AN AFRICAN HERITAGE DATABASE
THE VIRTUAL PRESERVATION OF AFRICA'S PAST

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ABSTRACT:

Many of the important African heritage sites are not well known, in a bad state of repair and poorly documented. Very few are declared World Heritage Sites and even some of those under UNESCO protection are poorly maintained, such as the WHS of Kilwa Kisiwani and Songo Mnara in Tanzania. The population of Africa is largely unaware of the significance of these sites and generally not in a position to visit any but those in their immediate vicinity. The author therefore proposes to record and document the historically most relevant of these sites using state-of-the-art digital photogrammetry as well as visualisation, GIS and database technology. The digital documentation will consist of metrically correct 3D computer models (CAD), 3D interactive visualisations, GIS coverages and databases of varying extent, which will contain site related textual and image data. This documentation can serve for restoration, documentation for the future, scientific research and -in CD or Web page form- for education and the promotion of tourism. The paper describes the concept of the documentation and the database and gives some examples of already completed or initiated site documentation projects.

1. INTRODUCTION

With very few exceptions, heritage Sites in Sub-Saharan Africa enjoy little attention from the local community and from the international public. Very few of the architectural sites in Africa are on the World Heritage list and many suffer from neglect and are in a poor state of conservation. Documents associated with such sites tend to be distributed over a variety of locations and generally more information on sites is available in the Museums and Archives of former colonial powers than in the countries of their location.

Conservation and restoration of such sites requires accurate spatial information such as shapes of remaining walls, location and physical extent of eroded surfaces, thickness of walls, dimensions of features such as windows and doors and so forth. A spatial information system of a site will also support the management of any restoration process.

Local education systems at all levels tend to concentrate on recent history and emphasise international heritage, while awareness of local heritage is limited. Providing educational institutions with a computer-based interactive facility to view and explore African heritage on a CD would make African heritage more easily accessible to Africa at all educational levels.

The author therefore proposes to establish a Database of Architectural Heritage Sites for Sub-Saharan African with an emphasis on 3D recording and visualisation of architectural structures.

2. A HERITAGE DATABASE FOR SUB-SAHARAN AFRICA - BACKGROUND AND MOTIVATION

The value and need to record African Architectural Heritage arises from diverse needs:

2.1 Conservation and Restoration

An important aspect of the planned database arises from the need to conserve and restore sites. While some of the better known sites in Africa, especially those in areas with significant tourism or those still in use, such as Fort Jesus in Mombassa, Great Zimbabwe or the Great Mosque of Djenne in Mali, are well maintained, others are in a state of severe and often rapid degeneration. Among the latter are Fort Kilwa in Tanzania and many of the rock-hewn churches of Ethiopia.

Photogrammetric or laser scan recording, as proposed as some of the data capturing tools for this project, differ from others, less complex recording and visualisation techniques in that they provide metrically accurate data. While this is less relevant for education and tourism, it is highly significant for architectural, historical and other scientific research as well as for conservation and restoration projects. Photogrammetric recording of structures results in spatial data which allow the precise measurement of dimensions, areas and volumes in CAD and GIS systems on a computer screen or on hardcopy diagrams.

For the planning and execution of restoration work it is important to have accurate and reliable quantitative information on the:

i. Dimensions (lengths, areas and volumes) of structure elements to be restored

   During the planning process for a restoration project it is necessary to assess damage and evaluate the amount of material (stones, building material, chemicals, paint and so forth) required for the restoration. This information can be obtained from metrically accurate 3D models.

ii. Detail dimensions of features such as windows, doors, ornaments

   Accurate dimensions of structure details and decorative elements are relevant when destroyed sections of a building are to be restored. In this case dimensions of destroyed components can be derived from remaining portions of buildings, assuming symmetry, and duplicated. 3D CAD models are ideally suited to extract these dimensions.

iii. Structural design

The detailed 3D dimensions of buildings are required to determine stresses and loads and design support structures and shelters.

iv. Site plans

Site maps are essential for the planning and management of restoration projects. Such maps are traditionally produced using conventional survey techniques. However, photogrammetry is often better suited to the generation of site maps.

v. City plans

To monitor the condition of historical cities, especially in view of possible illegal destruction, modification or new constructions, detailed City maps are required.

Each of the sets of 3D data will be integrated into a Spatial Information System (SIS/GIS) of the site.

In general, it can be said without much fear of contradiction that a SIS is today considered essential for any conservation or restoration project.

2.2 Heritage-Oriented Education

Due to lack of heritage-oriented education, limited communication and poor infrastructures as well as the urgency of other more pressing priorities which dominate all aspects of life on the continent, the African population is, to a large extent, unaware of its rich culture heritage. The project proposed here aims at the generation of heritage awareness through the creation of computer based visualisations and Spatial Information Systems for architectural heritage sites in Africa. Computer models can be distributed on CDs to educational institutions and used as support material at all levels of education

2.3 Tourism

The economical importance of tourism for Africa is beyond question and need not be emphasised here. While cultural sites are major tourist attractions worldwide, Sub-Saharan Africa is not known to the broader tourist community for its heritage sites, and visualisation of structures and landscapes on CDs or web pages can create awareness of the existence of African heritage and potentially increase tourism to such places.

It is also well established that tourism provides, through entrance fees and the sale of site related material and handcraft, the funds necessary for maintenance and possible restoration of sites.

2.4 Capacity Building

It is intended to make use of local staff wherever possible and to use students for all data processing components of the projects. This will result in the creation of expertise in digital photogrammetry, remote sensing, GIS and visualisation.

If planned appropriately the proposed database and visualisations will contribute significantly to the above areas of education, conservation, recording for the future, scientific research and tourism.

2.5 Technologies Utilised

The proposed documentation and recording will be based on state-of-the-art methods of:

i. digital photogrammetry (aerial and close range)
ii. laser scanning
iii. remote sensing and image processing
iv. Geographic Information Systems (GIS) and CAD
v. computer visualisation
vi. database design as well as
vii. modern surveying methods

3. PROJECT OBJECTIVES

From the above derive the principal objectives of the database, which are the provision of:

i. metrically accurate 2D ground and elevation plans of structures as well as maps of the immediate vicinity of sites for analysis by historians, archaeologist, architects, conservationists and/or other scientists

ii. accurate full 3D computer models, visualisations and virtual reality scenes (walk-through and fly over) as permanent and metrically accurate records of structures in digital and hard copy form to guarantee survival of the design in case of deterioration or partial or complete destruction.

iii. solid surface CAD models of the structure

iv. CAD models with ortho-image textures ‘draped’ over the surface

v. CAD line models of the structure showing the outline as well as all visible surface features

vi. detailed, metrically correct 3-D surface models of selected facades of structures in the form of a point cloud of xyz points, contour maps of surfaces and solid models for the assessment of surface damages (erosion, breakage etc)

vii. 3-D CAD line models of the inside of structures possibly based on based on conventional survey techniques, where a photogrammetric survey is too complex.

viii. virtual (historical) cityscapes – and landscapes of based on ortho-images for historical modelling

ix. virtual reconstructions of structures

x. Spatial Information Systems of the site (SIS/ GIS/ HIS–Heritage Information System)

xi. Non-spatial document databases relevant to the site

4. DOCUMENTATION OUTPUTS

In order to achieve the project objectives combinations of the following outputs will be produced for each site. (A site database will typically not contain all of the products listed below, as not all the listed categories will be relevant for each site and in many cases not all desired data will be available):

i. 2D representations

- as-build ground plans of structures
- topographic maps of immediate surrounding areas
- elevation plans of facades showing building outlines, windows, doors, ledges etc.
- elevation plans with great detail (individual stones, ornaments, coats of arms, column capitals etc.)
- sections through structures
- ortho images or rectified (rubber sheeted) images of individual surfaces

ii. 3D CAD models

- 3D line drawings/wire frames with limited detail (structure outlines, windows, doors)
- 3D line drawings/wire frames with great detail (individual stones, ornaments, coats of arms, column capitals etc)
- 3D models with solid (computer-generated) surfaces
- Detailed 3D models (DTM) of selected individual surfaces to monitor erosion and surface damage
- 3D models with grey scale (BW or colour photography) surfaces generated from ortho images

iii. 3D models of surrounding landscape (virtual historical landscape)

Virtual landscape derived from satellite imagery and/or aerial photography and digital terrain models

iv. Spatial Information System (GIS/CAD and Database)

v. Geographic Information System of the structure/site and the environment

vi. Database of spatial and non-spatial site specific information

The GIS/CAD and the Database will be based on a generic design which will have to be customised for each case. The data stored and managed in the GIS/CAD/Database will consist of information on the following aspects of the structure/site:

- 2D and 3D structure plans as listed above
- Architecture (style, building materials, additions, demolitions and other changes over time)
- Conservation related information (damage, erosion, condition reports)
- Environment in the proximity of the site
- Geology
- Vegetation
- Excavation reports and diagrams
- History
- Publications and reports

vii. Meta-database for all site data

viii. Virtual Reality models (VRML- Java)

- Walk–in capability
- Fly-through capability
- On screen measurement capability for scientific and architectural analysis
- Scenario simulations (varying light, moon, sun, torch light)

ix. Reconstructed 3D model of original structure derived from remaining ruins

x. CDs for education and general distribution

xi. Meta-database for all recorded sites

5. EXECUTION OF THE PROJECT

It is proposed to initiate and partially implement the Heritage Database through a multidisciplinary and multinational initiative. The Department of Geomatics at the University of Cape Town (UCT) is suggested as the location for the database/GIS. Experts in all contributing disciplines are among the staff of UCT and have expressed an interest to cooperate.

The recording and establishment of the database and associated research will be done with the support of and in cooperation with experts from the Universities of Nairobi, Dar-es-Salaam, Kumasi, Stuttgart, Zurich and Melbourne.

In a first project stage it is planned to photogrammetrically record a variety of selected sites in Sub-Saharan Africa. This stage has already been initiated. In a second stage, non-spatial architectural, archaeological and historical data will be integrated into the Spatial Information System for each of the sites. Information on all these sites will then be provided through a meta-database. .

It is hoped that eventually enough interest can be generated to attract funding for a permanent African Centre for Heritage Recording.

6. ACCESS TO DATA

It is planned to make all generated data freely available on web sites for general use and, in more detail, for research and conservation projects on CDs, provided those government- or local authorities with responsibility for the respective sites give their permission to do so.

7. RESEARCH COMPONENTS OF THE PROJECT

Although photogrammetric recording of sites has been practiced for most of the last century and is well established (examples are Patias and Peipe (2000) and Visnovcova et al. (2001)), new technologies have opened new possibilities which need to be explored and research in a number of areas of documentation is necessary. Among the problem areas which require research are:

- Integration of digital photogrammetry, CAD, databases and GIS

- Development of surface models for irregular and complex surfaces (erosion, wall ornaments, complex doors and windows, column capitals etc)
- Integration of amateur and metric photography
- Integration of laser scanning and photogrammetry
- Use of Synthetic Aperture Radar for surface modeling
- Creation of historical landscapes
- Database design for heritage recording
- Optimal visualisation and visualisation data management techniques (management of large data sets)
- Design of documentation specific software
- Models for the optimal choice of detail-resolution (this seemingly trivial issue, is one of the central problems with respect to project design, methods, field work, staff and specifically funding).

Researchers and postgraduate students in the participating University Departments will carry out this research.

8. PLANNED DOCUMENTION SITES

Sites documentations already in progress* or under consideration for future work are:

1. Rock churches in Lalibela, Ethiopia* WHS)
2. Stele field of Aksum, Ethiopia (WHS)
3. Kilwa Kisiwani & Songo Mnara* (WHS)
4. Stone Town, Zanzibar, Tanzania
5. Great Mosque in Djenne, Mali (WHS)
6. Fort Jesus, Mombassa, Kenya
7. Pyramids of Meroe, Sudan
8. Royal Palace of Abome, Benin, (WHS)
9. Old Town, Lamu, Kenya
10. Fortress on Mozambique Island (WHS)
11. Great Zimbabwe (WHS)
12. Forts of Volta, Greater Accra, Ghana (WHS)
13. Ashanti Traditional Buildings, Ghana (WHS)
14. Old Town, Pemba, Tanzania
15. Churches on Lake Tana, Ethiopia

The above list is merely a selection of some of the most important sites in Africa, many more deserved documentation and conservation.

9. COMPLETED AND ONGOING DOCUMENTATION PROJECTS

As a first project, the documentation of the Laetoli hominid foot print trackway has already been completed successfully (Rüther, 1996, 1998; Taylor, 1997; Rivett, 2000). Two further projects are in progress, these are the recording of St Gyorgis, one of the rock churches in Lalibela in Ethiopia (Rüther et al., 2001) and the Fortress and Mosque of Kilwa Kisiwani in Tanzania.

The Laetoli trackway. The Laetoli trackway, Tanzania, discovered by Mary Leakey in 1978, was created when a group of three hominids (Australopithecus Afarensis) crossed a volcanic ash field deposited by the eruption of one of the many volcanoes along the African Rift Valley. A subsequent eruption covered the footprints with new ash preserving the moment in time over a period of three-and a- half million years. The Laetoli footprints are widely accepted as the first evidence of bipedal or upright hominid walk and are thus of principal relevance in the evolution history of man. In recent years the trackway has deteriorated through erosion and weathering and as a result of root and insect invasion.

When the Getty Conservation Institute, Los Angeles, made the conservation of the 3.6 million years old trackway, a GCI conservation project, it was decided to not only conserve the footprints using the most advanced modern technologies, but to also fully document the foot print site employing state-of-the-art documentation methods.

The GCI conserved and documented the trackway in cooperation with the Tanzanian Department of Antiquities and UNESCO. The photogrammetric documentation of the site was done by the Photogrammetric Research Unit of the Department of Geomatics at the University of Cape Town.

The documentation was based on data acquisition in two field campaigns, 1996/97. A GIS of the proximity of the site was created and close range photogrammetric images were captured with a variety of metric and non-metric cameras. Detailed surface models of 69 footprints as well as the 40 m long trackway area were created. The surface models (Figures 1 and 2) for the individual footprints were produced by photogrammetrically acquiring between 10 000 and 20 000 surface points on each of the imprints. The individual points were established with standard deviations of better than 0.5 millimeter.

In addition to the photogrammetric data acquisition, data was collected on the geology of site, the condition of each imprint, state of erosion, root invasion, insect damage, previous treatment with preserving chemical and so forth, while any new chemical treatment was recorded on field sheets and later entered into the GIS and the Access database (Figure 3). The surface models were integrated in the GIS site coverages and linked to an Access database.

The Laetoli database has been completed and located at the GCI in Los Angeles and in the Tanzanian Department of Antiquities. A small subset of the data and an interactive visualisation can be accessed through the UCT web page on http://foxbat.sur.uct.ac.za/fresearc.htm.

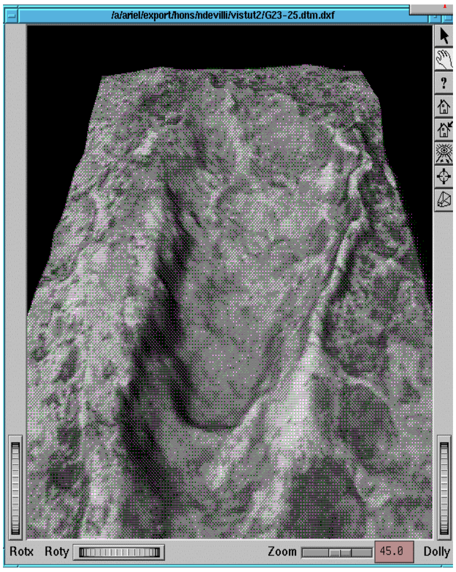

Figure 1. Photographic texture draped over the surface model of one of the Laetoli footprints. (The great detail achieved in the photogrammetric surface reconstruction is visible in the 'mud' ridge on the side of the imprint and a second heal imprint).

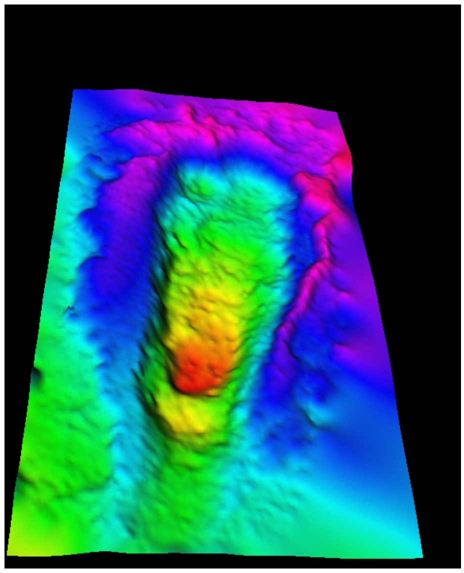

Figure 2. Colour coded surface model created to emphasise the second heal imprint.

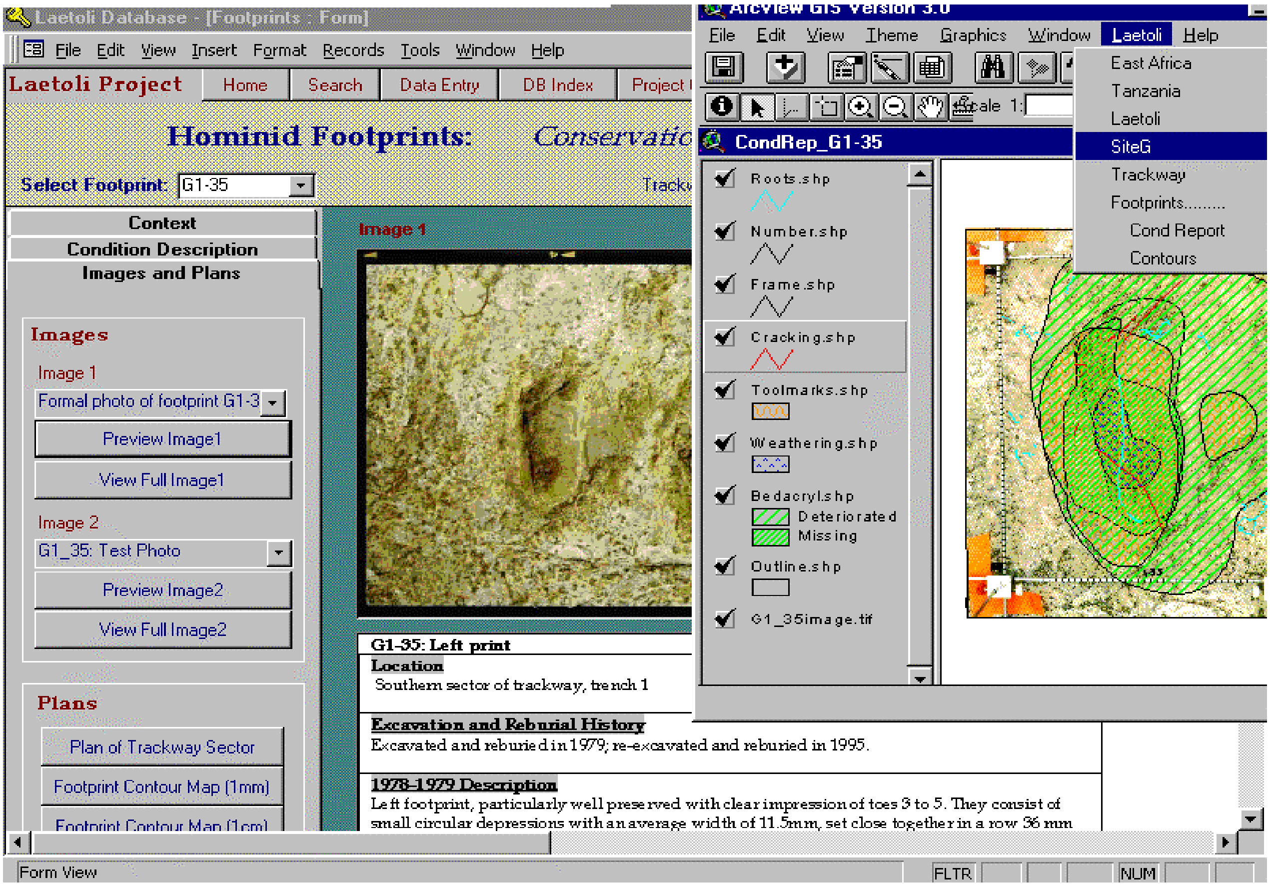

Figure 3. Example of Laetoli database form showing a footprint image together with a condition report with access to other site related information and to active ArcView coverages.

The Rock Churches of Lalibela. Around 1200AD, King Lalibela, one of the last kings of the Zagwe dynasty that ruled in Northern Ethiopia for 200 years, created a number of remarkable rock churches which remain to this day as functional places of worship. They also constitute symbols of paramount religious, cultural and architectural significance to the people of Ethiopia. Of the basically three types of these rock churches, one appears to stand apart in its uniqueness. This is rock-hewn monolithic church, which while imitating a built-up structure is actually cut in one piece from the rock and separated from it by an all-around trench. The best known of the monolithic churches is Bet Giorgis (St George's Church) (Figure 4) in the town of Lalibela, the structure has dimensions of 12 x 12 x 13m and stands impressively in a 25m square trench, the church being entered via a subterranean passage

Bet Giorgis is at present being documented as joint project by the Geomatics/Photogrammetry departments of the Universities of Cape Town, Melbourne and the ETH Zurich. A low-level visualisation technique was employed to create a preliminary model by simply 'rubber sheeting' images (Figure 5) and a full model produced by a combination of Australis (Fraser and Edmundson, 2000) and Photomodeller software is close to completion. A model of the landscape generated from B& W aerial photography has also been created. First achievements were reported in Rüther et al. (2001) and Buehrer et al. (2001). Work on this project is ongoing.

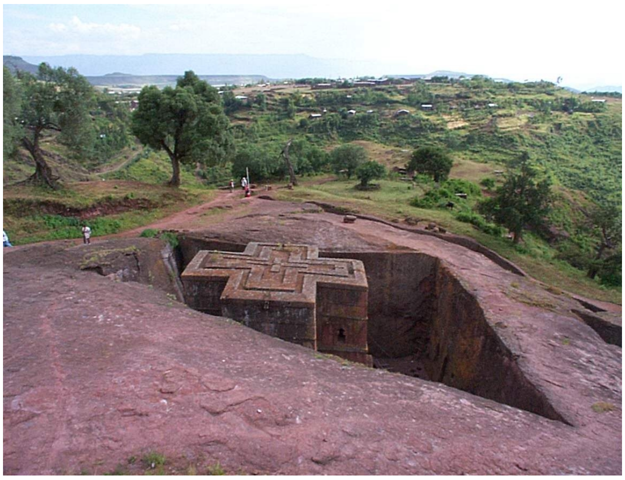

Figure 4. The monolithic structure of Bet Gyorgis cut out of volcanic tuff.

Figure 5. Screen capture from preliminary VRML model created by 'rubber sheeting' of imagery.

Kilwa Geresa and Mosque. Kilwa Kisiwani, once among the principal trading post on the East African coast, was founded in 957 by the Kilwa Sultanate and conquered by the Portuguese in 1597. Its wealth and greatness during the 11 to 16th century is still reflected in the ruins of the Mosque, the fortress and palatial buildings on the island of Kilwa Kisiwani itself as well as on the neighboring Songo Mnara Island. Kilwa Kisiwani is a UNESCO World Heritage Site.

Figure 6. Section of Mosque at Kilwa Kisiwani, showing some of the complexity of the building.

Figure 7. The Fort in Kilwa Kisiwani, also known as Geresa (prison).

The fieldwork for the Kilwa documentation is largely completed and the photogrammetric reconstruction has been started.

10. CONCLUSIONS

This project is an initiative to contribute towards the preservation of African architectural and archaeological heritage, and the generation of awareness of this heritage in Africa.

In its principal objective, a 3D Heritage Database offers a valuable tool for the planning and management of heritage site restoration and conservation projects. The contribution of a 3D database in this area is well established internationally and spatial information systems for such projects have been used worldwide.

Knowledge of heritage sites is essential for the creation of awareness and pride of cultural heritage. The author believes that visualisation on a personal computer, in which learners at all levels of education can interact with sites on the computer screen in the form of virtual walk- and fly-trough's, can contribute greatly to the generation of appreciation and understanding of African history and heritage.

The creation of the database will also build capacity in photogrammetry, remote sensing, GIS and computer visualisation in African educational institutions and government departments.

Equally relevant is the potential of photogrammetric visualisation for the recording of sites for future generations and as a means to attract tourists.

ACKNOWLEDGEMENTS

All three projects referred to in this paper involve teams totalling more than 30 individuals and it is unfortunately impossible to list everybody here.

Laetoli was a GCI project and funded by this Institute. All conservation aspects were dealt with by the GCI while the author was the project leader for the photogrammetric documentation and the database design. Principal researchers and conservators were Neville Agnew, Martha Demas and Gaetano Palumbo from the GCI, Donatius Kamamba represented the Tanzanian Department of Antiquities. The UCT team comprised of Julian Smit (Smit, 1997) Ulrike Rivett (Rivett, 2000) who assisted with the fieldwork and contributed to the project as part of their PhD theses. PhD candidate Terry Richards, guided by the GCI staff, was instrumental in the database design. Simon Taylor (Taylor, 1997), Ross Rozendal (Rozendal, 2000) and Simon Hull (Hull, 2000) contributed through project related work done for their respective MSc thesis.

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