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Relighting Egyptian Rock Art: Rapid, Accurate HD Imaging of Prehistoric Petroglyphs

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Abstract

Within the framework of the project “Tracing Palaeolithic Aurochs: Rock Art Survey in Upper Egypt”, financed by the National Geographic Society, the authors participated in the long standing tradition of Belgian rock art research in Egypt. Under the direction of Dr. Dirk Huyge, extensive stretches of rock formations along wadi's in the Eastern Desert between Edfu and Kom Ombo were surveyed in October-November 2014 for the presence of more prehistoric rock art sites, similar to the ones already discovered and studied by the Belgian team in this same region at Qurta and el-Hosh (Huyge et al 2007, 2011, 2012; Huyge 2009). This contribution focuses uniquely on a new component introduced to the 2014 mission: the development and testing of HD imaging techniques for rapid and accurate field recording of the sites with petroglyphs. Multi-light reflectance and 3D photogrammetry techniques were tested on their reliability and operability for a survey in the field.

Keywords: Rock Art, Prehistoric Art, Predynastic Egypt, Digital Technologies, Documentation Techniques, Reflectance Transformation Imaging, Photogrammetry, Structure from Motion (SfM)

Three wadi's cutting through the Eastern Desert were selected for the 2014 survey mission, the large Wadi Abbad, with its source area in the Red Sea mountains, and the much smaller and shorter wadi's Abu Zuru' (WAZ) and Zayd (WZ), that drain only the Nubian Sandstone plateau immediately east of the Nile valley. These were surveyed on a distance of maximum 20 km from that Nile valley. The aim was to find, identify and record all rock art

sites within the survey zone. The possibilities for immediate documenting and recording through on the spot imaging of these sites is the main object of this communication. In addition, the petroglyphs already studied at the sites of el-Hosh and Qurta were revisited for further imaging documentation.



Fig. 1: Map of Egypt and detail of the surveyed Wadi's (in red), in yellow the sites of el-Hosh and Qurta.

1. Recording rock art during a survey

When surveying and recording rock art sites in the Egyptian desert, several specific issues should be taken into account. First of all, the conditions and locations in which the Belgian mission surveys rock art must be regarded as harsh: the environment is dusty, temperatures rise easily towards 40°C, the sunlight is very bright and access to most sites is difficult due to the rocky surroundings and/or their remote location, in many cases only to be reached on foot. Old and new registration methods need to take this into account. In addition, the remoteness of the sites in combination with practical and security imperatives, makes it impossible to record these sites after dark. This would have significantly increased the quality of the results, especially with regard to the multi-light reflectance imaging approach.

During the expedition, around 85 km of desert tracks were surveyed by a team of 3 to 5 people. In most wadi-systems, only the first few kilometres could be covered by car, the rest was done on foot, along steep slopes, climbing over both small and large rocks and crossing ridges. Such specific field conditions require recording methods that use light weight equipment.

Another important element is time. Systematic rock art surveying in such an environment is very time consuming. In order to cover as much ground as possible and at the same time

document as much as possible, the time investment in survey and in recording should be balanced.

A third main issue is the standard of accuracy and objectivity of the documentation which can or should be obtained during a survey. Since graphic documentation is the heart of the recording process, this standard must be set as high as possible. The whole Upper Egyptian region is currently highly threatened by large-scale quarrying and mining operations, land reclamation, large-scale fertilizing projects and the implantation of a huge industrial infrastructure. Moreover, because of newly constructed roads across the Eastern Desert and the intensification of 4WD off-road traffic, human presence at the rock art locations has substantially increased during the past few years. In some occasions, this has already led to deliberate vandalism and even destruction of rock art panels (Huyge 2015; Storemyr 2012a, 2012b; Curci *et al.* 2012). Therefore, once a new rock art site is localized, accurate, systematic and objective registration of that site must be the immediate focus and is for the above-mentioned reasons of the utmost importance. Digital technologies, such as the here explored photogrammetry and reflectance transformation imaging, in combination with traditional methods, can significantly reduce the time which is needed to properly document a rock art site and help to reach these goals.



Fig. 2 – Left: Traditional hand tracing of a Predynastic rock art panel (site: WZ08) surveyed and recorded in the Wadi Zayd; Right: same panel in a 3D model post-processing phase based on photogrammetry (blue rectangles are the estimated camera positions during the recording phase – Software Photoscan), © Belgian Archaeological Mission to ElKab.

Good and efficient recording techniques are key for the preservation and future study of rock art. As such, rock art recording has necessitated the use and development of techniques which give rapid and objective (photography with mirror/oblique lighting), easy to obtain (rubblings) and highly accurate (direct tracing) results. At the same time, mostly due to the circumstances of the particular location, non-rapid, subjective, inaccurate and time consuming techniques stay in practice as well, such as scale drawing or tracing from conventional photographs. A fair conclusion should always be that all approaches pose relevant limitations. The challenge lies in finding an approach, not necessarily combined in one single all including technique, but rather a documentation attitude, which chooses an ad hoc set of techniques, appropriate to the factual situation of every individual site. This fits in the imperative of archaeological recording, in which all interpretations afterwards are based on the initial documentation and for which these wisely differentiated registration techniques should be able to address present and future research questions (Renfrew & Bahn 2004, 115, 118). Finally, another aspect to focus on is the question of how easily applicable the techniques are in the field when they have to be implemented by rock art

specialists themselves. Generally, the engineers who developed a new approach are not the ones conducting surveys in a remote desert area.

2. Digital Imaging Technologies: Photogrammetry and RTI

One of the main recurring limitations of conventional documentation techniques is the 2D outcome of what originally is three-dimensional. 2D+ (RTI) and 3D (photogrammetry) models can both partly or extensively overcome this disadvantage (Fiorini *et al.* 2011; Mudge *et al.* 2012; Curci *et al.* 2012; Olsen & Bryant 2013, 22-35; de Reu *et al.* 2013). But, as stated above, the principle goal of the introduction of digital recording technologies is adding new possibilities to the arsenal of documentation techniques, and where several of the applied techniques document the same details, this must be seen as part of an intentional diversification in the documentation process (Curci *et al.* 2012, 78).

Below we will focus on two digital aids that we applied as additional recording techniques during our survey in the Egyptian Eastern Desert between Edfu and Kom Ombo. A full frame sensor Nikon D800E (36MP) was used for the acquisition of data in both approaches. H-RTI works with a completely freeware software solution (RTIbuilder 2.0.2 & RTIViewer 1.1.0); for photogrammetry, several paid-for and free software packages are available, we primarily used Photoscan by Agisoft.

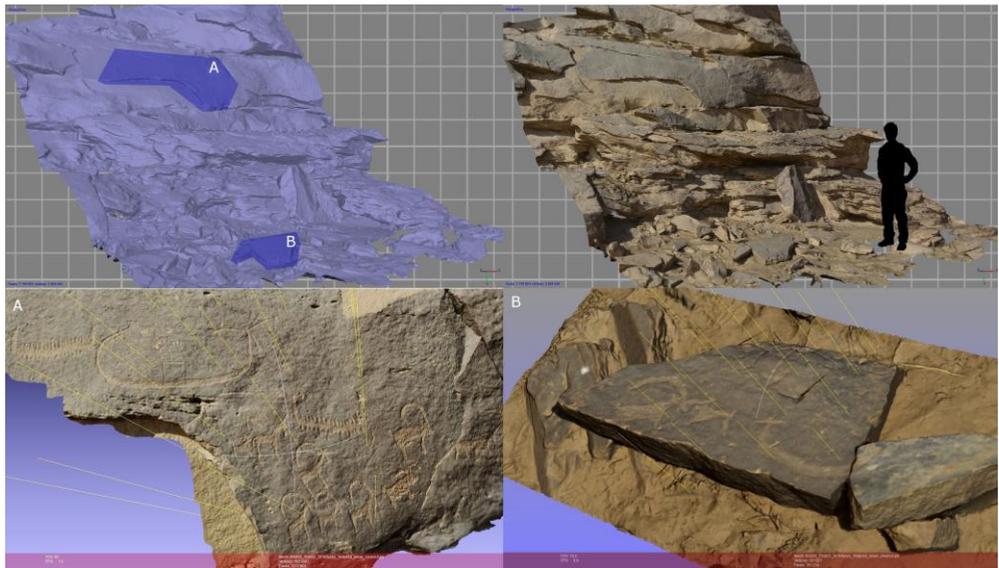


Fig. 3 – Textured photogrammetric 3D models: Rock art documented in its present physical environment (site: WAZ05). Above: A photogrammetric 3D model based on 147 images; to the left in *solid* view, to the right with *texture* (calculations with Photoscan). Below: Two details calculated with a series of images of the same data set as the 3D model above; to the left the main but fragmented Predynastic rock art panel, to the right two pieces of the original panel found at the base of the rock face (screenshots from MeshLab, yellow lines indicate the lighting angle), © Belgian Archaeological Mission to Elkab.

- **A. Photogrammetry**

Structure from Motion (SfM) Photogrammetry – three-dimensional image-based modelling – presents itself as a low-cost, non-intrusive documentation method. In short, by making a sequence of photographs of a surface, all taken from a different angle and position towards that surface, a data-set (# pictures) is acquired. The subject and the light source(s) are static, the camera positions the variable. The changing characteristics on these images of this data-set is used to calculate and estimate the relief (topography) of what has been photographed by comparing one image with the next. Such a sequence of pictures has to be taken in a particular order, not randomly (Fig. 2).

For a fast and fairly accurate (Stal *et al.* 2012) registration of rock art, photogrammetry has become a well exploited method, which has proven its value on many surface types and in many environments (Bryan & Chandler 2008; Plets *et al.* 2012; Rabitz 2013). Despite excellent results by laser & structured-light scanners and imaging stations, photogrammetry lends itself perfectly for the registration of rock art in their natural settings because of its low-cost (one camera and the choice between free or inexpensive software), the easy and fast acquisitions (5-10 minutes per setting) and the ultimate resulting multifunctional metric data. The flexibility of the technique allows to capture both small details and large surfaces in one and the same retrieval sequence, which can afterwards be processed into a single high-definition model and/or several separate ones (Fig. 3; 3D models: compare Fig. 8 & 9).

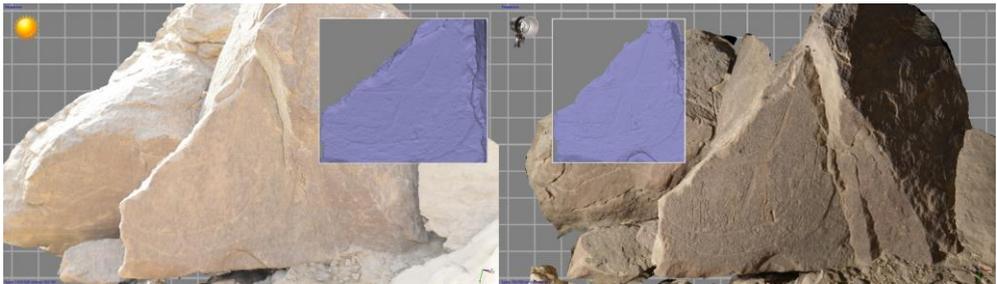


Fig. 4 – Textured photogrammetric 3D models of a Predynastic rock art panel at el-Hosh (site: GYU-KING). Left: The panel under natural lighting conditions (8:01h a.m., 15 November 2014); Right: The same setting illuminated with a flashlight from the left, some minutes later. In the cut-outs these same 3D models, in solid view mode in Photoscan, to demonstrate the much better detection of the topography when the flashlight is used. © Belgian Archaeological Mission to Elkab.

Acquiring a sequence of pictures of a newly surveyed rock art surface is done with the lighting conditions at that given moment in that specific place. However, experience teaches us that these natural conditions only exceptionally allow for the characteristics of interest to be properly visualized. As photogrammetry results in a 3D model, based on the variations detected between raster images, the quality of this model will increase depending on a better and higher contrast between the primary details (i.e. the rock art) and the secondary features (i.e. flat zones or the natural rock surface). Therefore, in some occasions we positioned a static flashlight with the most optimal oblique angle of illumination towards the rock art. In our opinion, the extra equipment weight of such a flashlight (we used the Jinbei FLII-500, see Fig. 5: the black storage case) is justified by the clearly improved results (Fig. 4, 3D models: Fig. 10 & 11).



Fig. 5 – Recording a medium sized panel with Palaeolithic rock art at Qurta (QI.3.1) by applying the highlight RTI method, Equipment: static camera on tripod, two reflective spheres mounted on tripods, a mobile flashlight and fixed distance measurement with rope; at least two people, © Belgian Archaeological Mission to Elkab.

- **B. Highlight RTI**

As for the effort of direct tracing on polyethylene sheets, H-RTI's (Highlight Reflectance Transformation Imaging) were made for key rock art panels or particular details (Fig. 6) only. This technology uses the changing lighting conditions – artificially simulated during the recording process with a flashlight (Fig. 5) – to reconstruct the surface characteristics with great detail (per pixel). In this approach the subject and camera position are static, the light source is the variable. This method has already been successfully applied in rock art research for several years (Díaz-Guardamino & Wheatley 2013; Mudge *et al.* 2006, Mudge *et al.* 2012; Olsen & Bryant 2013; Duffy 2013: in particular case studies 2 & 3). But, from a survey point of view, these methods require a much higher number of pieces of equipment to carry and the recording effort itself is more labour-intensive (+1h per recording) than the photogrammetry technique discussed under point A.

The result remains a flat 2D representation of a 3D reality. However, the interactive component, in which the surface virtually simulates the reflection from light coming from any requested direction, and the many enhancement filters, permit a study as detailed as the definition of the handled camera allows. The setup of this method is relatively independent from the natural lighting conditions; very bright sunlight is overridden by the flashlight (Jinbei FLII-500). For a survey in which documentation takes place immediately following the localisation – so without knowing in advance what the conditions will be on the rock art surface – this is a significant advantage. In estimating the luminous intensity needed for the light source, we tested for survey purposes the much lighter hand sized Nikon Speedlight

SB-900 and compared the results of the Jinbei FLII-500 with battery power pack (Fig. 7). Beyond all doubt, the more heavy and larger FLII-500 is indispensable for adequate results.

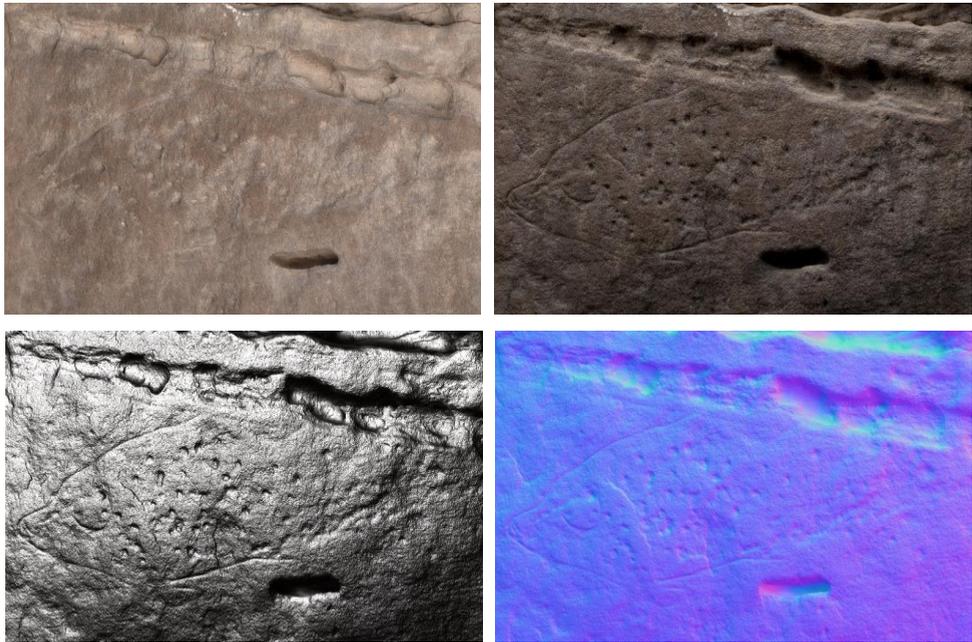


Fig. 6 – Four differently lit and visualized RTI's of a Palaeolithic representation of a Nile perch; detail of the Qurta III.1.1 rock art panel, © Belgian Archaeological Mission to Elkab.



Fig. 7 – Comparison of the use of two different light sources to establish the most suitable approach in the field for the use of the Highlight RTI technique in open air. Both figures visualize the same Predynastic panel at el-Hosh (site: GYU-KING). To the right, a much brighter, but more heavy flashlight on battery was used. The left example demonstrates the result with a less bright, but lighter in weight, speedlight. The normal map shows how the speedlight produced insufficient power to detect all the characteristics of the rock relief, arguing for the usage of the flashlight on battery, © Belgian Archaeological Mission to Elkab.

3. Conclusions of the field work

As stated above, a whole array of different recording methods and approaches exist in the scope of rock art research, each one of them with their own specific advantages and limitations (Loendorf 2001). Traditional recording techniques such as direct tracing can be very demanding in terms of labor and time. It may take several days to complete the tracing of entire panels, which also increases the probability of introducing errors into the drawing and of damaging the rock surface by successive removal and reapplication of the plastic recording sheets. Optimal lighting conditions are needed in order to identify the different motifs in elaborate panels and to distinguish important details such as superimpositions; some rock art may only be visible at certain times of day. Moreover, direct tracing can be extremely difficult due to specific site contexts (i.e. when the art is situated on the ceiling of a cave or a rock shelter) and can potentially be harmful to the art, certainly in the case of rock paintings. However, when done by a skilled artist or experienced recorder, direct tracing may still yield the most accurate and detailed record. When the act of direct tracing is performed by a researcher (instead of a professional draftsman) it forms part of the study and interpretation process of the recorded rock art. Although the final product will always be subjective in nature, the outcome of direct tracing is certainly the result of intense scrutiny. Whereas an objective recording method is no more but a starting point.

Therefore, the fundamental question in the use of digital imaging technologies is whether or not they have an added value. For many research fields, both photogrammetry and RTI have. Our goal was applying these imaging techniques and evaluating them in the light of their usage during a rock art survey in a desert environment. In that regard the SfM photogrammetric method proved to be – by far – the most useful. First of all, it provides the welcome added value of being able to register and image both all physical aspects of the rock art and its surroundings in one 3D representation; information which is registered only to a limited and/or selected extent when traditional documentation approaches are being applied. This allows the rock texture and preservation state to be recorded, as well as the positioning of the engravings in regards to the rock surface. Secondly, the method is adapted to a survey framework. As photography is nonetheless part of the standard documentation effort, the little time-consuming photogrammetry is easily enclosed in this procedure. From the same perspective, the cameras used for conventional photography can be used for photogrammetry as well, which limits the required documentation time per rock art site. In addition, as SfM photogrammetry stitches the separate images together for the texture reconstruction of the 3D models, the results allow high-quality representations of large and complex surfaces. In theory, there are no limitations as to the dimensions or shape of these surfaces, however the physical realities of the terrain remain restricting factors within the context of a survey.

Highlight RTI delivers the most faithful images since no stitching or camera alignments by software are needed, which eliminates erroneous processing of details. When executed well, this method always gives good results. However, one of the important limits of this technique lays in the ratio: size of rock art panels vs. size of resolution of the light sensor in the camera. As already mentioned, H-RTI does not stitch images together. What was framed during the recording phase is the maximum area size in the resulting 2D+ image. When the available resolution of the camera is focused on a small coin, this gives a large number of pixels per actual mm on the original surface. But when applied on large rock art panels, that

same resolution has to be spread on a surface of meters, instead of centimeters. To overcome this, many overlapping H-RTI recordings have to be made of one and the same panel (all to be viewed separately), or the resolution of the details of the imaged panel will be low. We used a camera with a 36.3 MP light sensor, but for area surfaces of +3m² we valued the resolution for rock art documentation as too low. A second, and within the survey context foremost, disadvantage is the heavier equipment load and the labor-intensiveness of the H-RTI method required by its implementation in the field.

Based on the practices and experiences built up during our survey in Autumn 2014 in the Eastern Desert between Edfu and Kom Ombo, the strategy of the Belgian mission is to continue the use of photogrammetry for a maximum number of surveyed rock art site. When it comes to H-RTI, this technique will be used for key rock art panels and/or panels that are problematic to interpret and/or document. To facilitate the surveying itself, photogrammetry can be used in a first line documentation effort (immediately after localization); for H-RTI, on the other hand, it is easier to apply it during a second documentation moment (the day after or later).

Both digital imaging technologies proved to be extremely useful during fieldwork and provide a clear added value for rock art recording. Not only do they expand the possibilities of traditional recording techniques by improving and facilitating the documentation and interpretation of rock art, from its setting or topography to the small details of individual motifs, these technologies also bypass certain practical limitations. Moreover, they provide new possibilities and prospects for future research, such as the production of direct, on-site, vectorial tracings on the basis of the digital 3D-images which considerably enhances the cost-effectiveness of the post-processing of the recorded material.

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3D models

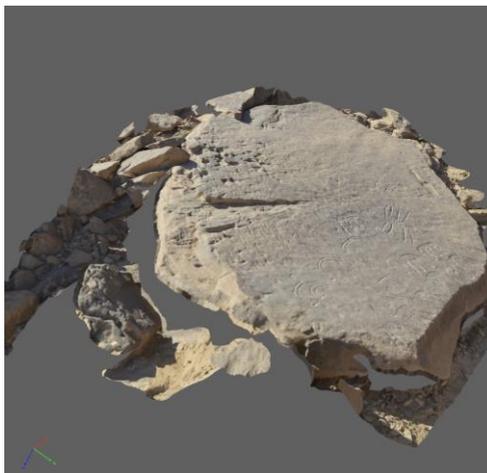


Fig. 8 – 3D model of site WZ08 - Trial 4, rock art panel isolated from its environment (natural lighting conditions), based on 35 images, 5 million faces, this model can be consulted online via <https://skfb.ly/HELw>, © Belgian Archaeological Mission to Elkab.

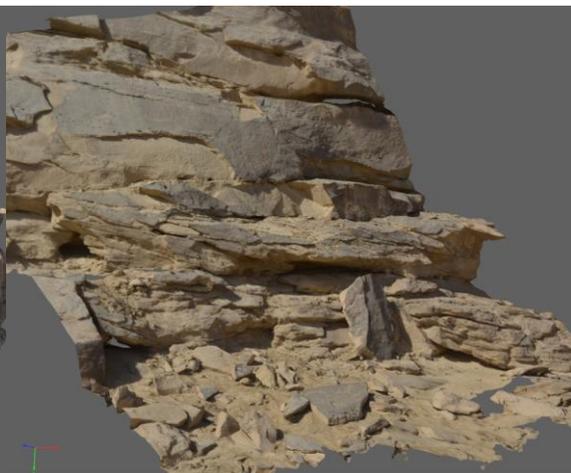


Fig. 9 – 3D model of site WAZ05 - Trial 01, rock art panel and fragments represented in their present physical environment (natural lighting conditions), based on 147 images, 7.7 million faces, this model can be consulted online via <https://skfb.ly/GNuZ>, © Belgian Archaeological Mission to Elkab.



Fig. 10 – 3D model of site GYU-KING - Trial 03 (natural lighting conditions). Model with 736K faces, based on 14 images, this model can be consulted online via <https://skfb.ly/HEME>, © Belgian Archaeological Mission to Elkab.



Fig. 11 – 3D model of site GYU-KING - Trial 04 (flashlight lighting condition). Model with 467K faces, based on 11 images, this model can be consulted online via <https://skfb.ly/HEUC>, © Belgian Archaeological Mission to Elkab.