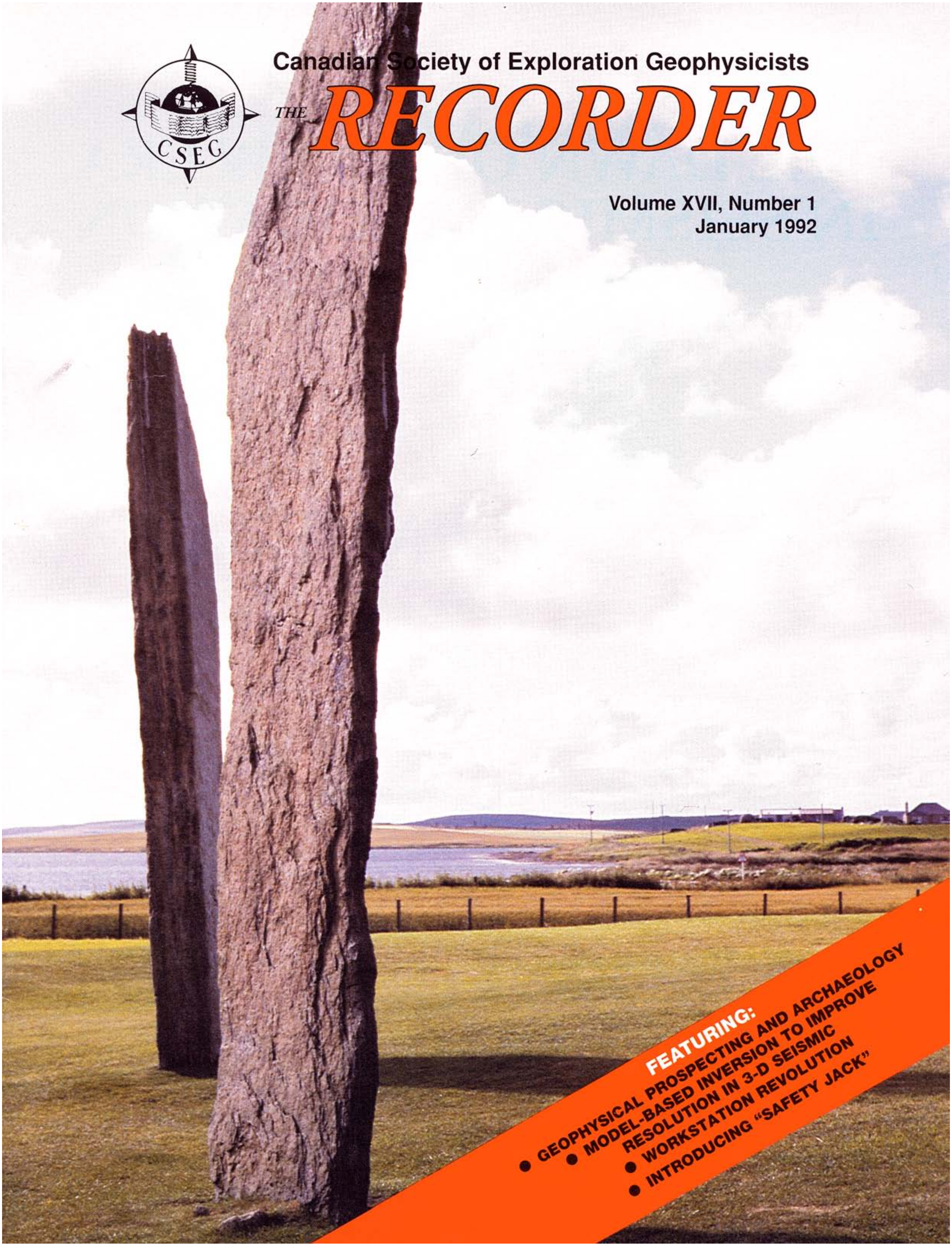
Canadian Society of Exploration Geophysicists

THE RECORDER

Volume XVII, Number 1
January 1992



FEATURING:

- GEOPHYSICAL PROSPECTING AND ARCHAEOLOGY
- MODEL-BASED INVERSION TO IMPROVE RESOLUTION IN 3-D SEISMIC
- WORKSTATION REVOLUTION
- INTRODUCING "SAFETY JACK"

Geophysical Prospecting and Archaeology

Figure 1. Aerial view of crop marks and outcropping architectural remains over a portion of the ancient townsite of Stymphalos in Arcadia, Greece. Note that recent cultivation at the right of the photograph has erased all visual indications of buried remains.

by Guy M. Cross

INTRODUCTION

Archaeological science encompasses a broad scope of interdisciplinary collaboration between archaeologists and their colleagues in the natural sciences. Techniques from physics, chemistry, biology and the geosciences have a prominent role in each phase of the archaeological process, including the reconnaissance of sites, their excavation and the subsequent analysis of recovered materials (Tite, 1972; Aitken, 1976; Butzer, 1982; Rapp and Gifford, 1985; Tite, 1991). This article is devoted to the use of remote sensing for archaeological site reconnaissance and, in particular, the adaptation of geophysical prospecting for detection and mapping of subsurface archaeological features (Weymouth, 1986; Scollar et al., 1990).

Archaeologists have long realized the potential of aerial photography to reveal the presence of patterned surface features that are either too large scale or too subtle to be recognized at ground level. Even where archaeological features are known to exist, an aerial perspective can expose unforeseen associations between individual features and, consequently, alter their interpretation. While relief features like earthworks and roads are archaeological remains in their own right, other features, including soil and crop marks, are more often a surface expression of buried remains. In these instances, anomalous soil moisture levels associated with subsurface structures are manifest visually as soil discolourations or related abnormalities in the maturity and vitality of overlying vegetation (Figure 1).

From its beginnings in First World War aviation, archaeological remote sensing has evolved from largely secondary examination of extant air photos to planned aerial reconnaissance using a variety of specialized sensors. Concurrently, with greater access to an aerial perspective, mapping of known archaeological sites has joined the search for previously undiscovered features as a primary objective of archaeological remote sensing. It was toward this aim, that investigation of complementary ground-based sensing techniques began by the early 1950s. In contrast with air photo analysis, which relies entirely on the visual indication of buried remains, geophysical surveys are capable of detecting a variety of subsurface material contrasts that have little or no surface expression. Consequently, in addition to ground truthing aerial reconnaissance, geophysical prospecting can substantially extend the base of remotely sensed information available to the archaeologist. As usual, the complementary nature of geophysical methods is crucial and the most appropriate technique remains site dependent.

Electrical resistance and magnetic surveying were the earliest and remain the most widely employed prospecting methods in archaeology. In the wake of pioneering efforts in Europe, archaeologists, though not without reservation, recognized the great promise that these methods possess for locating the most fruitful areas in which to focus excavation. Indeed, in view of restricted funding available for archaeological research, pre-excavation site reconnaissance is valuable not only for directing the focus of limited excavation but for extrapolating the resulting information within both intra-site and intersite contexts. Many archaeological features produce characteristic geophysical signatures and once the sources of

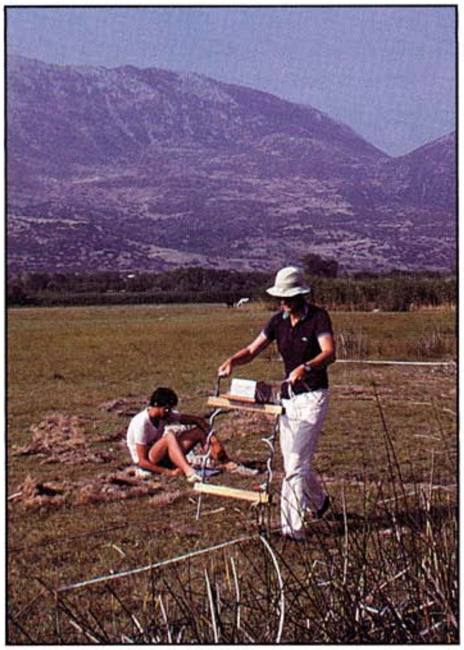


Figure 2. The Bradphys Mk IV resistance meter in operation at Stymphalos. The meter is mounted atop an insulating frame that incorporates a current-potential pair of electrodes as vertical members for rapid measurement.

these typical signals are established by excavation, recurrences may be interpreted on these precedents. Geophysical reconnaissance also has obvious advantages where archaeological excavation is obstructed by modern pavement and buildings or prohibited by legislation. Recent concern for cultural resource management acknowledges the nonrenewable nature of archaeological remains and has led to protection of sites in anticipation of future advances in archaeological method and theory. Legislation also provides for cultural impact assessments prior to initiating large-scale land development projects and, consequently, has necessitated time efficient methods of salvage archaeology. For these applications, geophysical sensing techniques are ideally suited for rapid non-invasive detection, assessment and inventory of cultural resources.

Over the past four decades, the full complement of geophysical methods has undergone adaptation, application and evaluation for detecting and mapping archaeological features. Although controlled source electromagnetic and radar surveys have proved well suited, none of the ensuing techniques have eclipsed the prominence of electrical resistance and magnetic mapping. The remainder of this article is devoted to two brief case histories illustrating archaeological applications of these methods.

CASE HISTORIES

The first example comes from the mountainous region of Arcadia in southern Greece. Although Greek authorities have not yet granted an excavation permit, electrical resistance measurements, since 1983, have mapped much of an orthogonally planned town of the fourth century B.C. on the northeastern shore of Lake Stymphalos. Guided by obvious visual evidence (Figure 1), a gridded area of roughly 50,000 m^2 has been surveyed at 1 m intervals using a Bradphys Mk IV earth resistance meter. The Mk IV unit was designed specifically for small-scale archaeological application and was employed in conjunction with a modified pole-pole electrode configuration known as the twin-probe array. This configuration maintains a reference current-potential pair remote from the measurement field while a second mobile pair of probes surveys the grid. The mobile electrodes are attached by an insulating frame that fixes their separation and also carries the meter as depicted in Figure 2. The interprobe electrode spacing was 0.5 m. Over much of the site, particularly near the lake, moist soil conditions ensured low contact resistances and, thereby, time efficient operation. On average, 400 measurements over a 20 m x 20 m grid required approximately 45 minutes. The resulting data are displayed in Figure 3, where image density is in proportion to the measured resistance. High resistance values are attributed to architectural remains constructed from local limestones having predominantly higher resistivities than surrounding lacustrine sediments. Additional anomalies reflect compacted soil structures including roads and walkways.

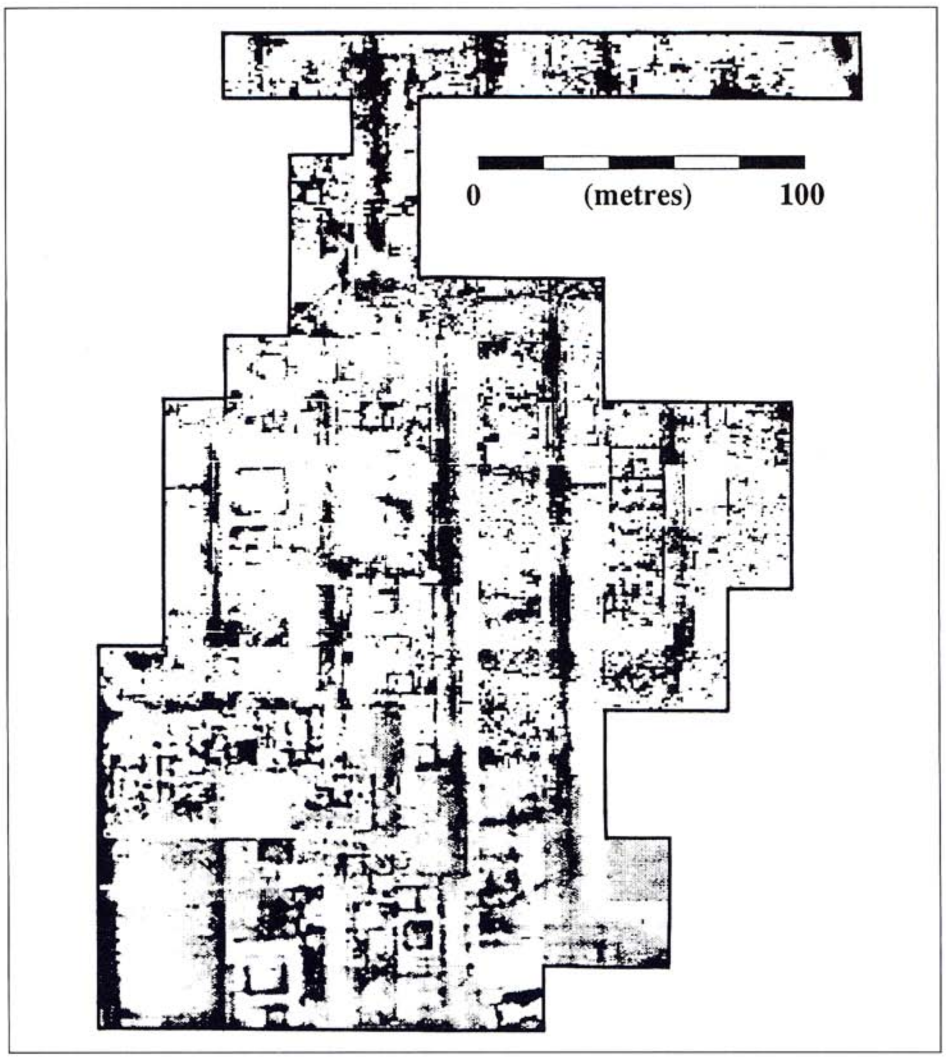


Figure 3. Variable density subsurface resistance map of ancient Stymphalos, revealing much of the town's orthogonal plan. The map is a composite of 20 m x 20 m survey grids each comprising 400 measurements. The mean grid value has been normalized from cell to cell to compensate for scale soil moisture variations over the site.

In summation, geophysical reconnaissance at the classical townsite of Stymphalos has already yielded preliminary interpretations of town planning and fortifications (Williams; 1983, 1984) and will undoubtedly prove valuable in guiding subsequent excavation, especially if costly land acquisition is required.

The Orkney Islands are the setting for a second example. Located north of the Scottish mainland and across the Pentland Firth, the Orkneys are well known for their wealth of megalithic monuments and otherwise rich Neolithic prehistory. Tofts Ness, on the isle of Sanday, is a Bronze Age settlement witnessed today by numerous earthen mounds on the northern coast of the island. Although excavation has been largely prohibited by the Scottish Development Department, much of the area has been surveyed geophysically using a combination of electrical and magnetic methods. Figure 4 displays a map of the vertical magnetic field gradient acquired over a 3200 m^2 grid including one of the surviving mound structures (Gater, 1987). Measurements were made using a Geoscan Research FM-36 fluxgate gradiometer, designed to accentuate shallow features of archaeological interest (Figure 5). The grid interval was 1.0 m, sensor heights were approximately 0.3 and 0.8 m and automatic data logging allowed survey of a 20 m x 20 m grid in less than 30 minutes. Although the resulting map is dominated by high gradients associated with the mound itself, the survey also exposed two circular features on the mound's flank. Evidence supplied by related excavation suggests that these features indicate the presence of a flagstone roundhouse and adjoining annex. This interpretation is based on a Bronze Age dwelling, having a similar plan and dimensions, that was revealed on excavating an adjacent mound. These excavations have also provided a physical basis for postulating the origin of magnetic anomalies observed in Figure 4.

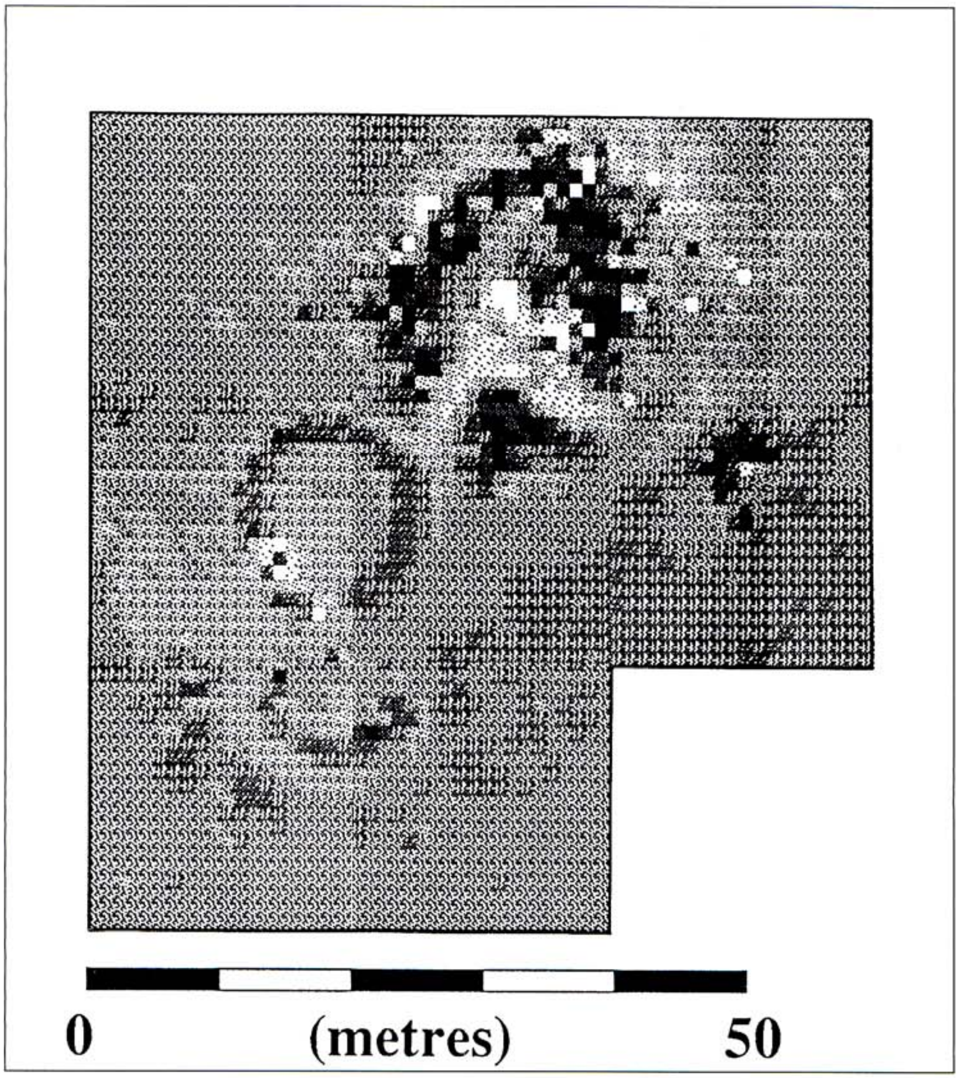


Figure 4. Vertical magnetic gradient map from Tofts Ness, indicating the existence of arcuate house forms (left centre) off the flank of an earthen mound (top right). The spatial sampling interval is one metre in both coordinates.

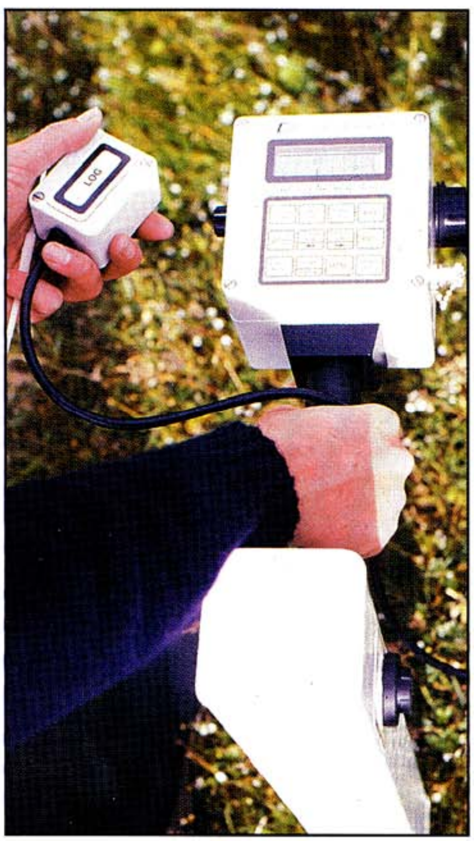


Figure 5. The Geoscan Research FM-36 fluxgate gradiometer as viewed by the operator. The fluxgate sensors are housed in the vertically oriented tube at the bottom of the photograph. The operator's left hand is holding a trigger device to activate an internal data logger.

The excavated mound was largely composed of rich midden deposits, including a mixture of burned soil, shell, bone and a variety of carbonized botanical remains; largely the refuse of food processing. As a result, high magnetic gradients associated with these deposits have been explained by reduction and subsequent re-oxidation in connection with burning. In fact, the conversion of natural haematite to maghaemite by this process is accepted as the chief mechanism responsible for enhancing the magnetic susceptibility of archaeological soils. The same explanation can be offered to account for the circular features observed in Figure 4. Here similar debris, including burned soil, surrounding the exterior of the roundhouse may give rise to the enhanced magnetic response outlining the structure. Reduced accumulation, together with a thicker overburden, can account for relatively lesser field gradients associated with the house forms than with the mound itself.

This example illustrates the utility of geophysical reconnaissance for extending information yielded by limited excavation to areas where excavation is prohibited or otherwise restricted.

CONCLUSION

Although geophysical mapping is already a routine component of modern field archaeology, growing pressure on limited cultural resources continues to drive development of new techniques for remote assessment of buried archaeological remains. Current research focuses on the adaptation and application of ground penetrating radar, high-resolution seismology and other techniques capable of extending remotely sensed data to three-dimensions. Having identified probable archaeological features by standard mapping methods, radar and seismic techniques can be subsequently employed to facilitate a cross-sectional perspective, revealing the depth and form of buried remains together with related stratigraphic information. Of course, an obvious future direction is to explore the potential of geophysical tomography to yield fully three-dimensional images of the subsurface. Although remote sensing can never replace archaeological excavation, there can be little doubt that geophysical prospecting will have an increasingly important role in archaeology of the future.

ACKNOWLEDGEMENTS

The author is grateful to Hector Williams of the Department of Classics at the University of British Columbia and Steve Dockrill of the Department of Archaeological Sciences at the University of Bradford for permission to use data from ongoing projects at Stymphalos and Tofts Ness, respectively, and to John Gater for providing the magnetic map from Tofts Ness. Thanks are also owed to the Archaeological Society of Athens, the Canadian Archaeological Institute at Athens, the Scottish Development Department (Historic Buildings and Monuments) and the Social Sciences and Humanities Research Council of Canada.

REFERENCES

Aitken, M. J., 1974, *Physics and Archaeology*, Oxford University Press.

Butzer, K. W., 1982, *Archaeology as Human Ecology*, Cambridge University Press.

Gater, J. A., 1987, Geophysical survey at Tofts Ness, *Archaeology Extra*, 4, Department of Archaeological Sciences, University of Bradford, U. K..

Rapp, G., Gifford, J. A., 1985, *Archaeological Geology*, Yale University Press.

Scollar, I., Tabbagh, A., Hesse, A., and Herzog, I., 1990, *Archaeological Prospecting and Remote Sensing*, Cambridge University Press.

Tite, M. S., 1972, *Methods of Physical Examination in Archaeology*, Academic Press.

Tite, M. S., 1991, Archaeological science - past achievements and future prospects, *Archaeometry*, 33, 139-151.

Weymouth, J. W., 1986, Geophysical methods of archaeological site surveying, *Advances in Archaeological Method and Theory*, 9, 311-395, Academic Press.

Williams, E. H., 1984, Investigations at Mytilene and Stymphalos, 1983, *Classical Views*, XXVIII, 2, 169-186.

Williams, E. H., 1985, Investigations at Stymphalos, 1984, *Classical Views*, XXIX, 2, 215224.

ABOUT THE AUTHOR

Guy Cross is working toward a Ph.D. in geophysics at the Department of Geophysics and Astronomy of the University of British Columbia in Vancouver.