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Mobile 3D recording as a means of digital preservation. An experience in documenting stone structures from the west bank of Aswan (Egypt)

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Abstract

This study presents our experience documenting stone structures during the 2022 Aswan-Kom Ombo Archaeological Project (AKAP) field season. Using a combination of smartphones and GIS software, we established a recording workflow for a week-long pedestrian survey at two prominent sites on the west bank, north of Aswan. These locations contain numerous stone structures that vary in position, typology, and function. WK71 is a cluster of Late Roman tumuli located on the plateau behind the modern village of Nag el-Qarmila, covering approximately six hectares. NH11 is similarly situated atop a plateau extending toward the river, just north of the village and namesake of the renowned rock art site of Nag el-Hamdulab (NH1). This site spans roughly 19.5 hectares and contains several archaeological features, including numerous stone structures of uncertain function and date. Satellite imagery was instrumental in the preliminary documentation and fieldwork planning. During the survey, we recorded the stone structures in 3D using smartphones, placing metric references on the ground to ensure accurate scaling and orientation of the digital models. To assess the accuracy and reliability of this experimental approach, we supplemented the documentation with additional 3D and linear measurements using other devices and recording techniques, such as digital cameras and Structure from Motion.

Thanks to the inbuilt GPS/GNSS receiver, all stone structures processed through the smartphone app were embedded with global WGS coordinates, facilitating precise geo-positioning within the project's coordinate system. Additional software allowed us to generate planar ortho-projections of each structure, which were then imported into the GIS project for vectorization and spatial analysis. This workflow enabled us to document over 140 archaeological features in a short time without compromising resolution or accuracy. Moreover, it allowed for a preliminary archaeological classification of these features before the field season concluded.

Keywords: *3D scanning app; Stone structures; Digital preservation; GIS; Egyptian Archaeology.*

1. Introduction

This paper provides a more technical perspective on the archaeological and topographic documentation of two large stone structure sites discovered within the concession areas of the Aswan-Kom Ombo Archaeological Project (AKAP) (Fig. 1).[1]

The two sites, Wadi Kubbaniya 71 (WK71) and Nag el-Hamdulab 11 (NH11), are both situated on the west bank of the Nile, near New Aswan City. WK71, named after its location in Wadi Kubbaniya, is part of a larger Late Roman stone tumuli site associated with the ancient town of Nag el-Tawil, approximately 20 km north of Elephantine, in the heart of old Aswan. NH11, on the other hand, is located atop a shallow plateau on the western edge of Nag el-Hamdulab, a modern village from which it takes its name. The chronology and function of NH11's stone features remain uncertain. The data obtained

[1] www.akapegypt.org

from the limited number of excavated structures are not yet sufficient to determine the site's purpose. However, its broader context and the materials discovered indicate that it predates the modern era.

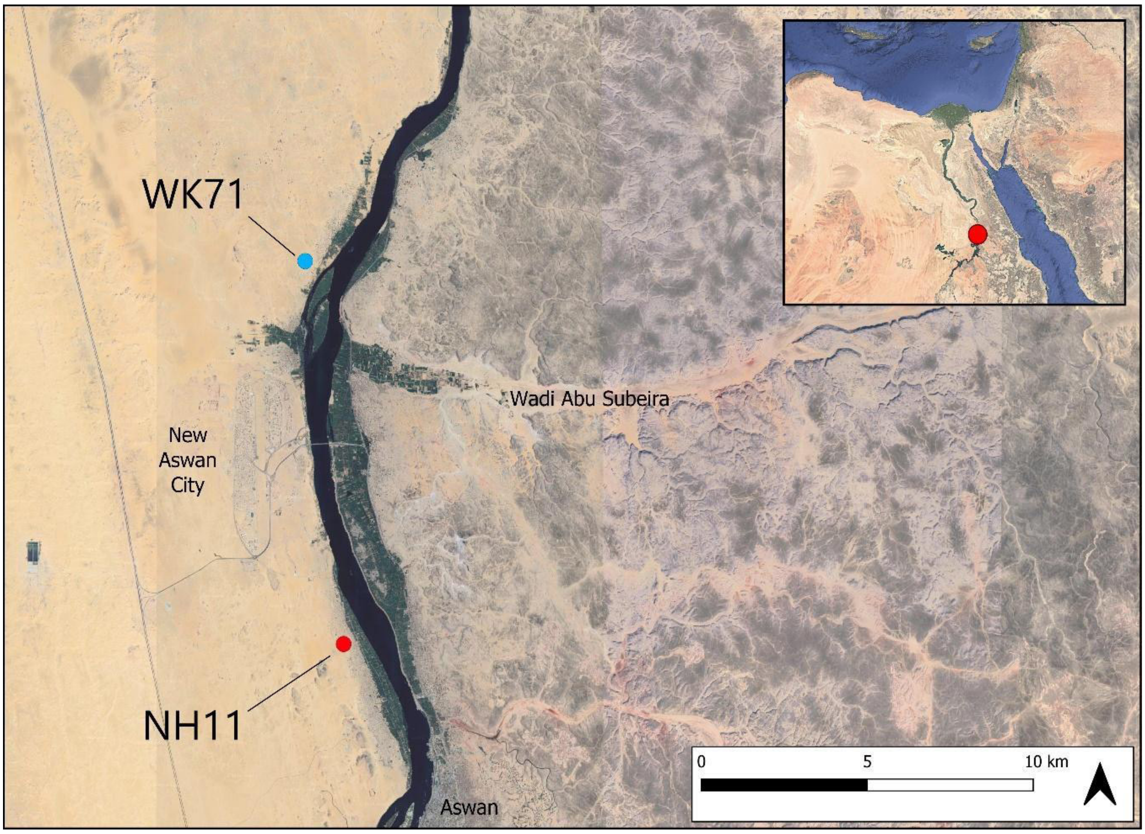

Fig. 1: Locations of WK71 and NH11 in the West Bank of Aswan (Egypt).

A crucial aspect of this case study is the precarious state of preservation of both sites. Their proximity to modern villages significantly threatens their survival. The increasing expansion of human activities along the Nile Valley—particularly urbanization and infrastructure development—continues to endanger Egypt's antiquities,[2] leading to substantial losses since the late 19th century.

Given these risks, it was essential to develop a fast yet effective recording strategy to document the large number of archaeological structures at these sites. The project was structured into four key phases:

1. Conducting a preliminary geo-morphological and topographic analysis using remote sensing applications.
2. Recording the sites through mobile-based photogrammetry.
3. Processing the collected data.
4. Managing and mapping the information within a Geographic Information System (GIS).

[2] Bewley *et al.* 2016; Rayne *et al.* 2017; Rayne *et al.* 2020.

This workflow allowed for a more systematic approach, helping to identify and address procedural, material, and technological limitations.

A standard photogrammetric workflow was unfeasible due to the high number of features requiring documentation, the limited timeframe (one week), and the small team (two members) available for the task. Additionally, a significant obstacle was the ongoing ban on Unmanned Aerial Vehicles (UAVs) and other aerial vehicles across Egypt. Imposed by the authorities for security reasons, this restriction applies to all nonmilitary activities. Beyond this limitation, access to professional topographic and 3D scanning equipment—such as laser scanners, total stations, and differential Global Navigation Satellite System (GNSS - dGPS)—was also a challenge. These devices are difficult to source or import into Egypt, and they were either unavailable on-site or beyond the project's budget, preventing their inclusion in the survey equipment.

From this perspective, the methodological framework for documenting NH11 and WK71 was further refined by maximizing the use of archival data and satellite imagery. Critical fieldwork data—including descriptions, sketches, photographs, and measurements—were integrated with 3D recordings of the stone structures, processed, and systematically stored within a GIS project. AKAP, a joint initiative between the University of Bologna and the Polish Academy of Sciences, has been conducting research in the region between Aswan and Kom Ombo since 2005. The project's primary field activity is a geoarchaeological survey focusing on selected areas along the river and the desert hinterland. Among the identified sites are the two large clusters of stone features discussed in this study.

2. Archaeological background of the two case studies

NH11 spans approximately 19.5 hectares and is situated atop a small plateau at around 160 meters above sea level (a.s.l.). It overlooks the modern village of Nag el-Hamdulab, located about one kilometer from the Nile (Fig. 2). This plateau marks the northern boundary of the wadi that shares its name, where the renowned rock art panels dating to late Dynasty 0 (3200–3100 BCE ca.) were discovered[3] and later documented by the AKAP team. More information on these rock art panels can be found in the Digital Interactive Book: AKAP NH1 DIB.[4] NH11 is positioned on the hill to the north/northeast of viewpoints A, B, and C.

[3] Hendrickx et al., 2012

[4] https://www.akapegypt.org/media/AKAP_NH1_DIB/index.htm

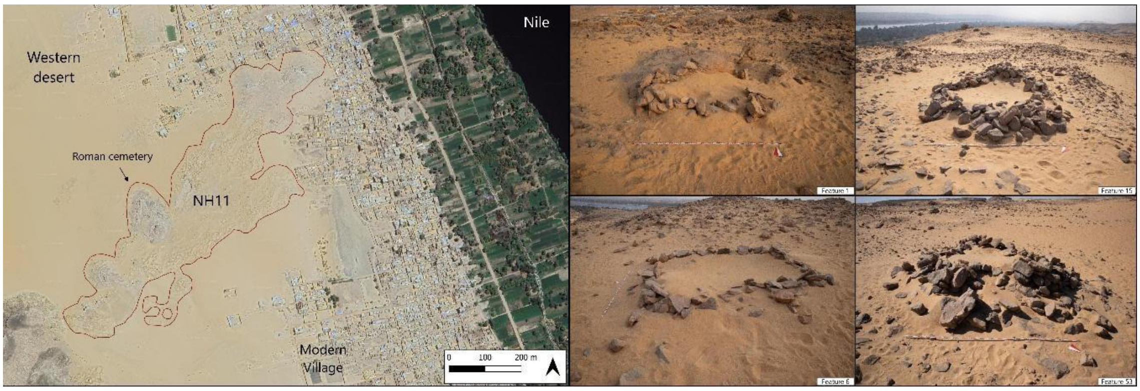

Fig. 2: (On the left) Location and extension of NH11. (On the right) Examples of stone structures at NH11

On the steep northwestern slope of NH11, where an intermediate terrace runs along the flank of the main relief, numerous looted Late Roman hypogeal tombs are present. Similarly, at the southwestern end of the plateau, a massive circular mound (tumulus) measuring 21 meters in diameter dominates the small hill atop a low inselberg rising from the southern slope. Beneath this imposing structure, several Late Roman features are carved into the inselberg's flanks, forming a complex network of underground tunnels.

A past topographic survey identified a large number of stone structures (244 recorded so far) of various shapes and sizes in the surrounding area (Fig. 2). These features, scattered across the relief, do not appear to be directly associated with the Roman burials or the large tumulus. Their forms can be categorized into eight classes: subcircular rings, square rings, double rings, small rings, rings with accumulations, elongated structures, and round or amorphous stone accumulations. The average size of these structures is approximately 5.6 m^2, though there is significant variation in dimensions across the site. No distinct orientation or distribution patterns have been observed. Their function and chronology remain uncertain and will be clarified through future investigations.

Approximately 11 kilometers north of NH11, site WK71 is located on the eastern edge of another large plateau (altitude ca. 154 m a.s.l.), near the villages of Nag el-Qarmila and Wadi Kubbaniya.[5] This site was first identified during previous AKAP field missions (Fig. 3). While the entire archaeological area of WK71 spans approximately 6.6 hectares, the stone structures examined in this study are concentrated along the plateau's Nile-facing side.

[5] Banks *et al.* 2015.

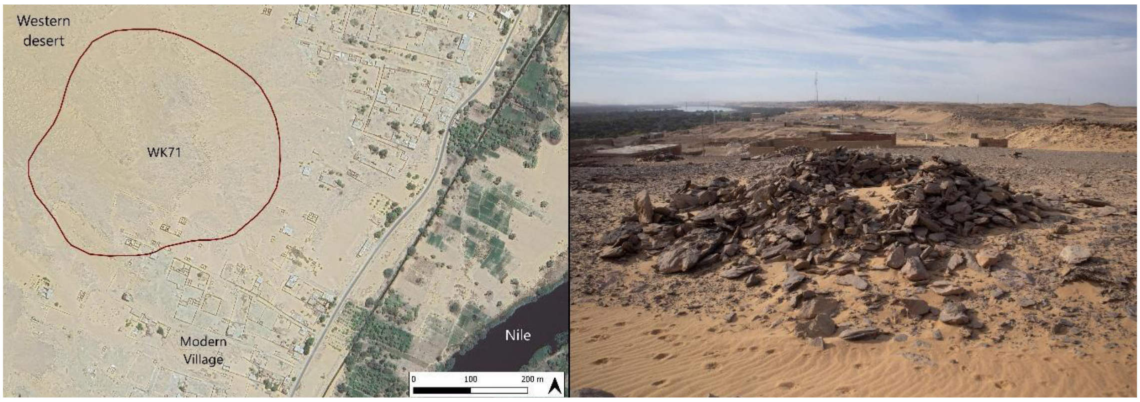

Fig. 3: (On the left) Location and extension of WK71. Example of a tumulus from WK71 showing the overlooking position of the site

Initial investigations suggested a preliminary Roman-period chronology for these structures, though they had not been extensively documented. During the 2022 field season, 38 stone features were recorded, showing little variation in morphology and orientation. Most of these structures are located on the eastern side of the relief, with only two isolated examples found to the west of the main site. They consist of stone slabs quarried from the local bedrock, arranged in subcircular formations. Their diameters range from 2 to 7.5 meters, with a maximum height of approximately 0.60 meters (Fig. 3).

In both NH11 and WK71, the high visibility of the archaeological features in satellite imagery and on the ground greatly facilitated preliminary documentation and planning for 3D recording. However, these same conditions have also made the sites vulnerable to looting and other destructive activities over the years, often compromising their integrity. This ongoing threat underscores the urgency of promptly documenting both sites before further damage occurs.

3. Acquisition and processing methods

3.1 Remote sensing

Two team members completed the entire project in approximately two weeks, organizing the work into four operational phases:

1. Preliminary observations using remote sensing
2. 3D recording of the structures and field annotations
3. Post-processing of 3D data and measurements
4. GIS mapping and analysis

The satellite-based investigation of the two sites was conducted alongside other project activities during the first week of fieldwork. This step was crucial for generating preliminary documentation to support the ground-level survey. Key attributes such as the number of structures, their average dimensions, orientation, shape, and position were imported into a Quantum GIS (QGIS) project.[6] A selection of base maps was integrated,

[6] https://qgis.org/

ranging from widely used datasets like Bing Maps and Google Earth to more specialized resources such as the Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Map (ASTER GDEM) open-access repository.

Bing and Google imagery, which provide composites of Very High Resolution (VHR, <1m/px) RGB raster files from various sources (Earthstar Geographics SIO, Maxar 2023, Landsat 8 NASA, IKONOS, QUICKBIRD), were sufficient for detecting and analyzing the spatial distribution and general morphology of the structures. However, ASTER GDEM's lower spatial resolution (>15m/px) allowed only for broader landscape evaluation.

To mitigate georectification errors inherent in non-professional mapping sources like Bing and Google[7], additional manual adjustments were required to ensure proper overlay alignment before analysis. In the NH11 and WK71 areas, the Bing Map tiles provided more accurate location and projection data than Google Earth tiles. However, Google Earth imagery had superior color and pixel resolution. To optimize both accuracy and visual clarity, the remote sensing analysis was conducted using Google Earth tiles reprojected onto a Bing Map base layer.

3.2 Photogrammetry

Building on the preliminary results from remote sensing analysis, the fieldwork was initiated, structured into four distinct operational sub-phases. The first step involved verifying satellite-detected features on the ground. This process was crucial for distinguishing genuine archaeological anomalies from modern disturbances. Notably, most of the features identified in satellite imagery corresponded accurately to the findings observed onsite. Simultaneously, new descriptions and measurements of the structures were recorded and integrated into the archaeological database. Special attention was given to assessing the degree of preservation and documenting the presence of surface materials associated with each structure.

Following traditional archaeological documentation, 3D recording of the main archaeological features was conducted using either a Canon M50 Mark II reflex camera or an iPhone 11 Pro smartphone. The mobile application Scaniverse (www.scaniverse.com), available for iPhone and iPad via the Apple Store (www.apple.com), was tested for this research. Our team selected Scaniverse over other similar apps primarily because it operates entirely offline, utilizing the iPhone 11 Pro's A13 Bionic chip (Apple, 2019) for both Graphics Processing Unit (GPU) and Central Processing Unit (CPU) processing. This offline functionality allows for on-site scanning without reliance on internet connectivity. Despite not using external servers or cloud computing platforms, Scaniverse can generate 3D point clouds and high-resolution textured meshes within 5 to 15 minutes. Another key advantage of Scaniverse was its compatibility with Apple devices, which AKAP has previously relied on for their durability, reliability, and portability in hot and harsh desert environments. These factors made Apple devices the preferred choice for this type of survey.

Scaniverse offers scanning options based on photogrammetry and, when available, laser measurements. While all Apple devices from the iPad Pro 2020 and iPhone 12 Pro onward feature built-in Laser Imaging Detection and Ranging (LiDAR) cameras, our study relied solely on photogrammetry-based functions, as we used an iPhone 11 Pro. The Structure from Motion (SfM) algorithm processes frames from a real-time video captured

[7] Youngu *et al*. 2022.

by the phone's front camera (typically the highest-resolution camera). It then calculates depth masks and generates digital surfaces (meshes) of the scanned object or scene. A key feature of Scaniverse is its ability to embed and preserve GPS, gyroscope, and accelerometer data, allowing for rough positioning and georeferencing of the models.

Scaniverse provides three object size presets for calibration:

- Small (<1m)
- Medium (≈1–4m)
- Large/Area (several meters)

During scanning, the app uses Augmented Reality (AR) to guide user movements and acquisition. A real-time video frame overlay provides progressive visualization, enhancing resolution while employing false-color or blurred overlays to highlight the scanned object's structure. More details on this functionality can be found at Scaniverse Support.[8]

Once the video-based acquisition is complete, the point cloud can be optimized before processing the 3D mesh. Scaniverse offers three processing modes:

- Speed – Uses a basic Depth Fusion, providing a fast but less accurate result.
- Area – Employs an advanced Depth Fusion, balancing accuracy and processing time (a few minutes).
- Detail – Based on Photogrammetry/SfM, producing the most accurate model but requiring the longest processing time.

The scan's raw data (video-derived images and point cloud) can either be saved or deleted, but only the point cloud can be exported. The final texturized model can be visualized in Virtual Reality (VR) or as an Augmented Reality (AR) scene within the app. Scaniverse also allows users to measure, edit textures, create video clips, and export 3D models in multiple formats (FBX, OBJ, GLB, USDZ, STL, PLY, LAS).

On April 20, 2024, Scaniverse introduced an update featuring Gaussian Splatting, a volume rendering technique that visualizes 3D objects without converting them into surface or line-based representations[9]. This update significantly improved AI-trained photorealistic rendering, particularly for shiny or transparent surfaces. Users can also reprocess older scans using Gaussian Splatting, provided they have retained the raw data—though this replaces the original texturized mesh, as the app currently lacks a duplicate scan feature.

The average time required to scan and fully process each stone structure at NH11 and WK71 was approximately 10 minutes. Despite the advantages of mobile 3D scanning, this technology remains relatively new and requires careful data acquisition (including metric, georeferencing, and orientation redundancy) and rigorous archiving (with enhanced annotations and measurements). To ensure accuracy, each structure was scanned with multiple references (e.g., scale bars, north arrows).

Since the phone's internal gyroscope lacks the precision needed for vertical orientation, manual verification and correction were performed. Additionally, the mobile scans were compared against traditional camera-based photogrammetry and stratigraphic excavation data from one of the NH11 structures (F53). This comparative analysis proved invaluable for assessing resolution, texture quality, and geometric accuracy across different 3D modeling methods (Fig. 4 and see *infra* § 3.3).

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[8] How to use Scaniverse 3D Scanner for iOS and Android https://scaniverse.com/support

[9] Westover 1991

3.3 Data Processing

The camera-based 3D recordings were processed using professional image editing software such as Adobe Bridge and Lightroom[10] to equalize and prepare the images for the 3D workflow. The 3D models were then generated using Agisoft Metashape Pro,[11] a widely recognized software with a robust processing workflow that extends beyond Structure from Motion (SfM). Metashape enables advanced operations such as point cloud and mesh filtering, classification, geo-processing, 2D/3D drawing, and ortho-rectification.[12] The orthorectification function in Metashape is particularly crucial for producing ortho-mosaics (composite orthographic views) of archaeological features. However, since Scaniverse automatically processes footage into 3D data within the app—without the ability to create ortho-mosaics—each model was exported as an OBJ file and subsequently imported and processed in CloudCompare (CC).[13] CloudCompare (CC) is a point cloud editor capable of performing various operations on 3D models, including ortho-projections, making it an essential tool for refining and analyzing the data collected during the survey.

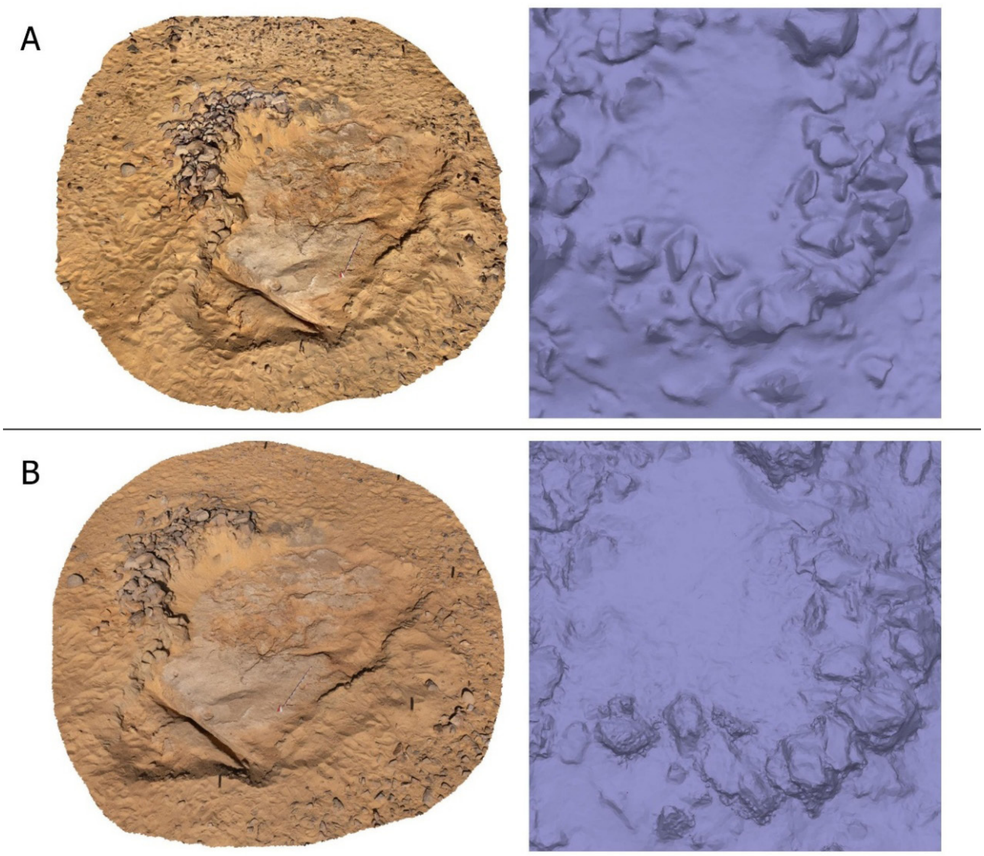

Fig. 4: Structure F53 - Comparison between: A. Model produced using the smartphone + Scaniverse; B. Model produced by camera + Metashape

[10] www.adobe.com
[11] www.agisoft.com
[12] Metashape User Manual (https://www.agisoft.com/downloads/user-manuals/; Gonzàlez-Quiñones *et al.* 2022.
[13] www.danielgm.net

3.4 Mapping and drawing into the GIS

The resulting ortho-images were then imported into QGIS for vectorization and subsequent spatial analyses. Due to the relatively simple morphology of the stone structures, ortho-rectification of the models was unnecessary, as exporting them as orthographic top-view images did not introduce any significant metrical distortions. This is because our tumuli are not characterized by significant reliefs (data along the Z axis) in relation to their planimetric shape (data distributed on the X, Y axis), a condition that keeps errors between the 3D projection of the object on the bidimensional plan or its view from above, equal or less than 1cm (so largely within our range of accuracy). This approach provided a reliable dataset of raster images, which were then vectorized and exported as shapefiles for further geospatial analysis. However, due to discrepancies between the spatial accuracies and coordinate reference systems (CRS) of the satellite images and the model-derived ortho-images, it was necessary to override the embedded location data of the ortho-images. To correct this, satellite base maps were used as a reference. This georectification process was carried out using the QGIS Processing Toolkit along with the Freehand Raster Georeferencer plugin, enabling the graphical alignment of all documented data.

All ortho-images of the structures were carefully vectorized as polygonal shapefiles, and the associated database was populated with archaeological and metric information. The integration of satellite data with fieldwork observations enabled a comprehensive documentation and description of the majority of structures at both sites. Finally, within QGIS, various spatial analyses were conducted, including distribution and density evaluations of the structures. These analyses facilitated the creation of detailed graphic layouts and maps, enhancing the overall interpretation of the sites.

4. Results and Conclusions

The main goal of our paper is to describe and share the results of our field experience, which focused on documenting stone structures using app-based and non-Structure from Motion (SfM) recording techniques, while combining the data with GIS. During the experimentation, we gathered a series of technical and methodological insights, as well as identified advantages and disadvantages.

Firstly, the combined use of satellite analyses and SfM recording allowed us to promptly complete the documentation of 140 stone structures (102 in NH11, 38 in WK71) and the excavation of Feature 53 at NH11. Secondly, the preliminary use of remote sensing enhanced the effectiveness of our fieldwork by quickly gathering diverse information about the topography, landscape, and structures. In less than two weeks, we processed, validated, and organized all data from satellite readings and analyses, as well as topographic and photogrammetric recordings.

The mobile and camera-based 3D documentation of the structures allowed us to enrich the archaeological dataset and enabled comparisons between the two recording approaches. The acquisition time, influenced by the dimension and complexity of the structures, was almost three times faster using Scaniverse compared to the reflex camera. The larger image format of the DSLR camera (6024x4020 pixels) facilitated the creation of more accurate geometries compared to the iPhone 11 Pro camera (2436x1125 pixels). This higher resolution is also reflected in the difference between the point cloud counts of the two recording and processing approaches: Feature 53 scans showed a camera-based point cloud count of 700,000 versus a Scaniverse-based count of 170,000 points. Consequently, the meshes generated also differed in resolution (about 1,000,000 faces versus 350,000). Differences were also noticeable in the texture: those produced by Scaniverse can achieve a maximum of 8k resolution, while the camera-based models always attain higher definition (thanks in part to the Metashape texture count tool).

In our case studies, the reduced resolution of mobile recording did not affect the visibility and interpretation of the archaeological structures, but it could represent a significant obstacle for documenting evidence with a high degree of detail and complexity (e.g., rock art panels, very small objects, etc.). Additionally, favorable environmental brightness and the almost complete absence of undercuts were advantageous conditions for performing the 3D recording. It would have been a different issue if the goal was to investigate highly detailed surfaces, such as depicted/carved rock art or inscriptions, and tiny decorated objects. Based on these results, the Scaniverse models generally show a resolution loss of about 70% compared to standard SfM models (Tab. 1).

Stratigraphy	**Software (Vertices / Faces)**	
	Camera-based / Metashape	**Mobile-based / Scaniverse**
Surface meshes	ca. 502.360 / 1.000.000	ca. 110.703 / 220.785
Layers 1-2-3 meshes	ca. 965.226/ 1.929.640	ca. 160.895 / 321.196
End of Excavation meshes	ca. 720.080 / 1.439.627	ca. 176.100/351.977

Tab. 1: Comparison between model mesh resolutions in F53 excavated layers

An interesting option offered by Scaniverse is the ability to generate 3D models immediately after acquisition onsite, enabling a rapid check of the quality of the geometries (Mesh). Furthermore, like other similar apps, Scaniverse allows for the automatic calculation and embedding of metrical information, GNSS positioning, and geographic orientation with sufficient accuracy (at least for our type of structures and landscape). Nonetheless, we included metrical references such as scales and a north arrow in each recording scene to ensure redundancy and provide a backup control for the measurements.

This study also led to the identification of essential improvements and new functions for future applications in archaeology that are currently unavailable in the app:

1. Exporting pictures/video frames in raw formats (not only as points cloud);
2. Processing and exporting models in batch;
3. Enabling background mode processing;
4. Creating an ortho-rectification function within the software.

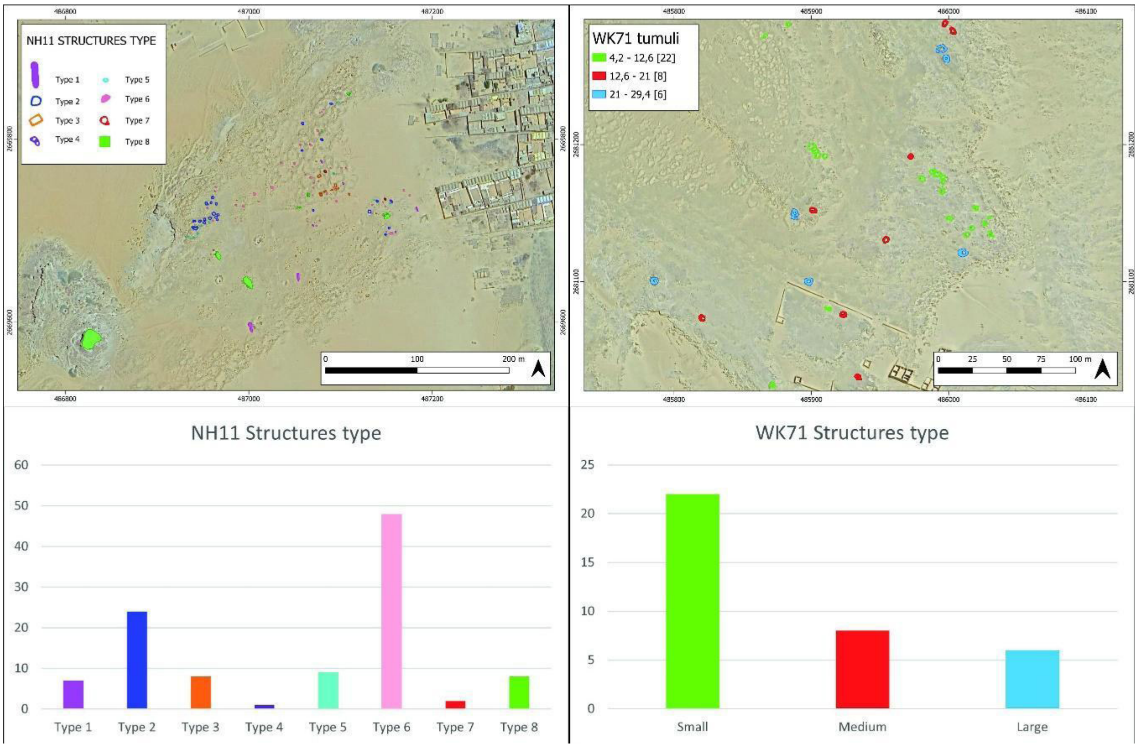

Fig. 5. (On the left) Morphological classification of stone structures at NH11 and their spatial distribution. (On the right), Dimensional classification of stone structures at WK71 and their spatial distribution

QGIS was a very convenient choice to combine and manage all the data within the same environment, as it allowed us to easily integrate, process, and classify the features by morphologies, dimensions, positions, and densities. At NH11, we identified eight morphological classes (Fig. 5): subcircular ring, square ring, double ring, small ring, ring with accumulation, elongated shape, round accumulation, and amorphous accumulation. From a dimensional perspective, no significant differences were found at NH11 between the documented stone structures within the same morphological category. Conversely, in WK71, the main classification is determined by dimension (Fig. 5): small tumuli (ca. 4-8.9 m^2), medium tumuli (ca. 9-13.9 m^2), and large tumuli (ca. 14-29.4 m^2). They could also be classified based on their position: most mounds are concentrated on the central plateau, with only two stone structures isolated on the western side of the site.

Throughout our work at the NH11 and WK71 sites, we observed that using smartphones to document large archaeological structures is a reliable and functional strategy, especially for endangered sites and challenging work conditions. By the end of the field mission, we were able to properly document two large areas without the need for advanced and professional topographic and 3D scanning equipment (such as Laser Scanners or UAV systems) and leave the field with sufficient data already processed and ready for archiving and publication.

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Online Resources

AKAP	www.akapegypt.org
Rock Art Site of Nag el-Hamdulab	https://www.akapegypt.org/media/AKAP_NH1_DIB/index.htm
QGIS	https://qgis.org/
Scaniverse	https://scaniverse.com/support
Adobe	www.adobe.com
Agisoft Metashape	www.agisoft.com; https://www.agisoft.com/downloads/user-manuals/
Cloud Compare	www.danielgm.net/cc/