

## Visualizing Legacy Stratigraphic Data From Archaeological Handbooks

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**Abstract.** In 2001, Harris strongly emphasized the need for Geographical Information Systems (GIS) to force archaeologists to acknowledge the pre-eminent position of surfaces, rather than deposits in stratigraphic analysis and recording. This is certainly a problem since stratigraphic data is often recorded in a haphazard and incomplete fashion such that it disallows the accurate and convincing representation of the original stratigraphic surfaces. This publication looks at the reconstructions possible from current stratigraphic data by recreating in 3D an excavation unit showing the resulting accuracy, and the suitability for the later automatic creation of plan maps. This paper describes the ongoing development of a secondary knowledge creation tool for archaeology, capable of the entry, reconstruction and visualization of stratigraphic layers in three dimensions based on the varying and sometimes incomplete records of the field-archaeologist.

**Keywords:** Visualization, 3D Simulation, Reconstruction, Stratigraphy, Real-Time Rendering for Virtual Heritage, Secondary Knowledge Creation Tools.

### 1 Introduction

A variety of work has been carried out in visualizing stratigraphic relations in two dimensions using the Harris Matrix. In 1990, Herzog and Scollar outlined existing programs for Harris diagram generation and described a system for manually and automatically removing cyclical relationships between layers and detecting errors, for example, the duplication of layers. They indicated the need for extending stratigraphic visualization applications to combine a finds database so that finds can be visualized in the Harris diagram.

In 1990 Boast and Chapman presented a Harris matrix generation program that has the ability to be integrated with other forms of information. Fundamentally they described a database schema capable of storing stratigraphic layers (contexts) in relation to one another allowing significant time savings for archaeologists engaged in the analysis of site records.

In the same year, Desachy and Djindjian presented an approach of building stratigraphic graphs using a simple interactive method of matrix processing. They aimed to reduce the number of crossing lines in matrices to create a new stratigraphic graph with a better formalism than the Harris graph.

In November 2001, Harris strongly emphasized the need for Geographical Information Systems (GIS) to force the archaeologist to acknowledge the pre-eminent position of surfaces, rather than deposits, in stratigraphic analysis and recording. This is indeed a problem since stratigraphic data is often recorded in such a haphazard and incomplete fashion that it disallows the accurate and convincing representation of the original stratigraphic surfaces as described by Green in 2001(a).

During an archaeological campaign, data relating to stratigraphic positioning (SP) is recorded in a variety of ways. The exact practice varies from site to site but generally this data is recorded in a number of ways:

- In individual excavation hand books
- Pre-prepared stratigraphy forms
- With a theodolite.

The widely used practice of analysis and representation of SP is the Harris Matrix approach. This is a valuable technique to analyze and compare 2D SP data. With the advent of cheap and powerful 3D computing, there is a growing need for the archaeologist on site to test hypotheses and gain immediate results. The 3D representation and analysis of this SP data, with the ability to perform real-time hypotheses without prolonged sifting through hard copies of excavation handbooks presents a real innovation to future archaeological interpretation.

In 2001(b), Green presented the development of a stratigraphic visualization tool (STRAT) for archaeological use allows for the importation of highly detailed 3D stratigraphic reconstructions retrieved from image sequences using methods developed by Pollefeys. For complete site visualization, legacy data also needs to be considered and visualized within the same system. Often, the only data recorded for a site is in the archaeologist's personal handbook. The STRAT tool is a stratigraphic entry, visualization, hypothesis testing and query tool being developed by Brunel University as part of the MURALE project using as a test-base the ancient site of Sagalassos in Turkey. The tool is flexible enough to be used at any archaeological dig where layers are excavated. This paper discusses the problems associated with the entry of this legacy stratigraphic data, which is probably the most haphazardly recorded and challenging of all stratigraphic legacy data. Results are presented in the form of screenshots from the recently developed STRAT tool.

In 2001 Bibby presented an approach to increase compatibility and permeability between popular software systems, tested and in active use for stratigraphic visualization.

### 2 Archaeological Notebook Data

For each site on a campaign, a hardbound paper handbook is used for the recording of a variety of archaeological information. It includes a grid drawing with site locations and their relative positions from the origin, the names of the archaeolo-

gists working on that site, Polaroid photographs of each stratigraphic layer with sector and layer numbers indicated, hand drawings indicating the extents of excavation units, textual descriptions of how work was carried out, a list of contexts (finds) for each layer with their unique context numbers, textual descriptions of the layer, hand drawings of the layer with thickness recorded in centimeters and volume of tiles recorded in number of boxes.

At first glance this data can appear disorganized and may require repeated reading to understand. Photographs are not always taken from the same angle so it can be hard to determine which side is north. For the recorded depths of stratigraphy, sometimes the archaeologists average the four depths and give only one depth. On some occasions the extents of the strata are defined, and on other occasions omitted.

### 3 STRAT Forms

Once the archaeologist has excavated a layer they fill out what is known as a STRAT (stratigraphy) form. These vary from campaign to campaign; Harris published one example in 1989. On the STRAT forms developed for Sagalassos the archaeologists fill out the site name, sector number, layer number, archaeologist name, date, page number of plan and photograph. It also contains a section for the layer description that includes space for textual descriptions of the compaction, colour, composition, inclusions and an interpretation. It includes a field for the recording of the thickness and extent of the layer. The final section of the form is used to describe stratigraphic sequence; layers are connected to one another with lines describing their relationship, for example, superposition or original continuity.

### 4 Physical Legacy Data Entry

Test data for entry into the STRAT tool was collated from a handbook used on a previous year's excavation at Sagalassos. Based on pre-prepared stratigraphy forms recorded by the archaeologists, data was compiled for the site of "Theatre Streets West1", located at sector (2560, 2655) on the Sagalassos grid, hereafter known as TSW1. Based on hand-recorded stratigraphy measurements from the TSW excavation handbook made by Martens in 1990, data was then compiled for the same excavation unit.

There also exists a third set of data reporting the height measurements contained within an internal report, which was also collated. This data has been taken directly from the excavation handbook. However this data appears to be more closely related to the data recorded on the STRAT forms. Layers 3 and 4 may have been transcribed incorrectly, because according to the report, the extents are written:

*extent: 1m/2m x 1.70m in the northern part of the trench*

According to the archaeologist, extents are written in the order E/W x N/S. However, for layers three and four, the data for the North and South faces seems to have been swapped with the East and West faces. This would result in a rotation of 90 degrees for the stratum. This highlights problems associated with the duplication of data and of inconsistently writing extents without indication of which side is north. The archaeologist should carefully resolve this, preferably after the day's excavation whilst the site is still fresh in their minds.

### 4.1 Explanation

Typically, one length and width are recorded on a stratigraphy form, but for oddly shaped excavation units, differing lengths are written (for example in layer three where a different measurement is recorded for the east wall than that for the west). Where only one width has been recorded (for example the top width) the figure has been duplicated into the bottom width and vice versa. This is also the case with the length of the excavation unit. A clear picture of the dimensions of which we are interested is provided in Fig 1.

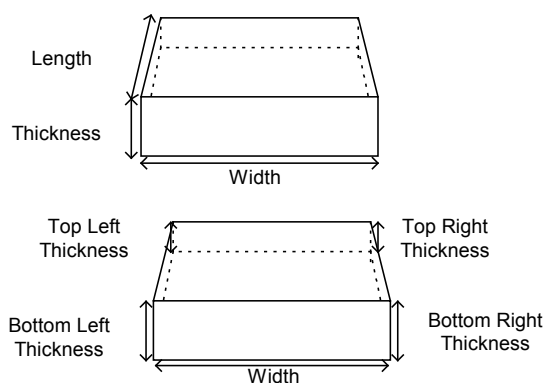


Fig. 1. Strata dimensions

### 5 Recording Errors In Existing Data

Due to the duplication of data that occurs on site and problems that arise by transmitting data between archaeologists by word of mouth, errors in recording occur. This can be clearly seen between the measurements recorded in the excavation handbook compared with the same measurements recorded on STRAT forms, Fig. 2 shows a bar chart indicating the error differences.

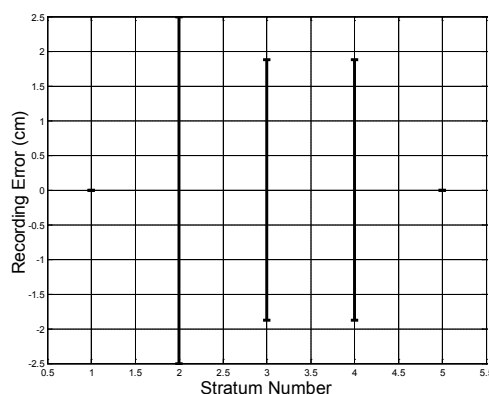
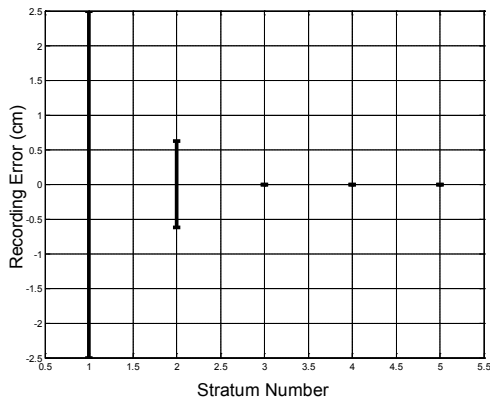


Fig. 2. Strata thickness errors from data recorded on STRAT forms compared with data recorded in the handbook for TSW1, sector 2560/2655.



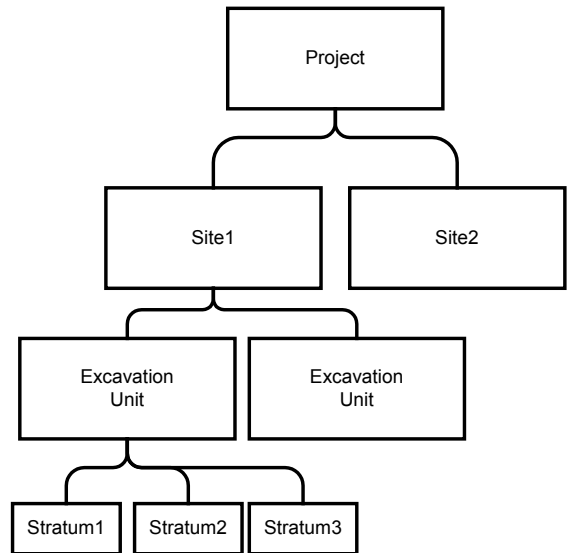
**Fig. 3.** The error between the average recording of archaeological strata and mean average.

Fig. 3 shows how the average recorded by archaeologists in their handbook differs from the computed mean average of the four recorded height measurements. In other words, the archaeologist has made a mental attempt of computing the average of the four depths, which is not mathematically correct. This is of no consequence as long as the four height measurements are recorded. This level of error in recording indicates that the final visualization of our results is only going to be accurate to within several centimeters.

## 6 The System Structure

The archaeological project or campaign is structured in the computer's memory in the STRAT tool hierarchically as illustrated in Fig. 4. At the top level of the hierarchy is the project, which is a generic name for the campaign; this includes the name and abbreviation of the project, for example "Sagalassos" and "SA". A project can include one or more sites, for example, "Upper Agora North" and "Theatre Streets West1". These are clearly defined separate excavations within the campaign. A site such as this then in turn inevitably includes individual excavation units of a fixed width and length of which the archaeologist then begins to excavate on a stratum-by-stratum basis.

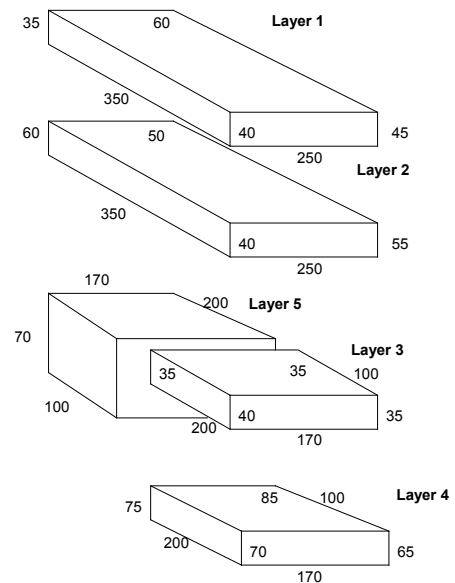
Dialog boxes are provided for the entering of site and excavation unit data, as shown in Fig. 5 and Fig. 7. A site holds a minimal amount of data, the site name, and an abbreviation that is later on used to identify finds. The excavation unit dialog box, allows the user to first pick which site the excavation unit belongs to and they are then asked to enter the offset from the origin at which the excavation unit lies, for example 2560,2600 would indicate an offset of 2560m East of the previously marked-out origin and 2600m South. The extents of the excavation unit are also entered here in metres; a typical excavation unit example may be 5m by 5m. At all times, images are used in the dialog boxes. Simplicity and ease of use is paramount to this system's success because the end-user of this STRAT system is the archaeologist, many of who are not computer specialists. First round testing of the STRAT tool was carried out in Sagalassos, Turkey in August of 2001 with great success.



**Fig. 4.** Project data structure.



**Fig. 5.** New site dialog box.



**Fig. 6.** The TSW1 site showing exploded strata with measurements in centimeters.

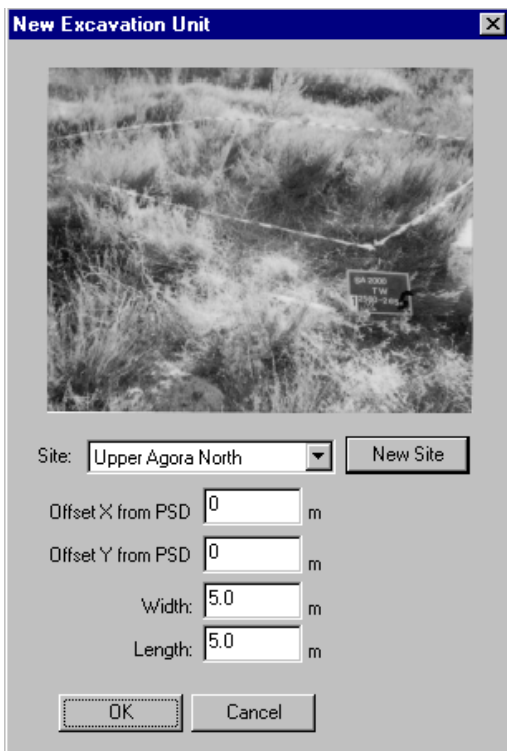


Fig. 7. New excavation unit dialog box.

## 7 Legacy Data Entry Into the GIS System

The point of entry for recording stratigraphic data from handbooks is shown in Fig. 8. By this point, the user should have defined in the system, the site and excavation unit they wish to excavate. These can be selected from the drop down boxes at the top of the dialog, but if the user has forgotten to enter this data, there is a foolproof mechanism which informs the user of the need to first create a site and excavation unit, and subsequently allows them to enter this data; see Fig. 5 and Fig. 7. The user can also enter this data by clicking on the New Site and New Excavation Unit buttons in the top right corner of the dialog.

The layer-number text-field allows the user to enter the number of the layer they are excavating. The program, based on how many layers have preceded it automatically calculates and completes the layer number, but the user can override this. A combination box is used to select the layer that is above the current strata, it is not always the previously entered layer, for example layer five and layer three both share layer two as its parent.

The system now knows which part of the site is being excavated, so the user then proceeds to specifying the dimensions of the stratum. They enter the depths in centimeters at the four corners of the stratum, which can be easily incremented in large or small steps with the adjacent spinner controls. An average depth can be entered which then overrides all previously entered heights. This is used in situations where the archaeologist has been sparing with documenting stratigraphic heights and has only recorded the average. An optional center depth can also be entered. To maintain the integrity of the data, there is a check box control for each recorded height datum marked with the letter “E”. The user checks this control if this data has been estimated, in other words, the data is not the original recorded by the archaeologist but an approxima-

tion used in an effort to reconstruct the scene. This checkbox corresponds to a Boolean value recorded in memory and in the database allowing correct new data to be entered if it is later discovered.

It is often the case that the layer which is being excavated is not of the same dimensions as the layer above, for example, a wall may have been uncovered, in which case the user must enter the new dimensions of the layer. This must be positioned relative to the previous layer by way of locking the stratum to the north, east, south and west faces. Selecting the appropriate radio button control easily does this.

A textual description of the stratum can be entered in the edit control, for example “Layer one is a sandy loose brown soil”. In an effort to make more accurate recordings of stratigraphic layering, an automatic photogrammetric method has been developed. To load a photogrammetric model that will be positioned at the previously defined position, the user clicks on the “Import Photogrammetric model” button at the bottom of the dialog and is then prompted with a dialog allowing them to open a previously recorded 3D computer model of the stratigraphy.

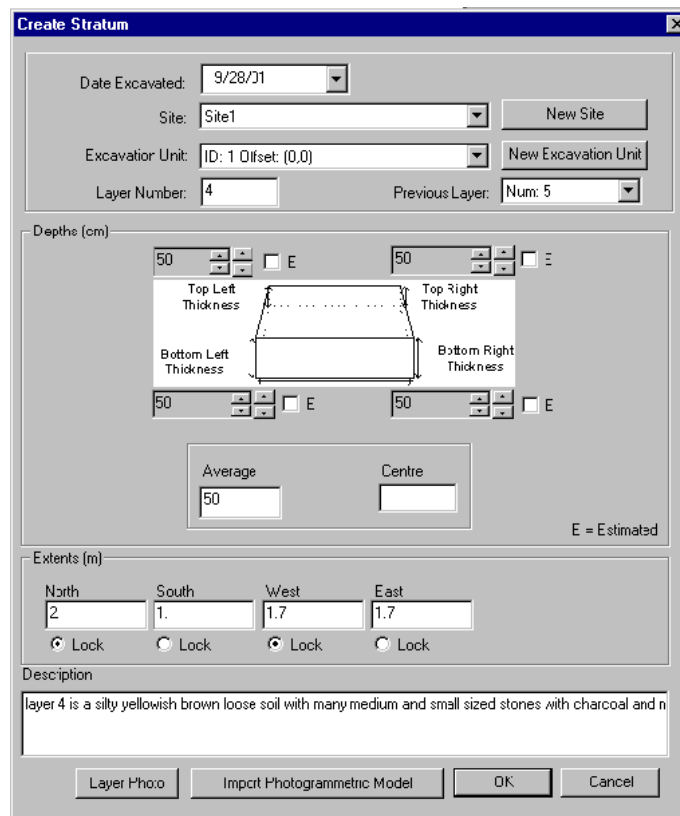


Fig. 8. Legacy data entry dialog box.

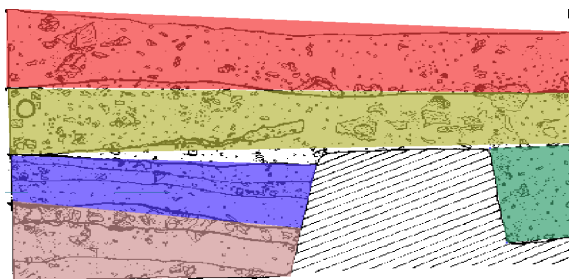
## 8 Visualization

Fig. 6 shows the strata for the excavation unit with measurements in centimeters (Martens, 2000a). Fig. 10 and Fig. 11 show the resulting 3D model of the stratigraphic data for the TSW1 site visualized using the STRAT tool. This data can be easily navigated and magnified. The walls are transparent and the bottoms of the layers are opaque so interfaces can be easily seen. The grid shown is defined in five meter units. It can be seen that the west and east faces of stratum one nearly fits

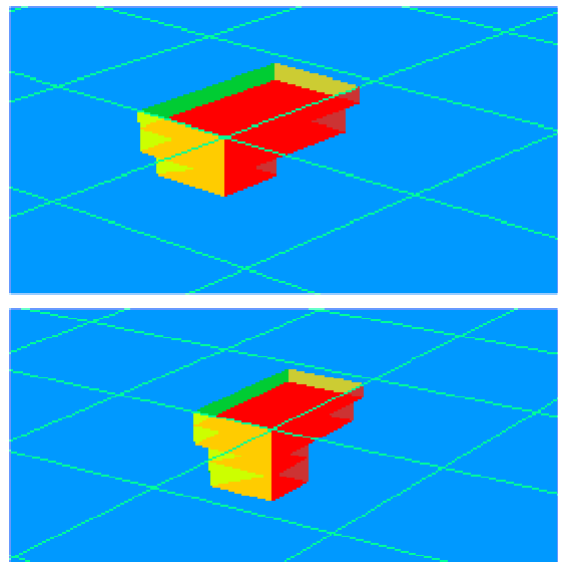
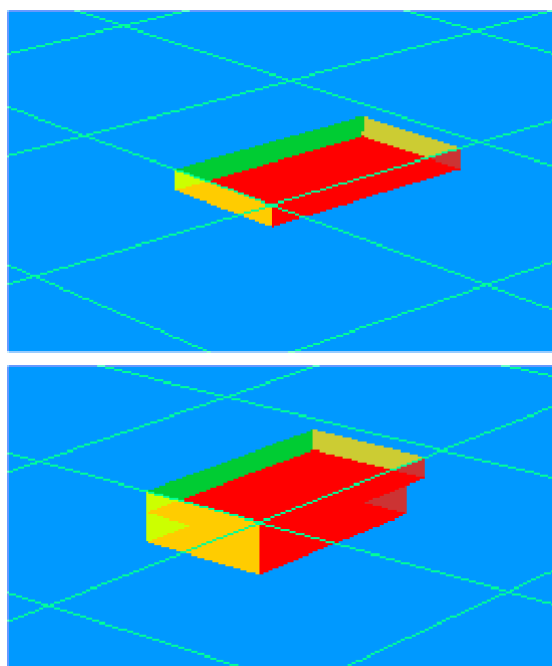
lengthways to this excavation unit, having a length of 4.5m. This grid can be replaced with a topographic map if available. Alternative views are possible in the STRAT tool, viewing from both the top and from the sides. Fig. 9 shows a profile drawing superimposed with a cuboid representation of each stratum. Discrepancies between the cuboid representation and the actual contour can easily be seen in this representation. Fig. 12 shows a 3D perspective drawing of TSW1 with embedded artefacts. If available, reconstructed models of artefacts are visualized, otherwise markers are used with a letter representing the material type.

## 9 Conclusion

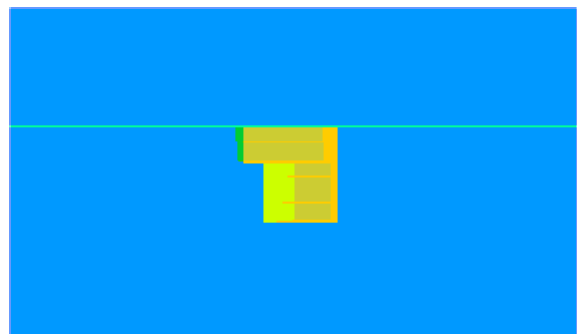
This paper has described a computer-based system for the entry, reconstruction and visualization of 3D stratigraphic layers of the recently developed STRAT GIS system based on the varying and sometimes incomplete records of the field archaeologist. Allowing for the highly detailed models produced with the self-calibrating photogrammetric work of Pollefeys from 1998, a complete reconstruction of an entire archaeological excavation can be made to a level detail that corresponds to that recorded by the archaeologist. During the summer of 2001, the author demonstrated and taught several archaeologists in the use of the STRAT tool at the Sagalassos excavations in Turkey to great success.



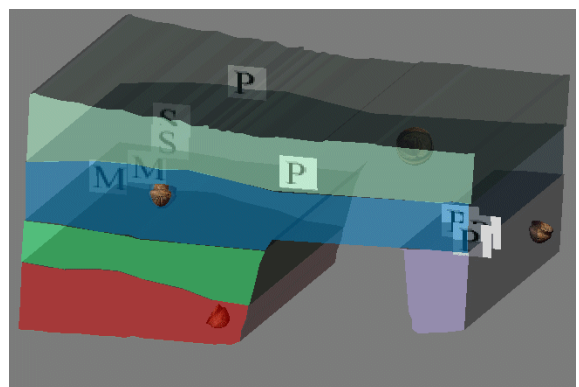
**Fig. 9.** A profile drawing (Martens, 2000b) of TSW1 superimposed with a cuboid representation of the stratum.



**Fig. 10.** Strata 1-4 of the TSW1 site at Sagalassos entered and visualized using the STRAT tool.



**Fig. 11.** A profile view of the excavation unit at the TSW1 site at Sagalassos entered and visualized using the STRAT tool.



**Fig. 11.** A 3D perspective render of the TSW1 site showing embedded artefacts.

## Acknowledgements

3D-MURALE is a European Union funded project (Proposal number: IST-1999-20273). The author acknowledges the help of F. Martens in confirming the accuracy of the compiled data and the archaeologists M. Waelkens and R. Degeest and the support of my supervisor J. Cosmas.

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