The Abu Ghurab landscape: from Total Station to GIS

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Abstract

Our study, following the practices of Landscape Archaeology, is focused on the relationship between humans and environment in ancient time, supposing that was not unilateral or rather passive: human choices were influenced by the landscape but gave to it a specific asset. Even if it is hard to understand how these relationships took place in the past, we try to reach a plausible interpretation of these phenomena, with a study centered on the Sun Temples of Abu Ghurab trying to also include the whole Memphite area, using different scales of analysis and specific and new technology.

We built a GIS environment where we process all collected data, from the first investigations of 2010 up to the most recent finds, trying to recreate a living historical framework of ancient Egypt, mainly relating to the 5th Dynasty.

For survey we adopted the most updated technology, including newest smart tools for centimetric satellite positioning, using a single antenna and a smartphone (Trimble Catalyst DA2), together with other innovative types of investigation, such high-resolution satellite images interpretation.

On the base of the collected data, the georeferenced historical/previous cartography and bibliography, we have performed different spatial analyses, like viewshed, intervisibility and least cost path analysis.

We want to point out that our study must not be intended as a result but as the beginning of a more complex investigation that, we hope, can lead to fruitful results in understanding some aspects of the ancient Egypt during the 5th dynasty, particularly related to the Sun Temples.

Keywords: *Sun Temple; Landscape Archaeology; GNNS; GIS; Spatial Analysis.*

1. Introduction

The archaeological investigation of the site of Abu Ghurab, located inside the Memphite necropolis area, immediately to the north of the pyramids of Abusir , has been carried out since 2010 by an international research team, currently headed by Massimiliano Nuzzolo and Rosanna Pirelli, Universities of Turin and Naples 'L'Orientale', in cooperation with the Uninettuno University of Rome and the Polish Academy of Sciences in Warsaw. The research work is conducted in close collaboration with the Egyptian Authorities and Scientific Institutions.[2]

[1] The authors have discussed and agreed on the general content of this paper, where the first part (§ 1-3) was edited by Emanuele Brienza and the latter (§ 4-5) by Marco Anzalone.

[2] For a preliminary report of the activities see Nuzzolo *et al.* 2020.

The investigations are focused on the Sun Temple of Niuserra, sixth king of the 5th Dynasty, already excavated by Ludwig Borchardt in the years 1898-1901.[3]

Our contribution, together with topographical support, was developed in the field of *Landscape Archeology*, a branch of antiquity study dedicated to space-time contextualization of the archaeological record inside a given territory whose characters are the result of the interaction between human activities and environmental features, from the beginning until today.[4] The analysis of the ancient environment is crucial to understand the scenario of past events. The landscape and natural resources directed the choices of human communities of the past. In the other hand, it is difficult to reconstruct ancient environments and landscapes characterized by human activities, because many transformations occurred in the past could be enormous or very little in number, realized in a short time, through big phenomena, or in a long time, by constant agents. We must also add the consequences of modern and contemporary industrialization, such as urban growth and abnormal exploitation of territory.

Normally for big changes in geography, linked to climate mutation and geological events, like shift of coasts or river courses, it is necessary a geoarchaeological approach:[5] this can be the case of the desert burial areas of the Old Kingdom, partially affected by alluvial processes and movement of waters towards the east.[6] In our case if the desert character of the area seems to have remained the same since millennia, we must take in account the continuous movements of sand dunes and wadies, which certainly changed the morphology and the ground level; we must also consider contemporary activities carried recently in the desert.

The flood plain, located between the rock desert plateau and the west bank of the Nile river, is a decisive item for the ancient landscape reconstruction. This area had to be characterized by intense cultivation and canalization for agricultural purposes but also for transport and communication: those canals probably run in parallel to the Nile but also transverse to its course. The appearance of this area was a mixture of desert and vegetation, plotted by channels managing the water regime, giving access to the entrances of burial and religious complexes, supporting the activities of small villages sprung around them and allowing the transport of objects and goods linked to calendar feasts: first of all the water itself, necessary for the purifying rites performed in the Sun Temples.[7]

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[3] The Sun Temple of King Niuserra (2400 BCE ca.), is the most significant evidence of architectural complexes dedicated to the solar cult in ancient Egypt: at the beginning of the 5th Dynasty, we find this new type of sanctuary, exclusively dedicated to the cult of the solar god Ra. The temple is structured according to a tripartite layout which is well known in Old Kingdom and can be found in almost all the contemporary pyramid complexes: 1) Valley Temple; 2) Causeway; 3) Upper Temple; the latter is composed of a surrounding wall, measuring 110 x 70 m, which encloses a varied ensemble of cultic rooms, open-air spaces and functional areas. These monuments played an important role in the religious life of Old Kingdom but were suddenly abandoned by the end of the 5th Dynasty. See Borchardt 1905.

[4] About *Landscape Archaeology* see, in general, Turner, Shillito, Carrer 2018 as an updated approach; about this kind of studies in Egypt see Tristant, Ghilardi 2018.

[5] For geoarchaeology applied to ancient Egypt see Tristant, Ghilardi 2012; see also Tristant, Ghilardi 2012b.

[6] About these processes see Jeffreys, Tavares 1994; Willems, Dahms 2017; Bunbury 2019.

[7] Nuzzolo 2018, 239-241.

This flood plain between the plateau and the Nile river has today a very different aspect compared to the Dynastic one, if we consider that ground level has risen in last centuries and the course of the Nile shifted hundreds of meters to east;[8] in addition, apart contemporary interferences, the general asset based on cultivation and canalization changed continuously during ancient periods (from Dynastic to Greek-Roman periods, and after, during Late Antiquity and Arabic times), so it can represent for us a vague reflection of Old Kingdom situation.[9]

Dealing with landscape, the accuracy varies according to the type of analysis level and to the quality of available data. This is why we adopted a multiscale approach, starting from a smaller area and moving toward a wider context. We began with a focus on the site of Niuserra's Sun Temple and its surroundings; then, we applied our analysis to a broader area, including the necropolis of Abusir and Saqqara; later, we embraced almost entirely the Memphite necropolis, up to Giza, to the north, and Dahshur, to the south.

The different analysis scales are part of a single study and are performed in the same GIS environment, taking in mind that the choice of a site or a building place could be influenced by parameters detectable using different approaches: decisions could be dictated not only by principles of economy, technology and minimum effort, but also by cultural parameters and by political will and its ideology.[10]

2. Survey and topography

Our first task was to give topographical support to excavation graphic documentation and to a multi-scalar GIS, managing both intra-site and extra-site data, connecting stratigraphic information to ancient landscape.

The first step of this work has been checking the general Borchardt map[11] (the most complete previous documentation about the temple), to verify its accuracy and to identify discrepancies with visible archaeological evidence.[12] This examination was made by total station, measuring the ancient architectures.[13] Even if a general validity resulted from Borchardt drawings, some discrepancies came out in several zones, caused probably by different survey techniques but also by ancient walls and blocks displacements made after Borchardt investigations.

In the second step we decided to set up a new topographical network by total station, based on fiduciary points physically represented by pegs fixed on the ground, choosing best reciprocal visibility without damage risks for ancient remains. The network was

[8] Jeffreys, Tavares 1994, 157-159; fig. 15.
[9] For these changes during past times see Alleaume 1992, Cooper 2015; Gonçalves 2019.
[10] Nuzzolo 2018, 53-54; 97-104.
[11] Borchardt 1905, bl. II.
[12] Nuzzolo, Pirelli 2011, 664–679.
[13] We took several detailed points using a temporary network, partially fixed on the ground, composed of 5 benchmarks around the temple area with a reciprocal triangulation carried out by resection from three points for each of them. For the use of total station in archaeology see in general Bedford, Pearson, Thomason 2016. See also Andrews 2009 for standard metric specifications.

based on a closed traverse, initially composed by 5 benchmarks set up around the temple where a forthcoming laser-scanner survey was planned.[14]

From 2017 this topographical network has been expanded, including the area of the terrace walls retaining the ancient complex, the Causeway and the Valley Temple: we traced an open traverse[15] addressed to the surroundings of the Sun Temple, including also some near *koms*, in the effort to detect their possible spatial relation with Niuserra Sun Temple, like affinities in orientation and elevation.[16]

During the following years this topographical network has been constantly used as the base of archaeological and architectural drawings, made by Structure from Motion (SfM) photogrammetry, integrating all graphic elaboration in a unique spatial framework.

Georeferencing has been for long our concern: national geographic benchmarks are not visible in the surroundings while the use of conventional Differential Positioning System (DGPS) devices normally is not permitted in Egypt for security reasons. Until 2022 we georeferenced our data using as spatial references notable features of the area, visible on maps and satellite-photos, and performing a manual roto-translation with a best-fitting procedure; concerning elevations, it was not possible to assign absolute sea-level values and we had to use our conventional values.

In 2022 we used the Trimble Catalyst DA2 centimetric Global Navigation Satellite System (GNSS) that was essential to geo reference all our data in a correct way: these tool, composed of a small single antenna fixed on a pole, interface directly with a smartphone via intuitive applications and speed up the data collection in the field, making the spatial and typological integration of archeological record increasingly faster and easier.[17] Since its centimeter accuracy in Africa is not fully guaranteed, considering also that the non-constant mobile line on the site decreases the real-time correction of the web-based software, we have repeatedly measured all the benchmarks of our topographic network, taking the same measures every day for many times, and then evaluating the mean squared deviation; apart from gross errors, we were able to obtain multiple measurements varying of two centimeters on X, Y and Z axes. For final data control we decided to compare the new benchmarks coordinates measuring them again by total station: having detected a similar error range and same good accuracy, we were finally pretty sure to place the excavation and our spatial data in a precise geographic context, with sea-level referred elevations exactly linking with those reported in the general map, deriving from the French survey[18] (Fig. 1).

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[14] D'Andrea *et al.* 2014.
[15] For open traverse see Bedford, Pearson, Thomason 2016, 19-20.
[16] See Nuzzolo, Zanfagna 2017, 114-120.
[17] For several use-cases of this new tool in archaeology see Brienza 2023; Brienza 2024.
[18] For this survey, published in 1978, see *infra* § 4.

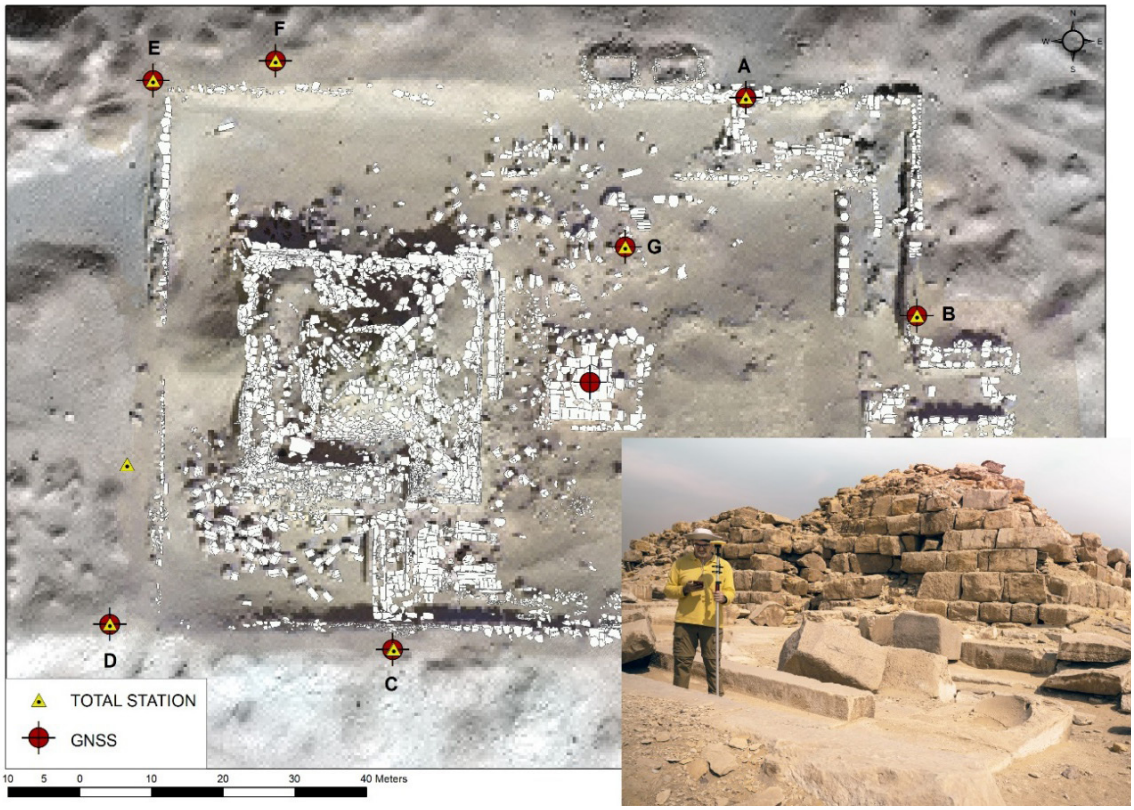

Fig. 1: GNSS Survey. Photo by Patricia Mora Riudavets

3. GIS

We built a GIS for geo-referencing and managing all surveyed data. This system is an advanced update of the *Risk Map for North Saqqara Site*.[19] Our GIS covers as much as possible the entire Memphite zone and its base-map is composed by the sheets of the *Survey of Egypt Topographical Series* (France – 1978, scale 1:5000, International Ellipsoid Hayford 1909, projection UTM 36N, produced by CONSORTIUM SFS/IGN and based on a 1977 aerial survey), different aerial photos and several satellite images (multispectral, panchromatic, S.A.R.); also, all historical and general archaeological maps of the area have been georeferenced and vectorized in layers. Finally, to reach the most detailed definition, several architectural drawings of the single monuments, published during previous archaeological research, even in recent years, have been georeferenced into the map and drawn in vectorial form.[20] Finally, we also imported the main web-cartographies of the ancient world available in digital format, in particular the digital maps of the *Barrington*

[19] For a general review of this project see Bresciani, Giammarusti 2003; for methods and principles used in planning and building this system see Brienza 2003; for technical aspects see Yehia 2003.
[20] The updated geodatabase has been used for a study of tomb distribution in Saqqara during the 5th Dynasty, see Nuzzolo, Zanfagna 2017b; in addition, the same spatial data have been shared with E. Sullivan for the project *Constructing the Sacred. Visibility and Ritual Landscape at the Egyptian Necropolis of Saqqara* https://constructingthesacred.org/

Atlas of Greek and Roman World,[21] those of the *Digital Atlas of the Roman Empire*[22] and other resource available at the *Ancient World Mapping Center*,[23] to relate our area with the most important ancient sites in the wider Egyptian framework (Fig. 2).

Once we could use exact coordinates in WGS84-UTM36N geographical system and elevation values linked to previous detailed cartographies reporting contour lines, we started to build DSM, DEM and DTM of all the area to try reconstructing the ancient landscape and its main features.

Fig. 2: Abusir and Abu Ghurab areas in our GIS

We have performed some spatial analyses, typical of *Landscape Archaeology* usually carried out by specific GIS tools[24] that, from a theoretical point of view, today can be grouped into three main distinct sectors: site location analysis, movement and transport modeling, visibility analysis.[25] There has been a long debate on the use of computerized procedures which involved exponents of Processual and Post-Processual Archeology but today this confrontation has faded: in fact, it is precisely in the field of GIS applications that it is possible to carry out pluralistic approaches and experiments, proving various probabilistic solutions to archaeological questions.

[21] Talbert 2000.
[22] https://imperium.ahlfeldt.se/
[23] https://awmc.unc.edu/
[24] Gillings, Mattingly, van Dalen 1999; Chapman 2008; Hu 2012; Gillings, Hacıgüzeller, Lock 2020.
[25] Verhagen 2018.

One part of our spatial analysis concerned the reconstruction of the communication network during the Old Kingdom, on land and by water, based on what is already known and implementing a least cost path analysis in order to identify the most accessible routes, from point to point, according to places morphology and accessibility:[26] focal points are the most important architectures, such as Pyramid complexes and Sun Temples, but also their Valley Temples and Causeways, which give us very important indications to interconnect, transversely, the desert plateau with the Nile Valley. From our results, it is difficult to suggest an uninterrupted main road in the desert plateau connecting all the sites of the Memphite necropolis: this role should be played instead by the main channel that flowed at the edge of the cliff. On the other hand, it is possible to reconstruct internal paths that connected the various monuments of the area.

A second part of our work concerned the visibility and viewshed analysis,[27] usually conducted in association with other spatial analysis types to understand the visual relationship between archaeological sites and their system of communication.[28] Some limits of this analysis have been highlighted in the past[29] but many have been solved over the years: it is now easy to set the distance and orientation of the visual ray[30] or the distance to the horizon[31] while binary responses are diluted through multiple, cumulative and total viewsheds.[32] Furthermore, it is now possible to use complex procedures, such as the *fuzzy viewshed*, which determines the visible surface from a multiple number of observation points, considering the recognition capabilities of the human eye and the size of the objects and the *probable viewshed*, which is based on a general re-evaluation of the heights, based on the evaluation of the mean squared deviation, of the DEM used as base-surface.[33]

The results of our analysis (see *infra*) show, that the Giza Pyramids were visible almost from the entire Memphite necropolis while Userkaf's and Niuserra's Sun Temples did not have a direct visual relation with Dahshur.

In a general reconstructed framework (Fig. 3), we must imagine a sequence of temples and funerary complexes, during the 5th Dynasty, that had to take into consideration symbolic needs and best places available for building.[34] In this process, the communication routes – internal or in the liminal area below the desert plateau – must have played a role of visual connection among the given monuments, which functioned as not only geographic guidelines, but also as symbolic markers: the roads must have been built following principles of practicability but also of visibility. In this way, a visual network was formed here like a monumental palimpsest that, already in antiquity, must have as-

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[26] Fábrega Álvarez, Parcero Oubiña 2007; White, Surface-Evans 2012; Murrieta-Flores 2014; Herzog 2014; Herzog 2016; Herzog 2020.
[27] Viewshed Analysis is the process of identifying locations that are visible from one or more observer points: usually is performed by GIS on the base of a digital elevation model.
[28] De Montis, Caschili 2012; Murrieta-Flores 2014; Lock, Kormann, Pouncett 2014.
[29] Wheatley, Gillings 2000; Gillings, Wheatley 2020.
[30] Wheatley, Gillings 2000, 16 -24.
[31] Lake, Woodman 2003, 697-698.
[32] Llobera 2003.
[33] Rášová 2014.
[34] Nuzzolo 2015, 296-303; Nuzzolo 2018, 53-54.

signed to the main monuments the role of reference points (spatial but also cultural) for those who were moving in the area coming from both directions, north and south, as still happens today. This cultural significance of the landscape memory which some places have played, as benchmarks of the territory and together with a road network of very long use, is a phenomenon of antiquity observed in many places and probably contains the fascination of landscape history.[35]

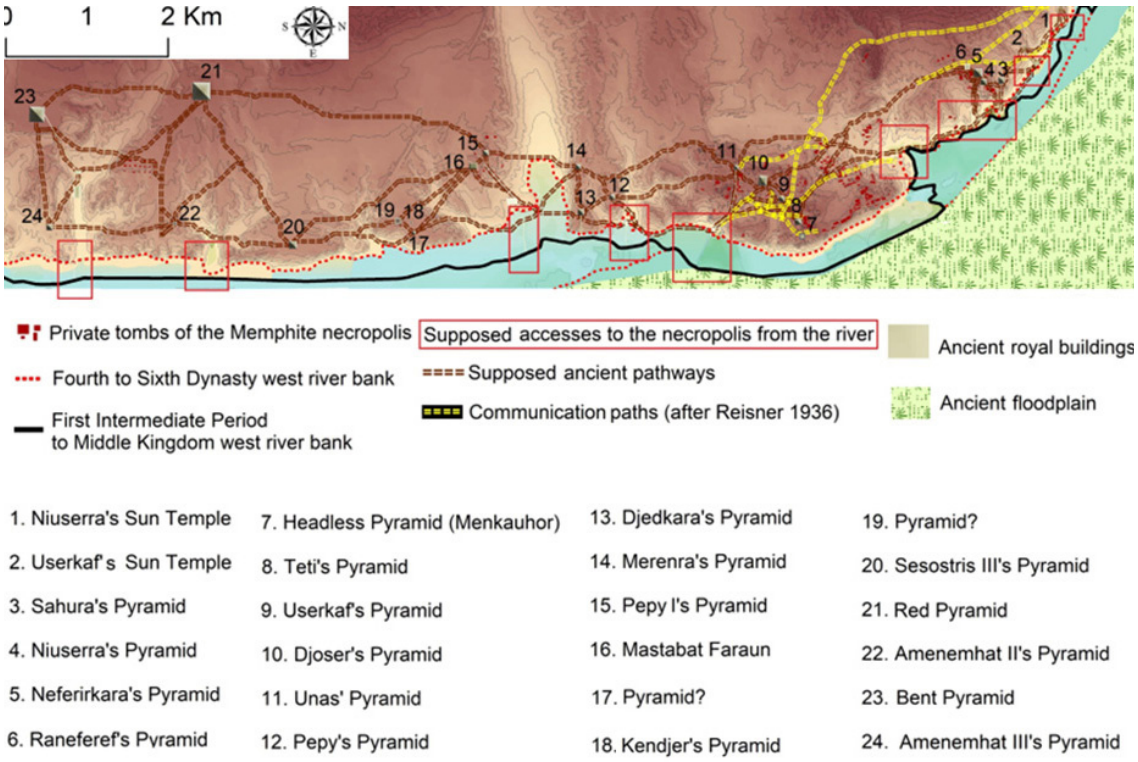

Fig. 3: Ancient landscape and pathways reconstruction proposal

4. Description of the methodological approach

As usual, the starting point of landscape analysis is the research of a good cartographic base, both historical and contemporary; so we used the plans of Lepsius,[36] De Morgan[37] and Porter-Moss,[38] needful for anyone that wants to study the Memphite necropolis; if the first puts the accent on pyramidal structures (many of which still not excavated at the time of the scholar), the latter focus more on tombs, even if they're not mastaba structures. We also used the geodatabase built by Emanuele Brienza during his work in Saqqara and Abu Ghurab.

[35] Garland 2013; Verhagen *et al.* 2016; Brienza, Cultraro, Draià 2020, 204-205.
[36] Lepsius 1849, Abth I, bl 32-34.
[37] De Morgan 1897, taf 1-11.
[38] Porter-Moss 1974.

These maps, of course, present problems in terms of metric accuracy; we used them overlapped to the satellite images provided by ESRI ArcGis,[39] trying to identify structures and remains of historical maps on data. Given the impossibility of varying the chromatic scale of these Maxar's satellite images, we also used images supplied by E-geos and Isi, detected with SAR dual use satellites COSMO-SkyMed, second generation COSMO-SkyMed satellites and EROS Next Generation Elettro Optical with a very high resolution. In the latter, each pixel represents an area of 0.30 m per side; they allow to elaborate variations of the 8 chromatic bands, highlighting possible remains (buried not very deep) with different index of reflection.

We also used the 1978 IGMF Cairo maps 1:5000; from the contour lines obtained by the vectorization of these, was therefore possible to extrapolate a Digital Terrain Model (DTM) with a resolution of 1 m per pixel, a useful starting point for the creation of a "calibrated" DTM, a model of the terrain in which were present only the structures certainly visible in the Fifth Dynasty, and thus eliminating modern buildings and Pyramids or structures subsequent to the aforementioned period.

We are aware that the elaboration of a DTM from contour lines extracted from French cartography dated to 1978 (see *supra* § 3) cannot be representative of the landscape situation of the 3rd millennium BC; but in our case it is useful both for the analysis of visibility and for the elaboration of possible connection paths. In the case of visibility, the absence, at least apparent, of works aimed at leveling hills or heights larger than the pyramids themselves (or which in any case could somehow obstruct their view) put this problem in background; we want also to remark that the dimensions of the structures have been inserted according to the most recent reconstructive hypotheses.[40]

In the case of the least cost analysis, however, the situation is different; the leveling work and the extraction of buildings' materials (for example for the two Pyramids of Snefru in Dahshur),[41] contrary to what happens for visibility, may have had a different weight in the choice of the routes used; in this sense we should imagine that such roads have been planned after all construction processes. We should add the process of sands' accumulation, carried by the wind or by the waters that descend from the wadies; considering these features recalibrating a DTM is quite difficult, at least at the current state of our knowledge of the area. It is also true that these accumulation processes seem to be less consistent in the areas of the plateau of the pyramids and necropolis and the wadi, with their extension on the E-W axis, may have served the funerary areas, especially in the construction phases, but may have acted as blocking points in the case of the N-S direction, both inter-site or infra-site;[42] however it's sure that they have changed the morphology of the east part of the Memphite necropolis, more than the west side (see *infra*).

From the DTM we extracted data relating to the slope (expressed in degrees and not as a percentage) and shading (with azimuth at 315 degrees and 45 degrees of altitude). If the latter helps to better highlight reliefs that are not very visible from satellite images or even from the DTM, the slope is needful to calculate travel costs; after having reclas-

[39] These are shots made between May and July 2020
[40] Lehner 2000, 16-17; Nuzzolo 2018, chapter III.
[41] Alexanian et al. 2012, 131-133.
[42] Bebermeier *et al.* 2011, 329.

sified the gradual values of the slope (from 1 to 9), a weight equal to 70% of the total was assigned; the remaining part was instead attributed to soil geology, remodeling the *Geologische Karte des memphitischen Raums südlich von Kairo*[43] 1: 500.000 with the help of military maps at 1: 5000 of 1978, and assigning values from 1 to 9.

From the overlay obtained it was therefore possible to calculate routes to and from points arranged near the most important buildings of the necropolis, i.e. Pyramids, Valley and Upper Temples and Solar Sanctuaries, trying to guess even if the currently known causeways used the most convenient route or not.

For the visibility analysis, two different approaches have been used:

- the macro level analysis was carried out using Google Earth pro and tracing more than 40 visibility's lines; due to the impossibility of converting the other part of the 1978 cartography relating to Memphis (now Mit Rahina) and Heliopolis (in the neighborhood of al-Matariya inside the city of Cairo), and also given the low level of detail of Barrington's DEM (whose pixels of 70 m per side make it useful only for a preliminary analysis of macro-visibility), we choose this solution; the tracking tool for paths of the Google software allows to extrapolate an elevation profile of these lines, and since the distances are always expressed in km while the heights in m, we needed to modify the images through a CAD software, re-projecting the most important altitude features of these profiles and proportioning them to the distance scale;
- for the area that goes from Dahshur to Abu Ghurab, it was instead possible to use the much more detailed DTM, and to realize a fuzzy viewshed analysis, i.e. an analysis that takes into account not only what is visible or not, but also the percentage of visibility; this percentage can be translated into the distance and size of observed objects, and also into the dispersion and absorption indices of light into the air mass placed between the observer and the objects; thus taking up Ogburn's formula, in turn a reworking of Fisher and Higuchi's theses on visibility,[44] it was possible to attribute values that had a constant degradation between 1 and 0; 1 represents full visibility, and is obviously an expression of the "close-up" of human eye, extendable about 1 km in radius; 0, on the other hand, tends to infinity, since anything with this value is invisible to human eye.

5. Achieved results

Analyzing the viability, we can see that the entire Memphite necropolis has very precise boundaries, and the fact that it extends in length for about 13 km from Dahshur to Abu Ghurab and for other 19 km from the last to Abu Rawash makes it very difficult to hypothesize land routes for the entire extension.

The area of Dahshur, for example, expands from the wadi flowing into the homonymous lake, in the south, up to the Wadi Taflah, in the north. Moving inside an area of about 6.5 km to transport the needful offerings for the cults was very hard, and certainly the orientation of the Causeways and the location of the Valley Temples had to play a key

[43] Bebermeier *et al.* 2011, 329, fig. 2.
[44] Ogburn 2006, 405-416.

role in this transport of goods for the sanctuaries; it would therefore have been easier to move in various points of the necropolis by crossing a canal, of which the Bahr Libeini is possibly an evidence still visible today. Within the median wadi of the Dahshur area there are the Valley Temple and Causeway of the Bent Pyramid, as well as a structure to the east of the same temple surely used as a landing place for boats and as a garden entrance to the Snefru complex.[45] The structure was located at about 20-21 m a.s.l.,[46] but today the area has an altitude of about 25-26 m, thus showing an accumulation of about five meters, probably created not only by the wind (someone talks about a climate change between 4th and 5th Dynasty – 2500 BCE ca.);[47] this would also explain the abandonment of the area during this period, only to resume in the Middle Kingdom, during the 12th Dynasty (20th-19th century BCE).[48]

Further north, and at the same time, Wadi Taflah must have been partly covered by the waters of what is known as the 'Lake of Saqqara' and served as an access point to South Saqqara. In the time of Pepy II (2270 BCE ca.) substantial changes in the layout of the wadi and the lake seem to have started, with a retreat, westwards, of the canal and the lake. The lake's shore seems to have shifted eastwards up to reach the altitude corresponding to the current 21-20 m contour lines.[49]

Going to north, in the southern area of Saqqara the monument of Pepi I (2300 BCE ca.) could reconnect its NE causeway to a possible artificial canal visible with high resolution images (canals of this type, already highlighted by the *Description de l'Egypte*[50] at the end of the 18th century in other areas, would also have carried out drainage and irrigation tasks of the alluvial plain),[51] reflecting a further situation of the lake, before Pepi II but after the middle 5th Dynasty, with a shore that could have reached the current 21-20 m contour line.

Two hypothesized paths could have connected South Saqqara with the area of Netjerykhet Pyramid in central Saqqara[52] (Fig. 3), since these are natural rocky depressions of about one kilometer of extension to the right and left of the small hill located south of the aforementioned pyramid, in the NW-SE direction. Moving to central Saqqara, the access to this area would certainly have been obtained from the area where the valley temple of Unas (2300 BCE ca.) was later built. The paths inside the central area of Saqqara, useful for connecting necropolis and monuments, are not known today, but the roads highlighted in 1936 by Reisner[53] (and still in use today) may have been used in ancient times.[54]

In the north part, instead, Abusir's area could be reached by the lake of Abusir (was it, in ancient times, part of a river?), whose coastline was probably located at the level corresponding to the current contour lines of 22-21 m.[55]

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[45] Bebermeier *et al.* 2011, 344-347.
[46] Alexanian, Arnold 2016, 1-16.
[47] Bunbury 2019, 64-65.
[48] Bebermeier *et al.* 2011, 328; Bunbury 2019, 120-130.
[49] Bunbury 2019, 120.
[50] Neret 2002.
[51] Antoine 2017, 31.
[52] Mariette 1885, Pl. II; see also Porter, Moss 1974, Pl. XLI-XLII.
[53] Reisner 1936, Tav. I.
[54] Barta, Brůna 2006, 25.
[55] Bebermeier *et al.* 2011, 327.

Going instead to the analysis of visibility, it is certain that at least the Pyramids of Giza were practically visible from the entire Memphite necropolis, and from the temple of Ra in Heliopolis; in the same way, the Pyramids of Abu Rawash and Zawyet el-Aryan were observable because they were in a higher plateau; from the Pyramid of Khufu it was certainly possible to view at least the upper part of the obelisk of the solar sanctuary on the opposite bank.

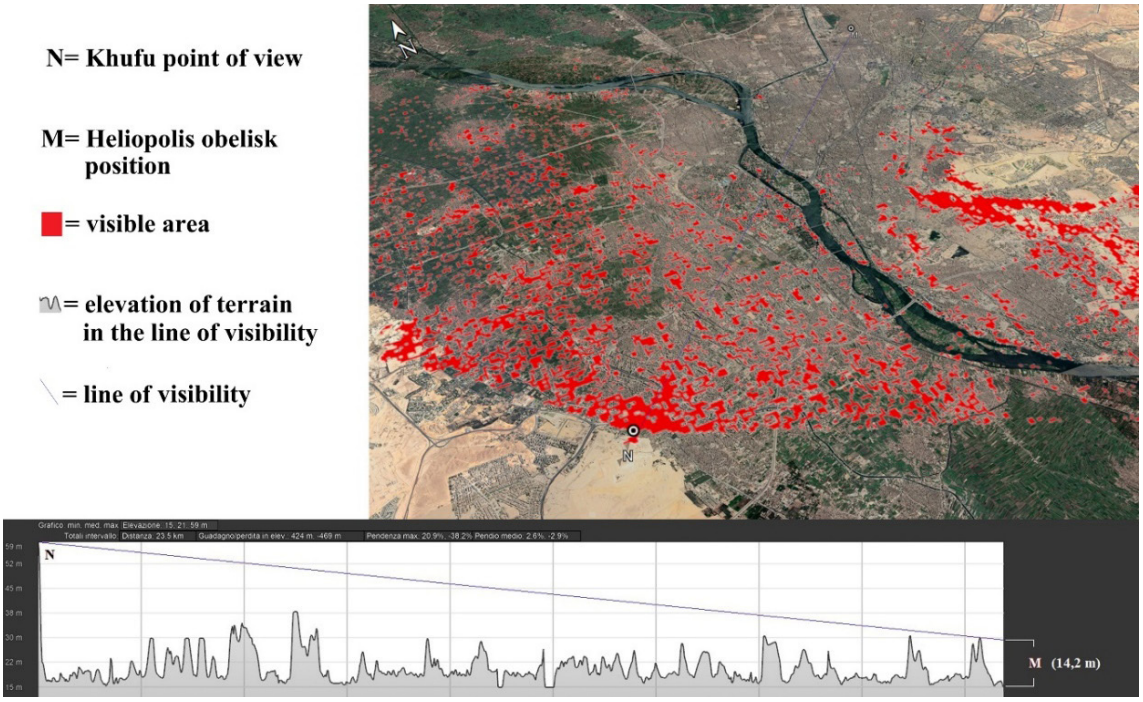

Fig. 4**:** Visibility line from Khufu's Pyramid to Heliopolis

But is there also a connection between the 5th Dynasty's monuments at Abusir and north Saqqara and the Solar Temple at Heliopolis? According to Jeffreys,[56] from the two Solar Temples of Niuserra and Userkaf it was possible to see the upper part of Heliopolis' obelisk; Verner argued that only from the Solar Temple of Niuserra[57] it was possible to see that obelisk .[58] Our analysis can now confirm that no one of these monuments had a visual connection with the obelisk.

In the North-East part Al Muqattam and Al Fustat hills cover every hypothetical line of sight between the solar temples and Heliopolis. But we also observed something more. If we track a hypothetical line of sight between the funerary monument of Neferefra and the South-East corner of Kufhu's Pyramid, this line will pass from the Solar Temple of Niuserra. And if we track the same line also for the funerary monuments of Sahura and the not sure Pyramid of Menkaurhor, these lines will pass respectively for the Pyramids

[56] Jeffreys 1998, 63-64.
[57] Verner, Brůna, 2011, 291.
[58] Nuzzolo, however, suggested that none of these two monuments was visible from Heliopolis. Nuzzolo, 2015, 289-292.

16 and 28 drawn by Lepsius. It's just a suggestion, and we need to prove it, but this could draw a distribution pattern between Sun Temples and funerary monuments, a kind of indirect connection between the Sun Temples and the obelisk of Heliopolis through its visual alignment with Khufu's Pyramid.[59]

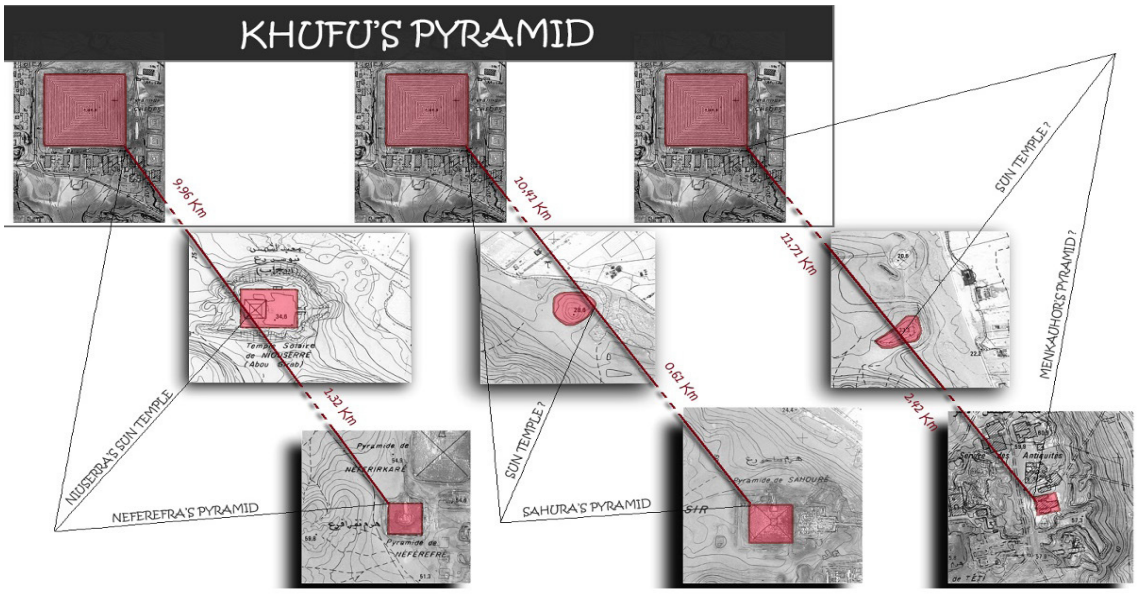

Fig. 5: Corners' alignment with Khufu's Pyramid

Therefore, we have seen that choosing the foundation places for royal monuments in Old Kingdom were considered ritual and political reasons, of course, but also climatic and territorial changes which, in addition to being fully attested by the scientific research of the last decades, find direct correspondence in various kinds of literary sources, and this can only comfort researchers about a progressive approach to the historical truth of the Old Kingdom.

We strongly underline that our research must be considered as a mere starting point for future investigation aimed at understanding the meaning of Memphite necropolis' monument's distribution.

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Online Resources

AWMC	https://awmc.unc.edu/
Constructing the Sacred	https://constructingthesacred.org/
Digital Atlas of the Roman Empire	https://imperium.ahlfeldt.se/