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Magnetometer surveys in archaeological research in Papua New Guinea: Keveoki 1, Gulf Province

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Abstract

A magnetometer survey was conducted on the abandoned village site of Keveoki 1, near the Vailala River, Gulf Province, PNG. The survey, using a single sensor proton precession magnetometer, was successful in locating and defining the boundaries of areas confirmed by excavation to contain dense assemblages of pottery. The combination of geophysical and excavation results allowed a broader understanding of the spatial distribution of human occupation at Keveoki 1 than would have been possible based on excavation or visual field walking alone. We suggest this technique should be applied more regularly.

Archaeological geophysical prospection techniques have not previously been applied as part of archaeological investigations in Papua New Guinea (PNG), despite an extensive history of archaeological research in this area (e.g. Bulmer 1978; Frankel and Vanderwal 1985; White and O'Connell 1982). In part, this deficiency may be explained by the perceived high cost of geophysical survey as well as the difficulties associated with operating and transporting electronic equipment to the often remote, extremely rugged, wet tropical and inaccessible archaeological sites of the region. Nevertheless geophysical techniques have a demonstrated history of making an important contribution to archaeological investigations world-wide (e.g. Witten 2006; Conyers 2004; Gaffney and Gater 2003) and have the potential to answer important archaeological questions in PNG also. In particular, they have the potential to extend site information beyond the limited spatial extent usually obtained through excavation, and thus promise to enable understandings of village sites as spatially extensive landscapes rather than more restricted spatial nodes (Kvamme 2003). This is particularly apt for PNG where thick vegetation and swampy conditions can make site discovery through more conventional field walking very difficult.

The archaeological record in many coastal parts of PNG is particularly amenable to geophysical investigations because here can be found extensive sites with dense ceramic deposits as well as numerous sub-surface structural features such as postholes, human burials and earth ovens. Since electromagnetic induction (EMI) and magnetic susceptibility in particular can directly detect pottery (Clark 1990) as well as the remnants of burning (Linford and Canti 2001) and anthropogenically-induced microbial activity (Linford 2004), geophysical prospecting evidently has great potential in such archaeological contexts. Other techniques, such as ground penetrating radar (GPR) (Conyers 2004) and direct current resistivity (Witten (2006) may find less regular application in this area, but could contribute where favourable site conditions exist.

Potential targets for archaeological prospection in PNG

While a variety of archaeological sites exist in PNG including rockshelter sites, coastal middens and agricultural landscapes, all of which have considerable potential for the application of geophysical techniques, here we focus our attention on the archaeological expression of an ancient village site from swampy southern PNG lowlands.

Recent villages of the Vailala River area – as of other areas of PNG also – typically housed a few dozen to a few thousand people, and contained from a handful to dozens of wooden and thatched houses. Some houses were particularly grand in size and reputation, such as the men's longhouses that could be over 100 m long and that housed sacred and secret ritual objects. Houses of all kinds were typically raised 1 m or more above the ground. It was common for family members to be buried in graves beneath individual houses.

Geophysical prospection techniques are well suited to investigating the spatiality of village organization in this

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part of PNG, and in doing so tracing archaeological expressions of local social institutions as recorded in the ethnographic literature. For example, the residents of Epemeavo and Kea Kea villages to the east of the Vailala River trace their ancestry to the upper waters of the Vailala and Purari rivers. Oral origin histories describe a series of 'halting places' occupied as people moved generally southwards toward the coast (e.g. David *et al*. 2009; Holmes 1903). This raises the question of whether ethnographically-described village layouts can be traced further inland and back in time. Delineating smaller domestic dwellings from small villages or temporary residences across the landscape would be difficult archaeologically, as these were more or less randomly scattered and regularly rebuilt. However, the orientation and utility of men's longhouses (*eravo*), especially common among the larger, coastal villages of this area, can be more clearly recognised. The eravo faces the sea, and is juxtaposed by two smaller *baupo eravo* facing inland. Outside times of ceremonial performance, these were places where men rested, socialised or entertained visitors (e.g. Williams 1940: 3-6). *Eravo* are not places where all the communal activities of day to day life took place, but rather in their positioning and hierarchical significance within village layouts signalled specific forms of social organisation involving gender and age relations; ceremonial procedures, obligations and schedules; and structures of ritual responsibility based around the clan and level of seniority which, in its archaeologically observable material expression (e.g. posthole distributions), can be expected to leave a unique material signature. However, such structures have not yet been recovered archaeologically.

Archaeological assemblages from village sites across this region are characterised by pottery, stone artefacts, bone, charcoal, abundant postholes, earth ovens, human burials as well as the geochemical signatures of occupation. These features have variable potential for detection using geophysical techniques, the most problematic being stone artefacts and skeletal materials. While large accumulations of stone artefacts might in principle be detectable using geophysical techniques such as GPR, EMI or direct current resistivity, their small individual size would make them very difficult to reliably detect in most cases. Further, it would be impossible to differentiate between worked and unworked stone with these methods.

More promising is the detection of skeletal material, particularly using ground penetrating radar (Conyers 2006, Ruffell and McKinley 2005). Most informed studies now consider that the direct detection of skeletal material under field conditions is impossible and that the best targets are the disturbance to the soil created through the act of burying the corpse or material culture items (such as coffins) associated with burials. For this method to be successful, it relies on minimal post-interment disturbance to the grave fill and surrounding stratigraphy (Conyers 2006: 67). In the tropical environments of PNG where jungle quickly overtakes any open ground, this degree of preservation is unlikely. An alternative approach is to detect the magnetic enhancement resulting from burial rituals involving fire or the use of ochre (Moffat *et al*. 2010; Wallis *et al*. 2008) which may have some potential for use in this region.

The target most amenable to geophysical investigation in much of PNG is increased magnetism caused by subsurface pottery, fire and other anthropogenic mechanisms of magnetic mineral formation. Of these pottery is, in general, the most likely to yield information about the chronology and material culture of a particular site. The increase in the magnetism caused by these features results from the cumulative contribution of both thermoremanence and induced magnetism, formed through different processes (Tauxe 2002) which (in this case) result from human activity.

Thermoremanence is acquired when iron oxide-rich materials (such as clay) are heated above the Curie point (578°C for magnetite and 578-675°C for maghemite; Schmidt 2007: 23), when the iron minerals are demagnetised then remagnetised *en-masse* in line with the earth's magnetic field when they cool (Clark 1990: 65).

The intensity of magnetic enhancement is greatest when the affected materials retain their spatial relationship, such as in an *in situ* kiln. When fired materials are found in different orientations relative to their thermally created magnetic field (such as in a collection of fired bricks in a wall) their directions of magnetisation are dispersed and the cumulative effect can be reduced (Bevan 1994). Despite this, the incorporation of broken ceramics and bricks into the soil can result in an increased magnetic signature (Weston 2002).

Induced magnetism is acquired by a complex series of processes first described by Le Borgne (1955), where iron minerals are reduced and then oxidised to form the more magnetically susceptible forms magnetite and maghemite. These processes, summarised by Aspinall *et al*. (2008: 22-26), include the heating of iron materials in reducing conditions; the microbial creation of reducing conditions and bacteria which internally reduce these minerals all rely on the abundant presence of organic materials.

The degree of the potential increase in the magnetism of the soil is controlled by the concentration of iron oxides present (Tite 1972), which can be measured experimentally (Crowther 2003). It is also possible to experimentally distinguish the enhancement in magnetic susceptibility caused by fire from that produced through weathering and soil formation processes (Oldfield and Crowther 2007).

Both of these mechanisms of magnetic enhancement have been the subject of significant experimental work to isolate the effects of parameters such as temperature, fire duration and the lithology of the study area on the intensity of the created thermoremanence and induced magnetism (Linford and Canti 2001).

The increase in magnetism can be detected using passive (magnetometer) and active (EMI or magnetic susceptibility) methods, with the most appropriate method depending on the nature of the targets and the site conditions (Clark 1990). Anthropogenic enhancement of the magnetism of a site through these methods therefore provides a robust basis for geophysical survey in this region.

Keveoki 1

The site of Keveoki 1 is located 9 km east of the Vailala River and 1.2 km north of the coastal village of Kea Kea (Fig. 1). The site was identified on the basis of pottery sherds by Bruno David and Nick Araho (David *et al*. 2008). The hinterland region behind the villages of Kea Kea and Epemeavo are interspersed with drainage ditches manually dug by local villagers to allow garden cultivation. These drains average approximately 1.5 m in depth and cut through old landscapes and shorelines, exposing archaeological material in the form of pottery sherds. Local villagers identify the pottery as being from old village sites, some remembered from the relatively recent historical past and others as part of oral traditions relating to ancestral villages. The Keveoki 1 pottery sherd concentration was thought by local clan members to be an old village but it was not known from oral traditions.

A single, small archaeological excavation was undertaken at Keveoki 1, where there was the highest density of pottery sherds in the bottom of the adjacent drainage ditches (Fig. 2). Pottery was visible along the length of the bottom of the drain for approximately 20 m, with minor densities along the top of the banks where mud had been excavated during ditch building, and *in situ* in the drain. Villagers from Epemeavo collected all but the smallest pieces from the ditch in the immediate vicinity of the excavation square using 2.1 mm mesh sieves, wet sieving inside the ditch and collecting all sherds above 20 mm in length. Densities were too great for a total sherd collection from the length of the ditch. The collected ceramics and those from the 50 x 50 cm excavation will be published elsewhere.

Geophysical survey methodology

Geophysical investigations were conducted using a Geometrics G-856 proton precession magnetometer with data collected on a regular grid with one metre line and station spacing in areas of the Keveoki 1 site where the vegetation had been cleared over an area of approximately 500 m^2. A data point was taken prior to the start of each survey line at a base station location situated outside the survey area to allow the calculation of a diurnal correction value, despite the absence of a second magnetometer.

Magnetometer investigations can be undertaken using a variety of instrumental configurations and positioning equipment. Common sensors for field based archaeological applications include proton precession, cesium vapour and fluxgate configured in single, gradiometer or multiple configurations, the relative utility of which are well summarised by Aspinall *et al*. (2008). Positioning information for the survey can be acquired by real time kinematic differential GPS, differential GPS, GPS, robotic electronic distance meter, electronic distance meter or survey tape depending on site conditions, required precision and accuracy of survey information, desired survey speed and available budget. The choice of a proton precession

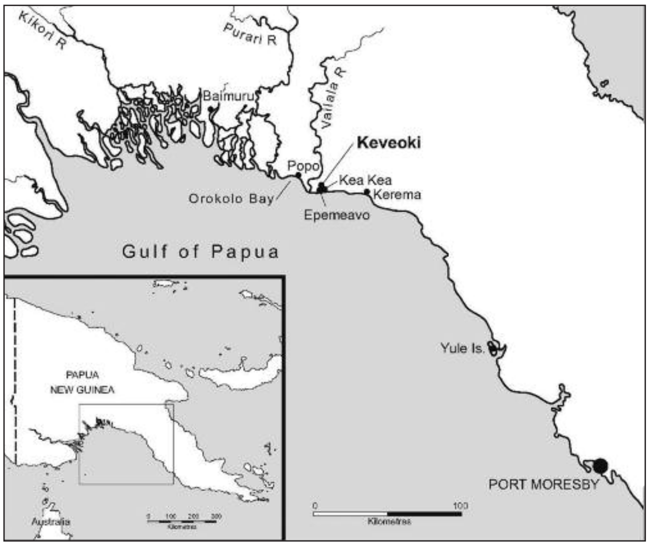

Figure 1. Study area.

magnetometer and survey tape for this survey reflects the low cost of this configuration, the very low power requirements of these tools in an area where recharging was impossible during the survey, the small area allowing a comparatively slow methodology as well as the high quality of both positioning and geophysical data that can be obtained (e.g. Moffat and Raupp 2008).

Following acquisition, data were processed to remove erroneous points, diurnally corrected from a base station, gridded using Magpick software using a spline interpolation (Smith and Wessel 1990) and presented as a contour plot. This was overlain on a baseline/offset site plan (Burke and Smith 2004: 96) to assist in data interpretation (Fig. 3).

Geophysical survey results

The magnetometer data show a number of both discrete and diffuse anomalies which may correlate to anthropogenic features as originally reported in David *et al*. (2009: 12) and reanalysed here. The most distinct is a positive monopolar anomaly of up to approximately 17 nanoteslas (nT) above background centred on the area of the channel and excavation, in an area found to produce the most ceramic material (Fig. 3, feature M1). This anomaly continues, with a more diffuse boundary and slightly lower magnetic intensity of between 13-15 nT above background down river (Fig 3, feature M2). Also adjacent to feature M1 is a diffuse lobe, with moderately elevated magnetic intensity values in the range of 11-14 nT above background, which extends west for approximately 15 m with a maximum width of 8m (Fig. 3, feature M3). An additional lower magnetic intensity and geographically smaller positive monopolar anomaly with a maximum intensity of 13 nT above background is located approximately 12m to the east of feature M1 (Fig 3, feature M4). A negative monopolar anomaly with a minimum intensity of -10 nT below background is located to the south east of the principal anomaly (Fig 3, feature M5).

Figure 2. Keveoki 1 Village Site. Excavation in progress at location of magnetometer feature M1 (photograph: Ian Moffat).

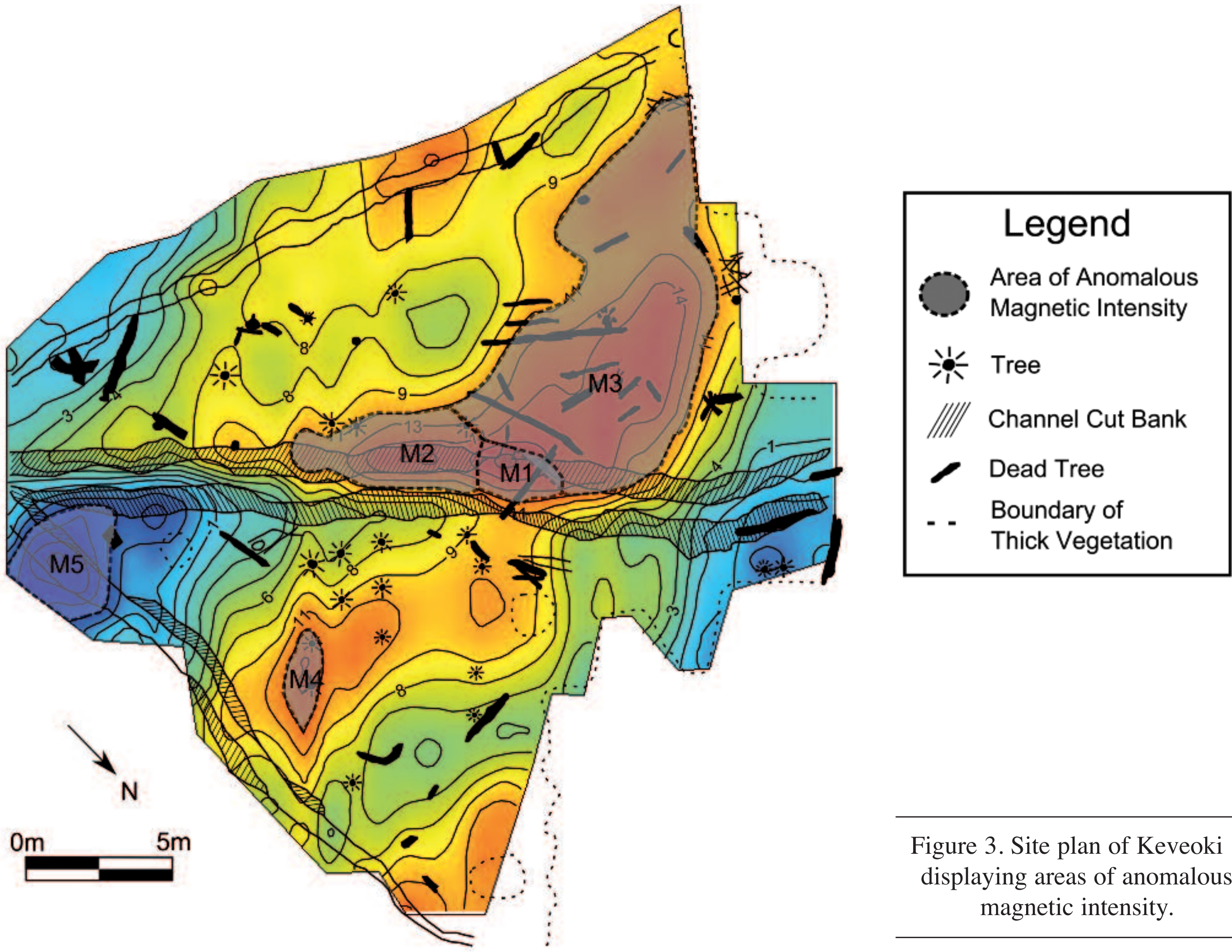

Figure 3. Site plan of Keveoki 1 displaying areas of anomalous magnetic intensity.

Discussion and conclusion

The results of the geophysical survey suggest that the channel has fortuitously been cut through the highest concentration of ceramic material in the area surveyed (Fig. 3, feature M1). This was the location of the excavation. The continuation of this anomaly downstream along this channel (Fig. 3, feature M2) is probably at least partly the result of fluvial transport of the pottery sherds, although part of this anomaly is located adjacent to the channel and so may be *in situ*. The eastward continuation of this feature (Fig. 3, feature M3) probably represents an additional, though less dense concentration of pottery material, as does the discrete smaller positive anomaly to the east (Fig. 3, feature M4). The anomaly to the southeast (Fig. 3, feature M5) probably does not represent a pottery accumulation. Its negative magnetic response requires direct investigation.

The results of the magnetometer survey suggest that despite the initial removal of the small number of pottery sherds analysed in David *et al*. (2009), a significant amount of material remains both in the creek bed and *in situ* in the creek bank. The continuation of feature M3 to the western edge of the survey area leaves open the possibility that further significant pottery deposits may be located outside the area surveyed.

The magnetometer data also suggest that significant regions of the survey area do not have extensive anthropogenic enhancement of their magnetic intensity and thus are unlikely to warrant further direct investigation. The implication is of a village site of limited spatial extent of some 25 m x 10 m, with outlying activity locations as would be expected in the case of individual houses lying on the edge of the village. We cannot comment on the possible extent of the village beyond the boundary of our survey area although note that feature M3 (Fig. 3) may continue to the west. This suggests that larger survey area may be useful in the future.

The Keveoki 1 results confirm the ability of magnetometer surveys to define the spatial extent of locations with rich buried ceramic assemblages in humid, tropical conditions. The significance of these findings is further enhanced by the fact that, historically, coastal villages in this general region are known to have tracked the rapidly migrating coastline. David *et al*. (2009: 13) have reported that in this area the coastline has prograded on average 3 m per year since 500–550 years ago. The implication is that magnetometer surveys of a more reconnaissance nature can assist archaeologists to track settlement locations relative to shifting coastlines. Such investigations are particularly useful in exploring the dynamics of settlement systems during the late Holocene.

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