Overview

Geophysical survey in archaeology most often refers to ground-based subsurface mapping using a number of different sensing technologies. Most commonly applied to archaeology are magnetometers, electrical resistance meters, ground penetrating radar (GPR) and electromagnetic (EM) conductivity. These methods provide excellent resolution of many types of archaeological features, and are capable of high sample density surveys of very large areas and of operating under a wide range of conditions. Other established and emerging technologies are also finding use in archaeological applications.

Geophysical survey has long been a standard tool of archaeology in Europe, particularly Great Britain, but is only slowly gaining acceptance this country. North American archaeology has presented unique challenges that have spurred the development of instrumentation, survey design, and interpretive models. With increasing numbers of skilled practitioners and the development of methodologies suited for North American sites, highly successful surveys are becoming the norm.

No geophysical method can be applied indiscriminately with any expectation of success. Soils, geology, surface conditions, vegetation and terrain, feature type, size, composition, depth, modern impacts, and many other factors must be considered in determining feasibility, appropriate instrumentation, and survey design. Although mathematical models may be applied to survey design problems, field conditions are difficult to quantify. In spite of ongoing progress in this field, assessment is largely qualitative and empirical. Issues related to interpretation are similar, and experience is critical in understanding how the archaeological record is expressed geophysically.

Use of multiple methods is good practice in most geophysical survey applications. Not only does this increase the likelihood of success with at least one method, it can greatly enhance interpretability. Because each geophysical method responds to different properties, multiple data sets are complementary rather than redundant. For example, a resistance high might correlate with a magnetic dipole, identifying (depending on the cultural context) a possible hearth, whereas either anomaly by itself would be ambiguous.

The general procedure followed to perform most ground-based surveys is to divide the survey area into a series of square or rectangular survey "grids" (terminology can vary). Each grid is surveyed by taking readings at regular intervals along regularly spaced transects. Successive transects are surveyed in a zigzag pattern until the grid is completed. The value and position of each data point is recorded, generally in digital format. Occasionally, these instruments are also used for less formally "scanning" areas of interest.

Application concerns

Cost effectiveness

Continuing advances in the performance and automation of survey equipment have made it possible to survey large areas quite rapidly, while simultaneously improving the quality and resolution of results. The cost of geophysical survey is very often offset by a reduction in the expense of exploratory excavation and associated analysis and curation. A subsurface map can allow researchers to target areas for excavation, allowing larger sample of positive data to be collected within limited budgets. Geophysical methods have been most typically employed on large, complex sites. However, geophysical survey can be an extremely effective (and cost-effective) approach to studying smaller or more ephemeral sites as well.

Survey speed (and therefore cost) is largely dependent on logistical factors such as survey design, vegetation, and the layout of the survey area, and these should be anticipated in the planning process. The cost of crop damage, if it cannot be avoided, should be considered as well.

Data Sample Density

Data sample density, often expressed in samples per square meter, determines the effective resolution of the survey as well as the rate of coverage. Sample density is therefore a compromise between cost and the likelihood of resolving anticipated features of interest. No meaningful consideration of survey design or budget can occur without considering sample density. Although appropriate sample densities differ between each instrument, the sample interval should be proportional to the scale and contrast of anticipated features. Appropriate transect intervals for mapping of archaeological features typically range from 0.25 to 1 meter, with multiple readings per linear meter along each transect.

Fast and efficient reconnaissance surveys over a very large area are sometimes applied. These surveys may in some circumstances be used to define areas with a high probability of containing archaeological features that can then be subjected to more rigorous (and expensive) high-resolution survey strategies. Reconnaissance surveys may also define the extent of an occupation, or more ephemeral patterning in the landscape such as roads, trails, drainage or irrigation systems, and fields, even where no tangible archaeological features survive. Reconnaissance surveys typically apply different geophysical methods than standard high-resolution survey (topsoil magnetic susceptibility for example), and employ a sampling strategy that is considerably coarser, with transect intervals ranging from one to ten meters.

Spatial Control

The usefulness of these survey results is dependent on accurately locating anomaly sources within the survey area. Accurate and repeatable spatial control is critical in both grid layout and data collection. It is strongly recommended that the survey grid system be permanently referenced using a GPS, permanent datums, or other suitable means. Whenever practicable, the geophysical survey grid should use the same coordinate system as the site grid.

Interpretation of Geophysical Survey Results

The results of geophysical surveys of archaeological sites are generally presented graphically. This is done because anomalies of cultural origin are recognized by their spatial pattern, rather than by their numeric values alone. When rendered graphically, we can better recognize cultural and natural patterns and visualize the physical phenomena causing the detected anomalies. Interpretation of survey data must be an ongoing process involving both archaeological geophysicists and archaeologists that are familiar with the specific cultural context. An understanding of the geological context of the survey area is also very important.

Ground truthing (limited invasive exploration) will greatly inform interpretation of these data. Ground truthing may employ a variety of techniques, including coring, slit trenches, or formal excavation. A successful testing strategy is rapid and methodical, and minimizes impact to the site. Verification (or refutation) of preliminary interpretations and insights into feature composition and geology can allow us to revise or elaborate our interpretations, and to do so with greater confidence. The results of geophysical surveys and ground truthing should be used in conjunction with other available sources of information to understand the general site context, to locate features for excavation, and to understand the results of excavation within the greater site context.

Integrating Geophysical Methods

Geophysical methods are most successful as part of an integrated and flexible research design. Planning for geophysical survey should be considered from the inception of a project, and the potential information that geophysical data may offer should be anticipated. Planning of a hypothetical project might anticipate the following stages:

- Define research goals
- Site reconnaissance, sample collection
- Assess feasibility
- Develop appropriate survey design
- Conduct survey
- Develop preliminary interpretations
- Ground truthing
- Refine interpretations
- Excavation
- Model site context integrating excavation, geophysical, environmental and other available data

Flexibility must be designed into every stage of the research program, as survey findings cannot be reliably predicted, and because each stage will inform subsequent stages.

As geophysical methods become increasingly common, their future use should be anticipated even when they are not part of current research plans. Noting conditions that might affect geophysical methods and collecting small samples of soils, rock, and cultural materials may be invaluable in the future. Very critical, and often overlooked, is the effect of metal artifacts left on sites by archaeologists themselves. Steel pinflag stakes, nails, datums, etc. that are deliberately or accidentally left on sites can have a very detrimental effect on magnetic data. Whenever possible, plastic, wood, or aluminum substitutes should be used for these items. It is hoped that these considerations will be reflected in standard archaeological practices in the near future.

Specialist Standards and Training

Although there have been successful geophysical surveys performed by non-specialist archaeologists, a high degree of training and experience is necessary to achieve consistent success. The cost of geophysical instrumentation can also be prohibitive. Archaeological geophysics is quite distinct in its emphasis and methods from other geophysical disciplines. The demands of extremely high resolution of generally shallow and very subtle phenomena have resulted in a very different methodology that that of other applications of geophysical sensing. Practitioners must also have an understanding of site formation, site structure, feature composition, and archaeological method and theory in order to make competent cultural interpretation and recommendations.

At this time, practitioners of archaeological geophysics come from a diverse range of backgrounds, as there has not been, until recently, formal specialist training in this field in the United States. Criteria for selecting a practitioner might include:

- A demonstrated ability to conduct a technically competent and cost-effective survey
- A demonstrated ability to make cultural interpretations and recommendations based on geophysical data
- Effective reporting and meaningful post-survey support
- A record of success in survey and interpretation in a variety of physical settings and site types
- Success in cultural and physical contexts similar to that of a proposed project
- They have an integrated, flexible, and site-specific approach to research design

In recent years, a number of Universities in this country have begun offering training and degree programs in archaeological geophysics. These programs are certain to result in the evolution of standards and greater use and availability of geophysical techniques.

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