21 A fragment of a *bḏꜣ* form (a) and the lower part of a beer-jar (b) documented in the upper temple of Nyuserre's solar complex (photo J. Krejčí)

As a whole, the results of the current mission, combined with previous analyses, seem to further confirm that while Borchardt's plan of the temple is very accurate, some of his interpretations of the temple spaces and his 3D reconstruction of the main cult symbol, *i.e.* the obelisk, present critical points and should be seriously reconsidered.

Several points, however, still need investigation. First of them is a complete study of the material culture of the temple which, as stated above, represents a huge black hole in Borchardt's publication of the sanctuary. Second, a complete re-excavation of the area of the so-called "slaughterhouse", where Borchardt documented the presence of considerable mud bricks structures (still currently visible), whose function and date (early building phase of the sun temple or a previous building?) are still fully unclear. Third, a wider investigation of the occupation history of the site of Abu Ghurab, which, as already recorded, may hide unexpected archaeological structures.

In fact, the last two points are strongly interrelated, for the understanding of the nature of the structures below the sun temple of Nyuserre is evidently connected with the history of the site. It was already noticed that one of the two sun temples of Sahure and Neferefre, which were both never completed, might be hidden below the sun temple of Nyuserre (see Nuzzolo 2018: 77–80 for the most recent summary of the issue). Moreover, the presence of another temple in the area between the latter and Userkaf's sun temple more to the north may further support these hypotheses by testifying that the Abu Ghurab area was indeed an area specifically dedicated to the solar cult during the Fifth Dynasty.

Conversely, the presence of mud bricks structures (mastaba tombs from the Early Dynastic Period) in the valley area to the north of Nyuserre's sun temple has been ascertained by Egyptian colleagues already in the 1990s (Radwan 2001: 509–514). This may imply that either the mud brick structures identified by Borchardt in the sun temple of Nyuserre or the structures evidenced by the remote sensing analysis in the area between Nyuserre's and Userkaf's sun temples might also be much older than the Fifth Dynasty. This would open a new, so far completely unknown research perspective on the early phases of the occupation of the site.

All the above-mentioned issues represent very promising scientific objectives for further investigations in the area. It will be the goal of our future missions to address them and try to broaden our horizons of the history of this pivotal area of the ancient Memphite necropolis.

Notes:

1 As a matter of fact, Borchardt neither describes nor draws the additional branches flanking the basic system of diagonal walls radiating from the centre towards the four corners of the building. This system with additional branches, however, is very well visible on the southern side of the "pedestal building" and evidently resembles the system described by Dieter Arnold for the Middle Kingdom pyramids of Senwosret I, Amenemhat II and Senwosret II (see Arnold 1991: 178, and fig. 4.109; the figure is adopted here as fig. 4b).This building system (*i.e.* diagonal walls radiating from the centre towards the four corners and flanked by several additional branches) was also used in the pyramid of Neferirkare (Borchardt 1909: 41, Abb. 49) and probably also in the pyramid of Nyuserre (Borchardt 1907: 99–120, esp. 100 and Bl. 17), although Borchardt could not determine it with certainty.

2 This is the reason why, in fig. 6, we imagined a reconstruction with two obelisks embedded one in the other, both of the same height but the first one with a base of 20 m and the second of 10 m.

3 The blocks are actually not even recorded on the general map of the temple (see Borchardt 1905: Bl. 6).

4 On the phases of the temple reuse and the finding of official inscriptions of restoration from the Ramesside period, see also Borchardt (1905: 72–73).

[5] A few blocks of this area have not been included in our analysis for, although being made of fine white limestone, they do not show any polished façade and thus cannot be categorized in any of the two above-mentioned types.

[6] It is interesting to note that, according to Arnold (2003: 45), the height of the individual courses of the pyramids casing usually ranges between 120/150 cm for the lowest ones and 50/70 cm for the highest ones. These are indeed the measurement we have ascertained for the casing of Nyuserre's sun temple, with the only difference being that the blocks of the bottom course show larger dimensions (160/130 cm) compared to the standard ones (120/150 cm).

[7] Borchardt (1905: 38, and Abb. 26) already noticed this building peculiarity of the sun temple casing. In fact, the use of this technique is not very common in stone architecture, whereas it is actually predominant in mud brick architecture (see Arnold 2003: 35).

[8] The interpretation of the name as well as the dating of the inscription proposed here have been put forward by Pirelli. For the reading of the personal name, see Ranke (1935: 343, no. 21) and also Erman – Grapow (1931: 116).

[9] Inscriptions left by scribes and other officials of the Ramesside period, which show a palaeography similar to our inscription, have recently been found by the French-Swiss mission (directed by Philippe Collombert) working in the area of the pyramid of Pepy I. The inscriptions are scratched on the limestone casing blocks of the king's pyramid (Philippe Collombert, personal communication, April 2018).

[10] The Ramesside period inscriptions found in the pyramid of Pepy I (see the previous footnote) were engraved on the bottom courses/blocks of the pyramid casing, which further confirms our hypothesis that the inscription was made when the blocks of the sun temple were already lying on the ground.

[11] For the sake of completeness, however, it is worth recalling that Borchardt was convinced that the collapse of the blocks was the result of stone robber activity rather than of a seismic event.

[12] For a brief overview of the main seismic events that occurred during the Pharaonic period, see Arnold (2010: 9–15).

[13] For a wider description of this area and all the archaeological elements, see also Nuzzolo (2018: 176–181).

[14] Block no. 5 is not included in fig. 10 here for its shape is very similar to that of block no. 25 (which is actually shown).

[15] These pieces are very small compared to the others mentioned above and devoid of any hieroglyphic inscriptions. This is probably the reason why Borchardt did not take them into account in his publication.

[16] Actually, as blocks nos. 5 and 25 cannot fit together, they belonged to two different doorposts.

[17] Borchardt actually referred to the southern entrance to the "chapel", for the main one, *i.e.* the one opening towards the central courtyard, was excluded for its considerable dimensions which do not fit the granite blocks in account here (see Borchardt 1905, p. 56 and Abb. 6).

[18] The inscription on the doorway as reconstructed in this paper is identical (only with different dimensions) to the one engraved on a granite portal found by Petrie in Mit Rahina in 1908 and nowadays kept in the Egyptian Museum in Cairo (see Petrie 1909: 6, and pl. III; Nuzzolo 2018: 177–178). The portal, originally belonging to the sun temple of Nyuserre but evidently not known to Borchardt at the time of the sun temple excavation, was reused in the western hall of the Ramesside temple of Ptah.

[19] As a matter of fact, the area to the south of the altar (see fig. 12) does indeed present a considerable concentration of granite blocks, albeit smaller than the large blocks we are discussing here.

[20] The lack of both the pavement and the foundation platform in this area of the temple allows us today to see the remains of the mud bricks structure identified by Borchardt and thought to be an earlier building. On the features and dating of these mud bricks structures (see Borchardt 1905: 66–69).

[21] It goes without saying, however, that this reconstruction with three chapels has to be taken as provisional, based on theoretical elements rather than archaeological evidence.

[22] For an example of an adjoining wall with masonry connection, see the pyramid of Unas where the bottom casing stones are directly worked out so as to accommodate also the beginning of the walls of the funerary chapel (see Labrousse – Lauer – Leclant 1977: 47–50, and figs. 32–33).

[23] These examples can be found in the pyramid temples of Meidum and Menkaure (see respectively Petrie 1892: 8–9, and pl. IV; Reisner 1931: 21, 26–27, 31–32, pls. 10(b), 11(a), plans I–II). In both cases, however, and especially for Menkaure, it seems that the temples were attached to the pyramid façade in the second phase of the building process. It is nevertheless interesting to note that the walls of the Meidum temple (in fact a very small and simple structure) are attached directly to the core masonry of the pyramid, which does not present any casing stones there. To the contrary, the walls of the innermost part of Menkaure's upper temple, which are composed of larger blocks of limestone, are directly adjoining the granite casing of the pyramid's eastern façade.

[24] The authors would like to thank the "Geo4fun company" (http://www.geo4fun.com/) from Rome for providing the mission with the necessary topographical equipment for our investigation.

[25] For the use of closed and/or open traverse in archaeology, see Capra – Dubbini (2009: 81–83); Bedford – Pearson – Thomason (2016: 19–20).

[26] For the resection procedure, see Bedford – Pearson – Thomason (2016: 28).

[27] See also the work done by the present author concerning the Saqqara necropolis within the framework of the *North Saqqara Risk Map Project*, later continued as *ISSEMM Project* (Brienza 2003: 266–287).

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Bibliography:

Arias Kytnarová, Katarína

2014 "Ceramic finds", in: Krejčí, Jaromír – Arias Kytnarová, Katarína – Vymazalová, Hana – Pokorná, Adéla – Beneš, Jaromír. *Mastaba of Werkaure, Volume 1. Tombs AC 26 and AC 32 – Old Kingdom strata*, Prague: Charles University in Prague, Faculty of Arts [Abusir XXIV], pp. 71–260.

Arnold, Dieter

1991 *Building in Egypt. Pharaonic Stone Masonry*, New York – Oxford: Oxford University Press.

2003 *The Encyclopedia of Ancient Egyptian Architecture*, Cairo: American University Press.

2010 "Earthquakes in Egypt in the Pharaonic Period: The Evidence at Dahshur in the Late Middle Kingdom", in: D'Auria, Sue (ed.). *Offerings to the Discerning Eye. An Egyptological Medley in Honor of Jack A. Josephson*, Leiden – Boston: Brill, pp. 9–15.

Bárta, Miroslav

2006 "The Pottery", in: Verner, Miroslav *et al. The Pyramid Complex of Raneferef. The Archeology*, Prague: Czech Institute of Egyptology, Faculty of Arts, Charles University in Prague – Academia [Abusir IX], pp. 289–324.

Bedford, Jon – Pearson, Trevor – Thomason, Bernard

2016 *Traversing the Past. The Total Station Theodolite in Archaeological Landscape Survey*, London: Historic England.

Borchardt, Ludwig

1905 *Das Re-Heiligtum des Königs Ne-woser-re (Rathures). Bd. 1. Der Bau*, Berlin: Duncker.

1907 *Das Grabdenkmal des Königs Ne-user-re*[c], Leipzig: Hinrichs'sche Buchhandlung [Ausgrabungen der Deutschen Orient-Gesellschaft in Abusir 1902–1904. Bd. 1].

1909 *Das Grabdenkmal des Königs Nefer-ir-ka-re*[c], Leipzig: Hinrichs'sche Buchhandlung [Ausgrabungen der Deutschen Orient--Gesellschaft in Abusir 1902–1908. Bd. 5].

1910 *Das Grabdenkmal des Königs Śꜥꜣḥu-reꜥ. Bd. I: Der Bau*, Leipzig: Hinrichs'sche Buchhandlung [Ausgrabungen der Deutschen Orient-Gesellschaft in Abusir 1902–1908. Bd. 6].

Bosco, Angela – D'Andrea, Andrea – Nuzzolo, Massimiliano – Pirelli, Rosanna – Zanfagna, Patrizia

2018 "A Virtual Reconstruction of the Sun Temple of Nyuserre: from Scans to ABIM", in: Matsumoto, Mieko – Uleberg, Espen (eds.). *Exploring Oceans of Data. Proceedings of the 44th Computer Applications and Quantitative Methods in Archaeology Conference*, Oxford: Archaeopress, pp. 355–366.

Brienza, Emanuele

2003 "GIS and Archaeological Data Collection", in: Bresciani, Edda – Giammarusti, Antonio. *The North Saqqara Archaeological Site. Handbook for the Environmental Risk Analysis*, Pisa: University Press, pp. 266–287.

Capra, Alessandro – Dubbini, Marco

2009 "Rilievo topografico per l'archeologia", in: Giorgi, Enrico (ed.). *Groma 2. In profondità senza scavare*, Bologna: BraDypUS Communicating Cultural Heritage, pp. 69–90.

D'Andrea, Andrea – Iannone, Giancarlo – Nuzzolo, Massimiliano – Pirelli, Rosanna – Zanfagna, Patrizia

2014 "The Italian archaeological mission in the sun temple of Nyuserre at Abusir: the use of combined technologies and the new perspectives on the monument", Newsletter Centro Interdipartimentale di Servizi per l'Archeologia 5, pp. 48–98.

Erman, Adolf – Grapow, Hermann

1931 *Wörterbuch der ägyptischen Sprache. Bd. V*, Leipzig: J.C. Hinrichs'sche Buchhandlung.

Garagnani, Simone

2012 "Semantic Building Information Modelling and high definition surveys for Cultural Heritage sites", DISEGNARECON 5/10, pp. 297–302.

Helck, Wolfgang

1977 "Die Weihinschrift aus dem Sonnenheiligtums des Königs Neuserre bei Abu Gourab", Studien zur Altägyptischen Kultur 5, pp. 47–77.

Kawae, Yukinori – Yasumuro, Yoshihiro – Kanaya, Ichiroh – Dan, Hiroshige – Chiba, Fumito

2016 "Abusir survey 3D 2015", Prague Egyptological Studies XVII, pp. 3–11.

Kees, Herman

1928 *Das Re-Heiligtum des Königs Ne-woser-re (Rathures). Bd. 3. Die grosse Festdarstellung*, Leipzig: Hinrichs'sche Buchhandlung.

Labrousse, Audran – Lauer, Jean-Philippe – Leclant, Jean

1977 *Le temple haut du complexe funéraire du roi Ounas*, Le Caire: Institut français d'archéologie orientale [Bibliothèque d'étude 73].

Murphy, Maurice – McGovern, Eugene – Pavia, Sara

2009 "Historic building information modelling (HBIM)", Structural Survey 27/4, pp. 311–327.

2011 "Historic Building Information Modelling – Adding intelligence to laser and image based surveys", in: Remondino, Fabio – El-Hakim, Sabry (eds.). *WG V/4. 4th ISPRS International Workshop 3D-ARCH 2011. 3D Virtual Reconstruction and Visualization of Complex Architectures*, vol. XXXVIII-5/W16, pp. 1–7 (https://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XXXVIII-5-W16/1/2011/) (doi:10.5194/isprsarchives-XXXVIII-5-W16-1-2011).

Nuzzolo, Massimiliano

2007 "The Sun Temples of the Vth Dynasty: a reassessment", Studien zur Altägyptischen Kultur 36, pp. 217–247.

2018 *The Sun Temples of the Fifth Dynasty. Kingship, Architecture and Religion in the Third Millennium BC*, Prague: Charles University.

Nuzzolo, Massimiliano – Pirelli, Rosanna

2011 "New archaeological investigation in the sun temple of Nyuserre in Abu Ghurab", in: Bárta, Miroslav – Coppens, Filip – Krejčí, Jaromír (eds.). *Abusir and Saqqara in the Year 2010/2.* Prague: Czech Institute of Egyptology, Faculty of Arts, Charles University in Prague, pp. 664–679.

Nuzzolo, Massimiliano – Zanfagna, Patrizia

2017 "Glossing the past: the Fifth Dynasty sun temples, Abu Ghurab and the satellite imagery", Prague Egyptological Studies XIX, pp. 110–123.

Petrie, William Matthew Flinders

1892 *Medum*, London: Nutt.

1909 *Memphis* I, London: Quaritch.

Radwan, Ali

2001 "Mastaba XVII at Abusir. Preliminary results and general remarks", in: Bárta, Miroslav – Krejčí, Jaromír (eds.). *Abusir and Saqqara in the Year 2000*, Praha: Academy of Sciences of the Czech Republic. Oriental Institute [Archiv orientální. Supplementa IX], pp. 509–514.

Ranke, Hermann

1935 *Die ägyptischen Personennamen. Bd. 1., Verzeichnis der Namen*, Glückstadt: Augustin.

Reisner, Andrew George

1931 *Mycerinus. The Temples of the Third Pyramid at Giza*, Cambridge (MA): Harvard University Press.

Ricke, Herbert

1965 *Das Sonnenheiligtum des Königs Userkaf. Bd. I. Der Bau*, Kairo: Schweizerisches Institut für Ägyptische Bauforschung und Altertumskunde [Beiträge zur Ägyptischen Bauforschung und Altertumskunde 7].

1969 *Das Sonnenheiligtum des Königs Userkaf. Bd. II. Die Funde*, Wiesbaden: Steiner [Beiträge zur Ägyptischen Bauforschung und Altertumskunde 8].

Svoboda, Jan

2006 "The King's knives: chipped lithics from Raneferef's mortuary complex", in: Verner, Miroslav *et al. The Pyramid Complex of Raneferef. The Archeology*, Prague: Czech Institute of Egyptology, Faculty of Arts, Charles University in Prague – Academia [Abusir IX], pp. 502–518.

Tobiáš, Pavel

2016 "BIM, GIS and semantic models of cultural heritage buildings", Geoinformatics FCE CTU, 15/2, pp. 27–41.

Verner, Miroslav

2005 "Abusir Pyramids Quarry and Supply Road", in: Jánosi, Peter (ed.). *Structure and Significance. Thoughts on Ancient Egyptian Architecture*, Wien: Österreichischen Akademie der Wissenschaften, pp. 531–538.

Abstract:

The article presents the results of the 2017 archaeological season in the sun temple of Nyuserre in Abu Ghurab. The works especially focused on three areas, namely the central obelisk, the alabaster altar, and the accumulation of limestone blocks in the south-western corner of the temple. Besides the documentation of these archaeological remains, an in-depth architectural analysis of the above-mentioned structures has been carried out, in particular as regards the obelisk area. In fact, as already noticed in other contributions, the 3D reconstruction of this part of the temple provided by Borchardt is not convincing for a number of reasons. A new reconstruction of the latter part of the temple has therefore been proposed, based on several archaeological, architectural and historical elements. This reconstruction involves not only the architecture of the obelisk but also the original aspect of the altar area, which is strictly connected to the obelisk as regards the cult practice and the overall temple symbolism. Another objective of the mission was to lay the foundations to a new phase of investigation of the area outside the temple, in particular of the area to the south-east of the sun temple of Nyuserre where the analysis of data coming from satellite remote sensing and historical cartography seems to indicate the possible existence of archaeological remains so far unexplored. Starting from this year, the mission has also become a joint Italian-Czech expedition within the framework of a wider research project (*The Rise and Development of the Solar Cult and Architecture in Third Millennium BC Egypt* – GAČR project no. 17-10799S), launched in January 2017 at the Czech Institute of Egyptology, Charles (https://cegu.ff.cuni.cz/en/research/grants/the-rise-of-solar-cult/).

Abu Ghurab – sun temple – Fifth Dynasty – Building Information Modelling – photogrammetry – GIS Spatial Analysis

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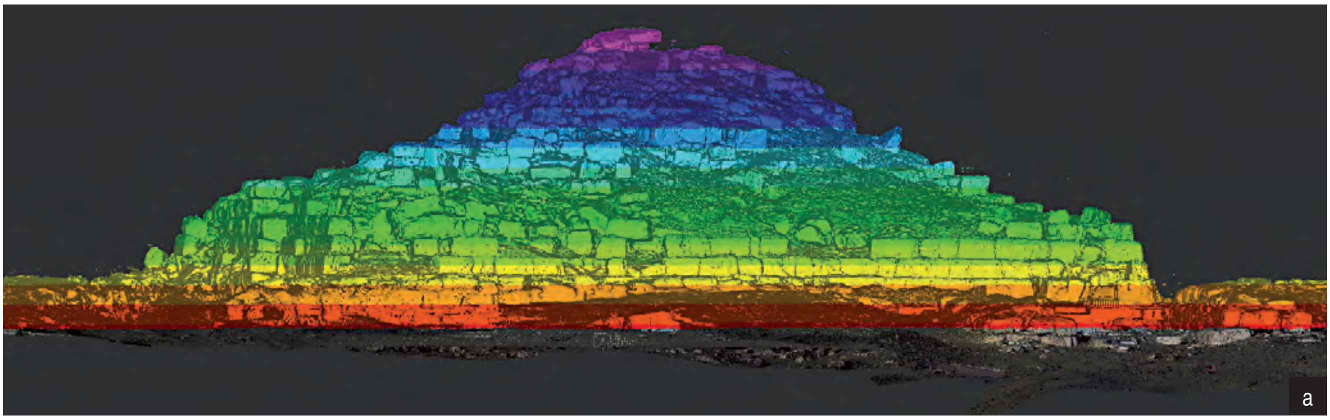

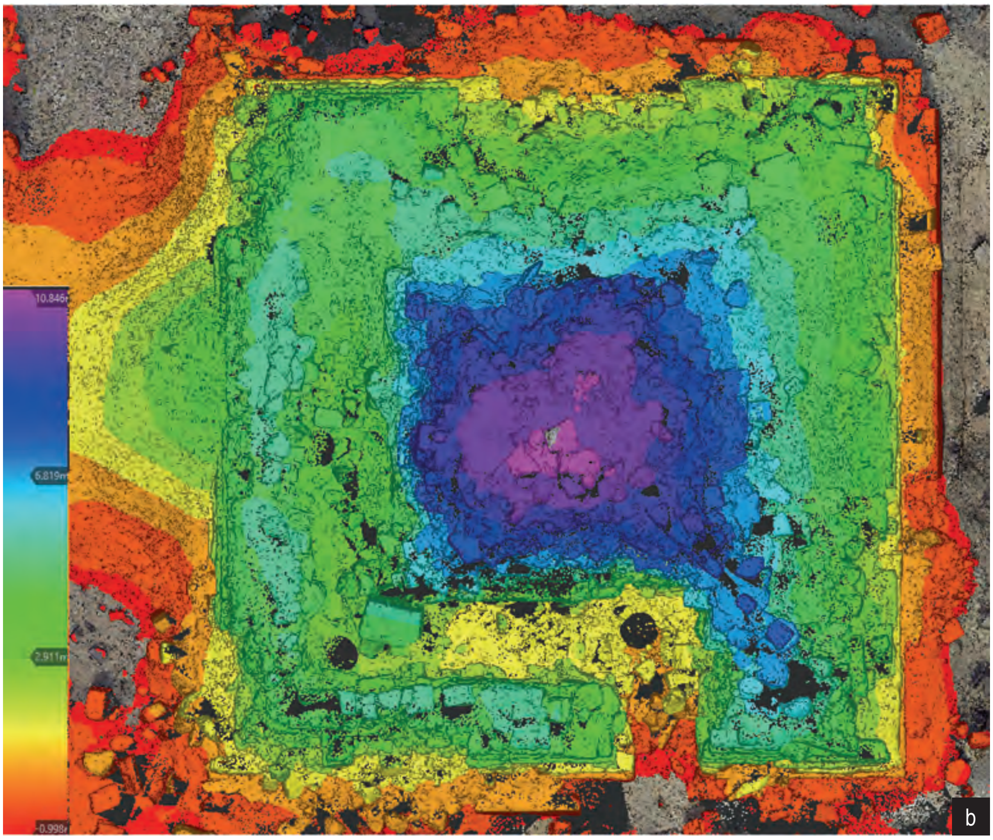

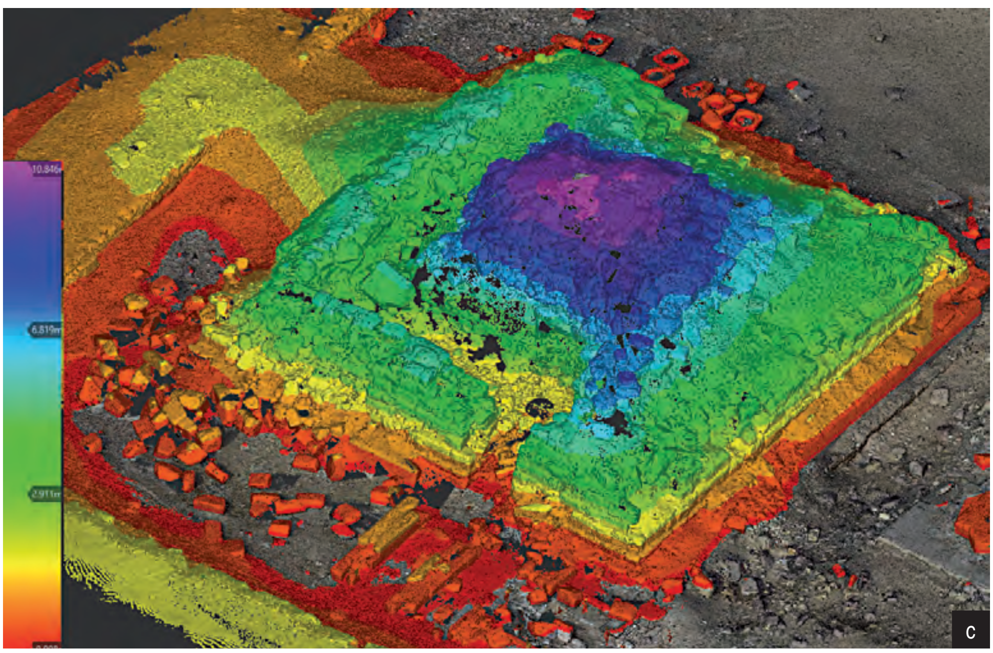

Fig. 12 Three images of the current remains of the “pedestal building”, with height indications in colour, shown in section (a), plan (b), and 3D view (c). The colour elaboration emphasizes the different components of the building architecture as well as the different sizes of the top blocks (light pink) in comparison with the rest of the core masonry blocks immediately below (dark pink). (elaboration in BIM by P. Zanfagna, based on laser scanner and photogrammetric data)