1) Introduction

This paper focuses on the results of geophysical survey at the UNESCO World Heritage site of Songo Mnara, a Swahili stone town situated in the Kilwa archipelago, Tanzania (slide 1). The data-sets presented today are a result of a combined effort. I must therefore first acknowledge my fellow author of this paper, Harry Manley, with whom I conducted this work last year as part of the 2009 field season of the Songo Mnara project. I would also like to thank the project directors Jeff Fleisher and Stephanie Wynne Jones for inviting us to participate in their research.

The previous speakers have already given us a really good introduction to the nature of the site and the collaborative nature of the Project. One of the real benefits in this Project is the combination of a variety of archaeological techniques including geophysical, geochemical and environmental survey combined with the results of targeted excavation.

In this presentation I am going to focus on the results of the geophysical survey which Harry and I carried out over the open areas of the stone town to explore the use of space, and the boundaries of anthropogenic activities within and outside of the Swahili town.
2) Background

Archaeologists have moved a long way from the use of geophysical data solely to inform in advance of excavation, or to target specific areas of interest (Gaffney & Gater 2003: 12-24) (slide 2). As intrusive excavations can only normally be used to investigate a tiny fraction of the landscape, geophysical survey can enable the broader overview that is vital when attempting to understand site relationships on a variety of scales.

In recent years, the number of large scale geophysical investigations has increased (Card et al. 2007, Gaffney et al. 2000, Kvamme 2003, Parker Pearson et al. 2004, Powseland et al. 2006). It is therefore perhaps surprising that given the iconic nature of some of the Swahili sites that more geophysical survey has not have been carried out. An exception to this has been the recent work by GSB Prospection in conjunction with Stephanie Wynne Jones at Vumba Kuu, on the southern Kenyan coast. Despite challenging terrain, the results obtained indicated considerable potential for this approach to yield very positive results (GSB Prospection Ltd 2008).
2.2) Geophysics at Songo Mnara

Songo Mnara is surprisingly well suited to geophysical survey, as it has relatively well preserved archaeology (Garlake 1966), and has had very little modern contamination (slide 3). We know from previous excavations that the archaeological deposits are relatively close to the modern land surface, which benefits detection (Pradines 2005). The relatively short occupation span of ~200 years at Songo Mnara (Chittick 1961) should potentially have less stratigraphic confusion compared to other nearby sites such as Kilwa Kisiwani with an occupation span of ~800 years (Chittick 1974). The site is also relatively open and easy to access, with coral sand above predominantly limestone bedrock.


2.3) Survey Techniques

A combined geophysical survey approach was taken at Songo Mnara, with fluxgate magnetometer and electromagnetic survey both being utilised. Fluxgate magnetometer survey (slide 4) is commonly used as a prospection tool on archaeological sites. It is ideal for identifying areas of anthropogenic activity including high temperature industries, ditches, pits and areas where soils have been magnetically enhanced (Gaffney & Gater 2003: 36-42).
In order to identify sub-surface structural remains electromagnetic survey was also employed (slides 5 and 6). Electromagnetic survey is comparatively underused in archaeology, and allows the consecutive measurement of both subsurface conductivity (the inverse of resistivity) and magnetic susceptibility. It is ideally suited to arid and sandy sites where electrical contact with the soil can be difficult to obtain (Clark 1990, 34).

Geonics EM38B (slide 5)

Electromagnetic instruments make use of the response from the ground to the propagation of electromagnetic waves. The transmitter coil induces an alternating magnetic field which creates electrical currents in the ground which are scaled to the conductivity of the ground at that point. These currents produce a secondary magnetic field that is measured by the receiver coil. The magnetic field is related to the conductivity of the soil in the environs of the instrument.

As conductivity is the reciprocal of resistivity the techniques gives us a proxy for earth resistance survey. Stone materials, great for identifying physical remains. The advantage here is that as this is a very dry site there does not need to be contact with the ground as you would need with traditional earth resistance techniques.

At low frequencies they can also measure magnetic susceptibility.
Geophysical Survey Techniques

Electromagnetic Survey
(Geonics EM38B)
The survey was conducted over the main areas of open space at Songo Mnara, as well as between buildings where rubble and vegetation permitted (see slide 6).
4.) Results of Geophysical Survey

4.1) Fluxgate Magnetometer Data

The results from the fluxgate magnetometer survey (slide 7) demonstrate that the site is magnetically remarkably 'quiet'. This is most likely due to the lack of modern occupation which has been of considerable benefit as there is very little ferrous 'litter' which adversely affects surveys of this type. The survey data contain a number of geophysical anomalies which can be directly related to anthropogenic activity. The area outside of the town walls is relatively magnetically 'quiet' and may indicate that the town boundary was an important one which strongly delineated the activities of the peoples within Songo Mnara.

There are two areas which relate to very high magnetic disturbance. The anomaly to the north of the site is close to the modern excavation headquarters and can be directly correlated to modern rubbish and burning activity. However, the anomaly at the south of the site has a geophysical response that is similar to those seen in iron working activities found in antiquity (Crew 2002). Subsequent excavation in this area confirmed that iron scale, droplets and slag were present, indicating the possible presence of iron smithing within the town.

The results of the fluxgate magnetometer survey indicate that there are discrete areas of magnetic disturbance within the open areas between
4.2) Subsurface Conductivity Data

The results of the subsurface conductivity from the electromagnetic survey are comparatively unclear when compared to the other two geophysical datasets (slide 8). However, the town walls can be identified as linear, low conductivity anomalies. Outside of the walls the conductivity readings are extremely high and reflect the high salinity of the soil where the mangrove and sea water come within a few meters of the site. To the west of the town there are two small circular, discrete high conductivity anomalies, associated with buildings. It is possible that these may relate to the presence of wells and these features have already been identified and excavated elsewhere at Songo Mnara.

Close examination of the subsurface conductivity results also indicates that there are areas of low conductivity that directly relate to the magnetically disturbed areas within the open areas of the stonetown seen in the fluxgate magnetometer survey above. Unfortunately the exact extent of these is difficult to define here.
4.3) Magnetic Susceptibility Data

The magnetic susceptibility results from the electromagnetic survey are extremely well defined (slide 9). The town walls are clearly visible within the data, but again there appears to be little activity outside of these. The modern burning and the possible iron working area show magnetic enhancement as would be expected from the fluxgate magnetometer survey results. What is most surprising is the clarity of the data with respect to the large number of circular (~10x10m) anomalies visible within the open areas of the town. These correspond directly to the areas of magnetic disturbance and low conductivity observed in the other two plots.
4.4) Seeing Red?

The geophysical data were combined and ground truthing carried out to determine the exact position of the circular anomalies. It was found that these areas directly related to patches of soil that had a marked red colour when compared to the surrounding environment (slide 10).
4.4) Seeing Red?

Preliminary excavation was then carried out over two of the anomalies (Trenches SM007 and SM011) to determine the nature of these deposits and their possible relationship to anthropogenic activity (slides 11 and 12). The results of the excavations determined that the on the ground exact delineation of the edges of these features was difficult to ascertain. Evidence of anthropogenic activity was present relating to the 15th and 16th century ground surface (coins, pottery, glass beads etc.). It is possible that in the case of Trench SM011 this area may represent the remains of a melted earth and thatch house as the finds were of a domestic type (Fleisher and Wynne-Jones 2010).

There is however, another potential interpretation of these enigmatic anomalies in the open areas. Analysis of the soils from the site by Frederica Sulas of Cambridge University has identified the possibility of orchards or gardens being positioned next to house compounds (Sulas 2010). It is clear that further investigation will be required to ascertain the exact nature of these features.
5) Conclusions and Further Work

In this paper I have aimed to demonstrate that the use of a combined and integrated geophysical survey approach has resulted in a more informative data-set than would have been achieved by using one technique in isolation. The work to date clearly shows how geophysical data is essential to the understanding of an archaeological landscape as a whole, having the potential to enhance our understanding of the use of space within and around Swahili stonetowns.

At Songo Mnara the results of the geophysical survey identified specific regions of activity, including town boundaries and areas of iron working. However, the most striking feature of the results was the reoccurring presence of circular anomalies seen within the open spaces between buildings. Field investigation coupled with geoarchaeological and environmental evidence has demonstrated a direct relationship between these areas and anthropogenic activity. The evidence indicates that it is highly likely that these open areas were being specifically used and managed. Further work will be required at Songo Mnara to elucidate not just the nature of the enigmatic red soils, but to continue the survey to include the rest of the town that has as yet to be investigated.
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