Geophysical Survey as an Approach to the Ephemeral Campsite Problem: Case Studies from the Northern Plains

Geoffrey Jones and Gene Munson

Temporary campsites and indeterminate artifact scatters are a perennial problem in archaeology. Features and artifacts are few, often scattered across an extensive area and representing considerable time depth. Meaningful and cost-effective data recovery is difficult using conventional methods. Integrated with more traditional methods, geophysical methods have proven to be an effective approach on many sites on the northwestern Great Plains. Hearths, stone rings, and other features can be detected and mapped, allowing researchers to target areas for excavation and understand intra-site patterning.

Keywords: magnetic survey, gradiometer, campsite, geophysics, hearths

Temporary campsites and indeterminate artifact scatters form a large percentage of prehistoric sites throughout North America, and especially on the northwestern Great Plains, where village sites are rare. It is obvious that our understanding of prehistoric lifeways is incomplete, if not deeply flawed, without understanding temporary campsites. Unfortunately, cost-effective data recovery from these sites is problematic using conventional sampling and excavation methods. Diagnostic artifacts and datable features are often present (or may be presumed to be present) but they are few and often scattered across an extensive area. When only a small percentage of a site may be sampled, recovered data are often inadequate to address meaningful research questions. Often these sites have distinct intra-site patterning and multiple components may represent considerable time depth.

Hearths and stone rings (tipi rings) are the most typical features of campsites on the northern Plains (for the purposes of this article, the term hearth is broadly used to indicate a variety of thermal features). Magnetic field gradient survey has been proven to be highly successful at detecting thermal features, and in certain conditions, stone rings, as well. Although this article focuses on a single method, there are a number of other geophysical methods commonly applied to archaeology. These case studies are generally illustrative of a geophysical approach, discussed in broader terms in a concluding section. As part of an integrated research strategy, geophysical mapping can allow researchers to better target areas for excavation, to collect a larger sample of positive data within limited budgets or schedules, and to study intra-site patterning beyond the limits of excavation.

The case studies presented in this article were selected from the results of 55 discrete survey areas at 21 prehistoric campsites in Campbell and Weston counties in northeastern Wyoming, and in Rosebud and Big Horn counties in southeastern Montana (Figure1). They have been selected because they are illustrative of issues associated with this approach. Most of the 55 survey areas contained anomalies thought to be caused by prehistoric hearths or other archaeological features, and they are reasonably well represented by the specific case studies presented here. Geophysical data collection was performed between 2000 and 2003 by David Maki and Geoffrey Jones of Archaeo-Physics, LLC,

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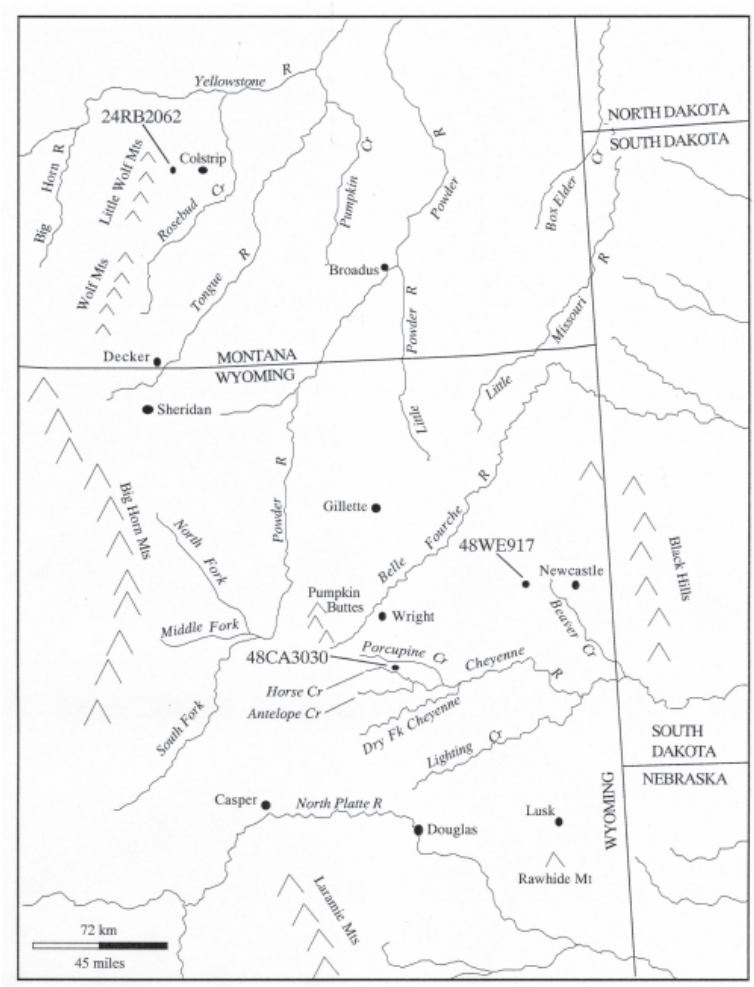


Figure 1. Regional map showing site locations.

as part of the archaeological treatment of these sites under the direction of Gene Munson of GCM Services, Inc. (Munson 2002a, 2002b, 2003a, 2003b, Munson et al., 2004).

METHODS

While an in depth discussion of magnetic theory, survey logistics, and data processing is beyond the scope of this article, both Clark (1996) and Gaffney and Gater (2003) provide excellent introductions to archaeological geophysics. Survey logistics, data processing, and technical parameters are dealt with in individual reports of investigation (Jones 2001a, 2001b, 2003). A brief non-technical introduction to magnetic field gradient survey is presented in the following paragraphs.

The geophysical surveys presented in this article were performed with a Geoscan FM36 magnetic gradiometer (Figure 2). This instrument records local variations in the earth's magnetic field, primarily caused by differences in the magnetic properties of subsurface materials. The instrument responds only when in close proximity to discrete anomaly sources. Near-surface phenomena can be mapped in detail while deep or large-scale phenomena (typically geological) are largely suppressed. The results are presented graphically because archaeological features are generally recognized by their pattern, rather than by their numeric values alone. Typically, the resulting map will have a background value of approximately zero, with local distortions in the geomagnetic field appearing as negative and positive anomalies. Values are recorded in nanoTeslas (nT), indicating relative magnetic strength.

The principal phenomenon causing detectable features on these sites is thermal alteration of minerals in soils and rock. The temperatures caused by prehistoric hearths can alter (usually increase) the magnetic susceptibility of minerals as well as cause thermo-remanent magnetization (TRM). Susceptibility is a measurement of the ease with which the geomagnetic field flows through a material. The geomagnetic field will flow preferentially through materials that are of higher susceptibility than their surroundings and cause locally higher field strength, called induced field magnetization. Other cultural sources of induced field anomalies include organically enriched deposits and disturbed soils. TRM is a permanent magnetization acquired when minerals have heated to a critical level called the Curie

Figure 2. Magnetic survey at the Malodorous site and FM36 Fluxgate gradiometer (inset).

temperature, generally between 120 and 675 ^{O}C. If its source is undisturbed, a TRM field will retain the orientation and intensity that were fixed at the time of cooling (the basis for archaeomagnetic dating).

Magnetic anomalies are often the result both of induced field and remanent magnetization. The observed magnetic field strength is the result of the total magnetization of an object. The total magnetization is thus a vector sum of the induced magnetization and the remanent magnetization (Sharma 1997). In general, induced fields appear in magnetic field gradient surveys as a positive monopole, while remanent fields appear as bipolar anomalies, having both a positive and negative component. In practice, it is not possible to quantify the different contributions causing an anomaly in survey data, although estimations may be made based on anomaly strength and appearance.

While in-situ hearths often appear as bipolar anomalies because of remanent magnetic effects, most of the suspected hearths at these sites appear with only a very weak negative component. An explanation for this is that with time, bioturbation and other small-scale disturbances randomly re-orient sediment grains in the soil. The many small randomly oriented remanent fields of each sediment grain would largely cancel each other out, leaving susceptibility effects as the dominant anomaly source. Other cultural features, such as pits, middens, and historic privies can also cause magnetic highs. These too are due to enhanced susceptibility, and may appear very similar to hearth features. In general, magnetic anomalies caused by organic enrichment or disturbed soils alone are of low amplitude, although additional components such as metal artifacts or thermally altered minerals may contribute as well.

The term "thermally altered rock" is used in this article to refer to either natural or cultural materials. The sedimentary bedrock in its original state does not display appreciable remanence (permanent magnetization) or high susceptibility, but may be altered by burning coal seams. Rock that had been altered by burning coal was found to display a strong remanence and enhanced susceptibility. Based on magnetic survey results alone, it is not possible to distinguish between rocks that have been altered by cultural processes from those occurring naturally except by their patterning. Rocks, otherwise natural, may also be culturally transported.

Near surface geology and historic cultural phenomena may also cause anomalies in survey data, commonly stronger and often more pervasive than those caused by prehistoric features. Metal, brick, and other historic materials and features can cause very strong anomalies. Fortunately, these materials are not often pervasive on sites on the northwestern Plains. Rock formations (especially igneous) and heterogeneous sediments may also cause strong and pervasive variance that can obscure more subtle anomalies of interest.

3030 WINCHESTER

The 3030 Winchester site (48CA3030) (Figure 3) is a Late Prehistoric campsite located 31 km south-southeast of Wright, Wyoming in the eastern Powder River Basin. The site is on the north side of Horse Creek in southern Campbell County just north of the Converse and Campbell County line. It was originally identified and evaluated by GCM Services (Munson 1997). At the time of its discovery, two eroding rock-filled hearths, two clusters of thermally-altered rock, and nine lithic artifacts were observed on the surface. The eroded nature of the terrace on which the site is located did not inspire confidence that additional features would be found. Gradiometer survey, completed in only a few hours, was performed over a 3900 square meter area encompassing most of the site. The results clearly showed an additional seven hearth features as well

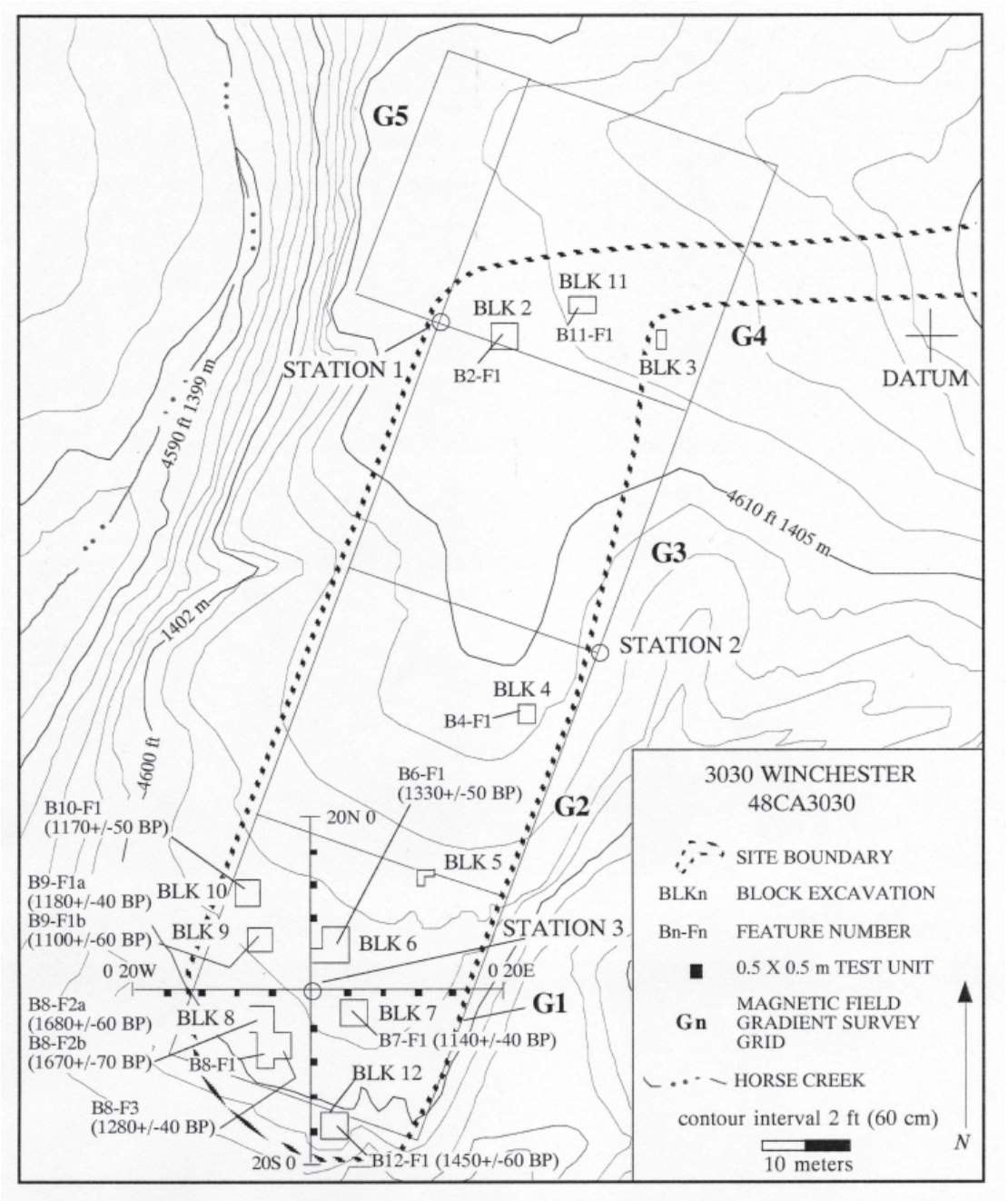


Figure 3. Site plan of the 3030 Winchester site (48CA3030).

as an exposed but previously undetected concentration of thermally altered rock. An exposed hearth that had been previously recorded was detected as well.

Excavations at 3030 Winchester consisted of 12 block excavations and 15 test units measuring 0.5 x 0.5 m. The block excavations were scattered over an area measuring 105 m north to south by

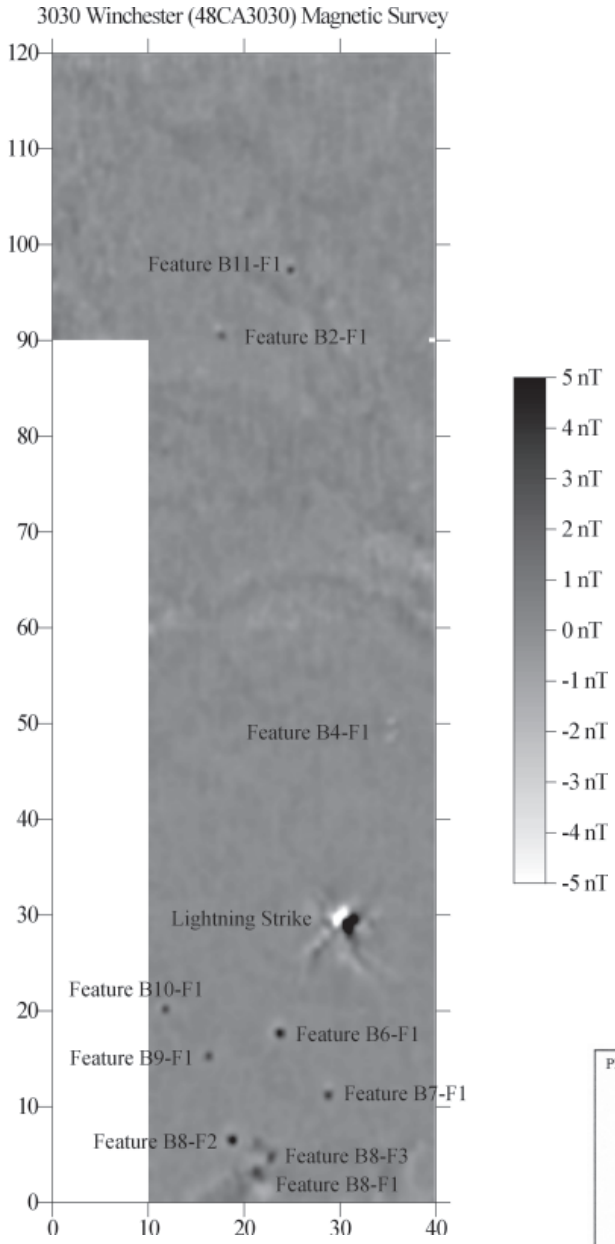


Figure 4. 3030 Winchester magnetic survey results.

125 m east to west. All except three of the block excavations were at magnetic anomalies. The test units were placed at an arbitrary interval of four meters, centered on Station 3. (Figure 3). Station 3 is where the majority of the cultural remains were located at the site. No features or intact cultural horizons were found in the test units. A total of 104.75 square meters was excavated by hand. In addition, 102 m of backhoe trenches were dug in search for deeply buried cultural deposits (Figure 3).

The seven subsurface hearths appear in the data plot (Figure 4) as circular magnetic highs, from 3.5 to 9.5 nT in amplitude. The associated negative component is diffuse and weak, but may be slightly stronger to the north of the positive component. An example of one of the rock-filled hearth features and the associated magnetic anomaly is shown in Figure 5. The single exposed hearth within the survey area (B8-F1) appears as a less distinct positive anomaly. The appearance of Feature B4-F1, a small exposed scatter of thermally-altered rock, as a largely negative anomaly was unexpected, and it is thought to be caused by the coincidental orientation of the TRM field of the rocks. A large complex bipolar anomaly was determined to be caused by a lightning strike (Jones and Maki 2005; Verrier et al. 2002).

There is a strong relationship between the size and composition of hearth features and the strength and appearance of the associated anomalies. All of the intact hearth features associated with >6 nT anomalies contained substantial amounts of thermally-altered rock; all of those associated with weaker anomalies contained none. Although negative components were weak, bipolar anomalies were associated

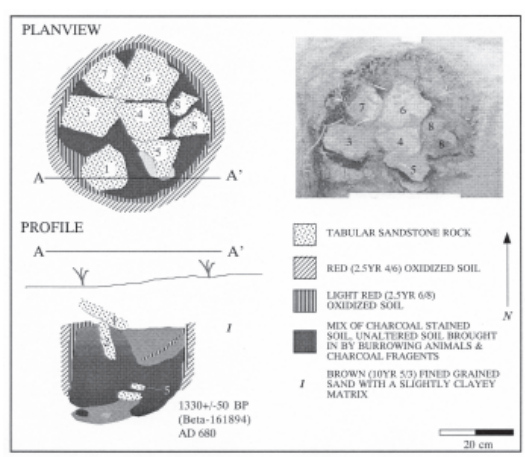
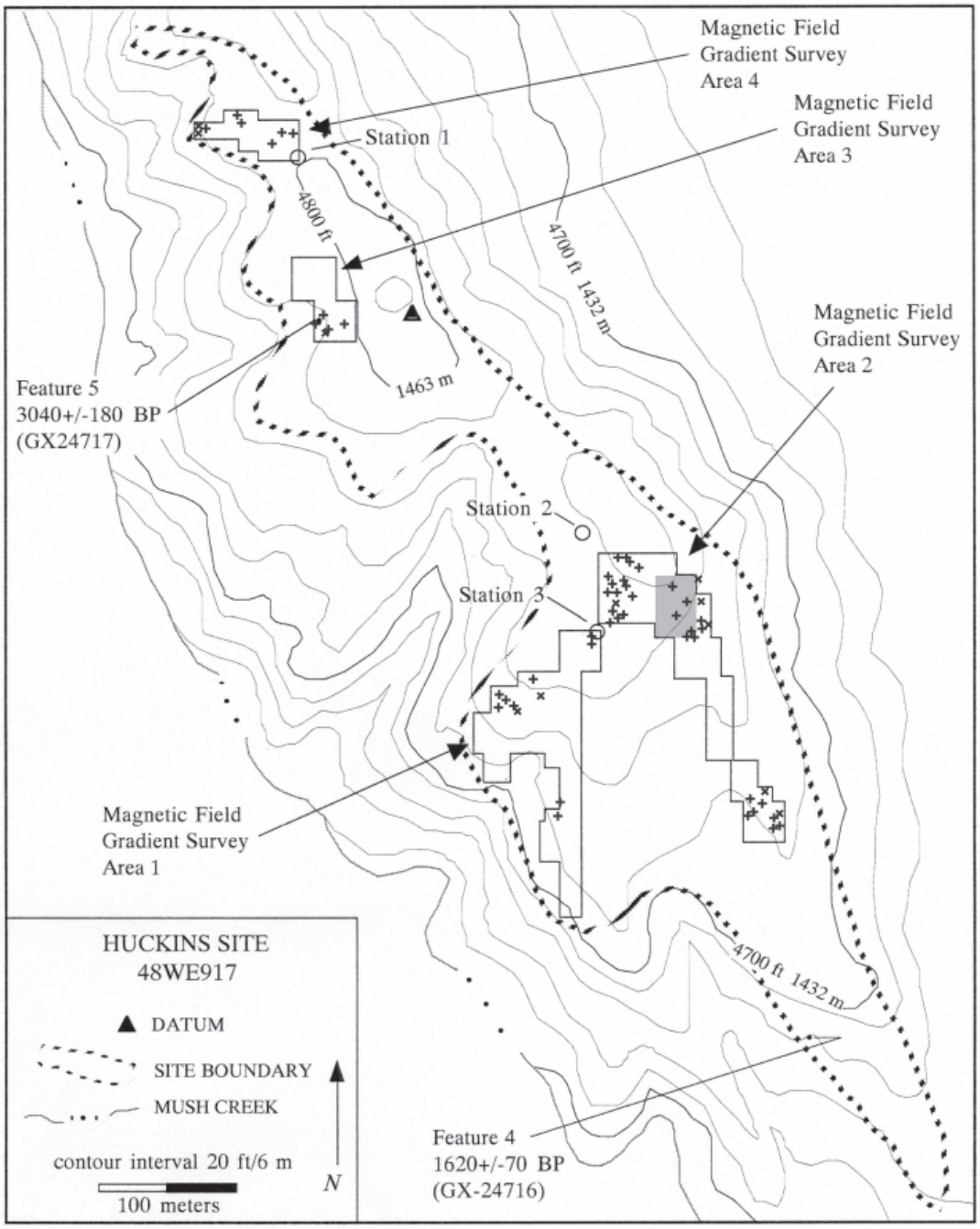


Figure 5. Planview and profile of Feature B6-F1.



+ Anomalies thought to be associated with hearth features
× Anomalies associated with confirmed hearth features
Shaded area is presented in detail in Figure 7

Figure 6. Site plan of the Huckins site (48CA917).

with thermally-altered rock. The two strongest anomalies were associated with the features containing the greatest volume of thermally-altered rock and soil (B8-F2 and B6-F1). Although all of the detected features were excavated, the correlation between feature composition and associated anomalies demonstrates that anomaly type may be of predictive value. Experience has shown, however, that geophysical results should be ground truthed on every site, and that interpretation should be made cautiously. The criteria posited above may be valid for this site, but cannot be extrapolated to other sites where geologic conditions, feature composition and preservation, and other factors may differ.

THE HUCKINS SITE

The Huckins site (48WE917) (Figure 6) is located on a timbered ridge on the eastern edge of the Powder River. The site is 27 km west of New Castle, Wyoming, and is on top of the first timbered ridge west of the Black Hills, 35 km distant. The view that this ridge offers across thousands of hectares of big game habitat is thought to be a major reason for the habitation of the site. Mush Creek borders the west side of the site. Here the creek has cut a steep-sided ravine into the upper Cretaceous Lance Formation's pale brown sandstone and gray to pale brown shale. The creek channel is some 30 m lower in elevation than the site (Figure 6).

Based on artifacts recovered from the surface, the Huckins site appears to have been repeatedly occupied from at least the Late Archaic to Late Prehistoric periods. At least four distinct point types are present. The Late Plains Archaic Period projectile points are Powers-Yonkee, Pelican Lake-like corner-notched and Besant side-notched, and the Late Prehistoric and/or Plains Woodland projectile points are small corner-notched arrow points.

The site is spatially extensive, running over a kilometer along the narrow ridge. Open air campsites such as Huckins are often a composite of clusters of features and artifacts. This type of site may cover hundreds if not thousands of square meters, but in reality there are large areas within it that are virtually devoid of cultural remains. The geophysical survey was undertaken as part of phase II evaluation of the site in order to identify loci that might be associated with different occupations and activities. It is unlikely that conventional methods alone could produce a large enough sample of positive data for meaningful description and hypothesis testing on a site of this size and complexity.

The magnetic survey was conducted over four survey areas totaling 1.9 hectares. This sampling of the roughly 10-hectare site covered much of the ridge top that was not extensively eroded and not overly rugged, and was based on the assumption that cultural features would more likely occur in level, even terrain.

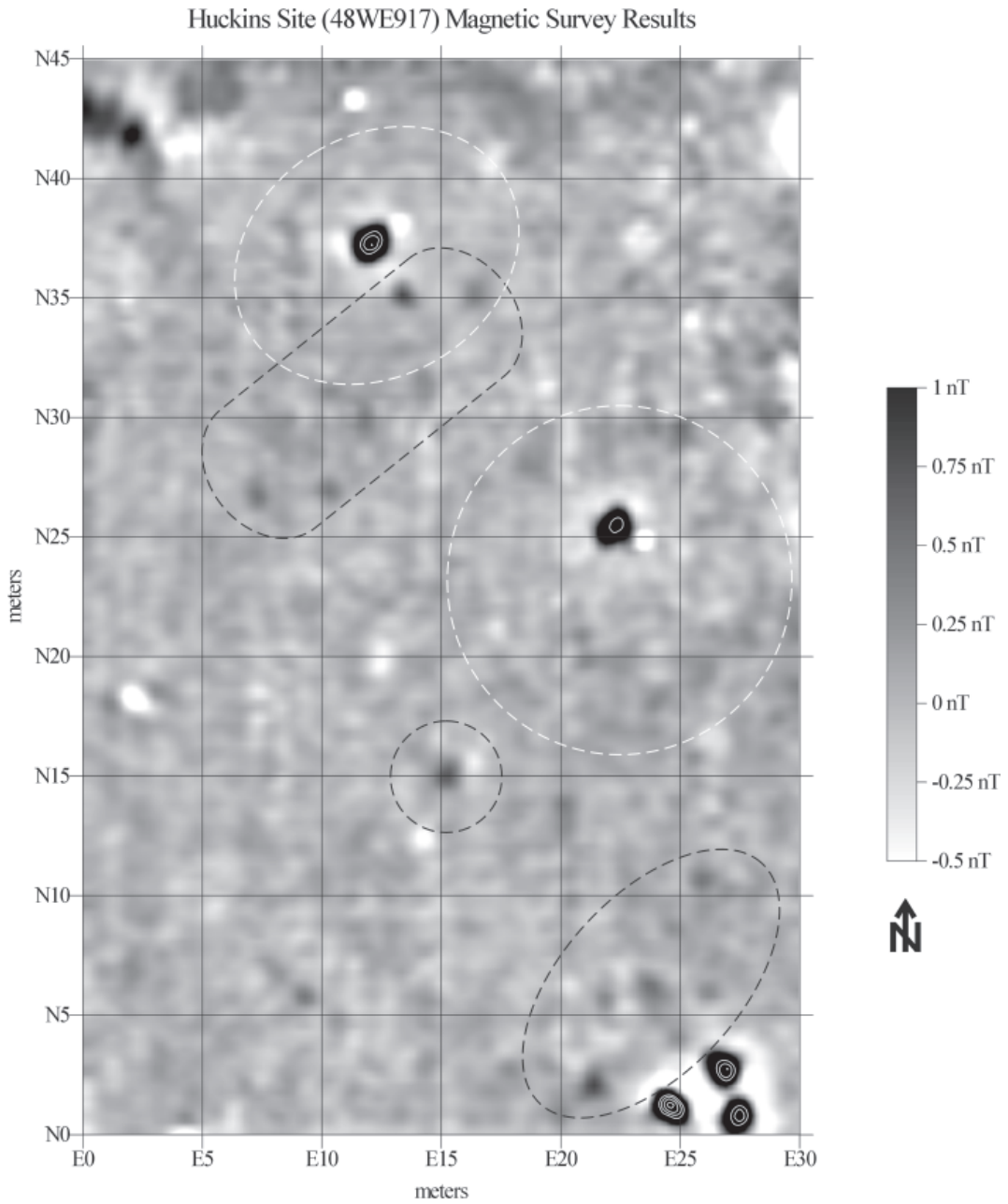
The distribution of suspected thermal features is illustrated in Figure 6. The 61 marked anomalies represent those thought to have a moderate to high probability of associated features. Of these, 10 have been confirmed as thermal features. Many weaker or poorly defined anomalies that may be associated with features are not marked, but are similarly distributed. A detail from Area 2 is shown in Figure 7, illustrating a typical range of anomalies from this site.

Preliminary ground truthing or exposure by erosion has confirmed that several anomalies are associated with prehistoric hearths. All six of the tested anomalies are rock-filled thermal features. Additionally, four anomalies are associated with hearths visible on the surface. Although systematic data recovery has not yet been performed at the Huckins site, it is probable that the survey results will not only guide the excavation of the site, but will be useful in addressing research questions regarding cultural chronology, site function and structure, subsistence, seasonality, and social organization.

Limited electrical resistance survey was performed on a portion of Area 2. This method records differences in the electrical resistivity of subsurface materials. The instrument responds to differences in grain size, organic content, moisture content, and chemistry. Hearths were detected as resistance lows, probably because of concentrations of rocks within the features.

Apparent patterning of the geophysical data suggests additional hypotheses that may be tested, all of which have implications on the types of research questions mentioned above.

1. The distribution of suspected hearths is distinctly clustered. Clusters of hearths may represent:
    a. Single components
    b. Multiple components representing re-



Contours represent values of 2nT and greater, at intervals of 1nT
Dashed black lines indicate faint or poorly defined anomalies of possible interest (not shown in Figure 6)
Dashed white lines indicate very faint "rings" around prominent hearths, possibly associated with structures

Figure 7. Detail from Area 2 of the Huckins site.

peated (seasonal or traditional) occupations by a single group

c. Multiple components representing repeated exploitation of favorable locations by various groups

2. There is a very wide variation in the magnetic strength of anomalies having the appearance of hearth features. The amplitude of suspected hearths ranges from nearly imperceptible to over 40 nT, a far greater range than was observed at 3030 Winchester. Variability in anomaly strength may be due to:

a. Feature type

b. Differences in physical properties within feature types (e.g., mass, degree of thermal alteration)

c. State of preservation

d. Geologic environment

e. Depth to feature

f. Age of feature

3. Anomaly strength appears to be spatially patterned. For example, the strongest anomalies appear in Area 2, while Area 1 is characterized by generally weak anomalies. If this patterning is cultural in origin, anomaly type might be used as an indicator of age, cultural affiliation, or site use. Of course, this kind of reasoning must be applied very cautiously (if at all), and only with a preponderance of corroborating evidence. The small sample of diagnostic artifacts and dates available at this time is insufficient to generate specific hypotheses.

THE MALODOROUS SITE

The sites under consideration have generally had little magnetic "clutter" from geologic or historic cultural sources. Relatively subtle anomalies due to prehistoric features are often readily detectable against fairly uniform geologic backgrounds. The Malodorous site (24RB2062) (Figure 8) is an exception to this generalization, and it was chosen as a case study illustrating the use of data processing to overcome the technical challenge of a strong magnetic field at a site. The survey also located buried stone rings (Figure 9). No stone rings were suspected at the site previous to the survey.

The Malodorous site is 16 km west of Colstrip, Montana. The western edge of the site borders a north- to south-trending ponderosa pine-covered canyon that is drained by the West Fork of Armells Creek. The site lies within the Tertiary Fort Union Formation. This formation contains thick seams of coal. Through erosion, many of the coal seams were exposed and some were subsequently ignited by lightning, grass fires or, perhaps, spontaneous combustion. The intense heat generated by the burning coal metamorphosed the interbedded sandstones and shales into various grades of clinker.

Sedimentary rocks typically lack appreciable remanence and are often low in susceptibility, but may become highly magnetic when thermally altered. This is, of course, the principle that makes many features detectable, but it becomes problematic where thermal alteration has occurred naturally. The burning of the coal seam beneath the Malodorous site has resulted in very strong magnetic fields whose gradients are too steep to be suppressed by the configuration of the instrument. Figure 10 shows high amplitude variance throughout this data set (note that range of the scale is 250 nT). Although some anomalies that were thought to be caused by features of interest do appear, they are difficult to distinguish.

A statistical filter was designed to suppress the geologic background and enhance small, weak anomalies. This technique, called highpass filtering, subtracts the local mean from each data point. The dimensions and weighting of the window used to calculate the local mean of each point must be adapted to site-specific conditions. Processed data plotted in Figure 11 shows small local anomalies in greater contrast against a "flattened" geologic background. Unfortunately, operator/instrument induced defects are enhanced as well. While these can generally be distinguished by their rectilinear patterning, they may obscure more subtle cultural patterning.

When excavation results are compared to the magnetic data plot, the relationship between many of the features and associated anomalies can be seen. This data set has a standard deviation of 3.8 nT, roughly four times that of the other sites under consideration. Although anomalies of interest are less apparent in this magnetically cluttered data set than in the other case studies presented, many of the features were accurately identified prior to excavation. While hearth features proved difficult to distinguish, all of the stone rings recorded at the site (with one exception) were identified based on the magnetic

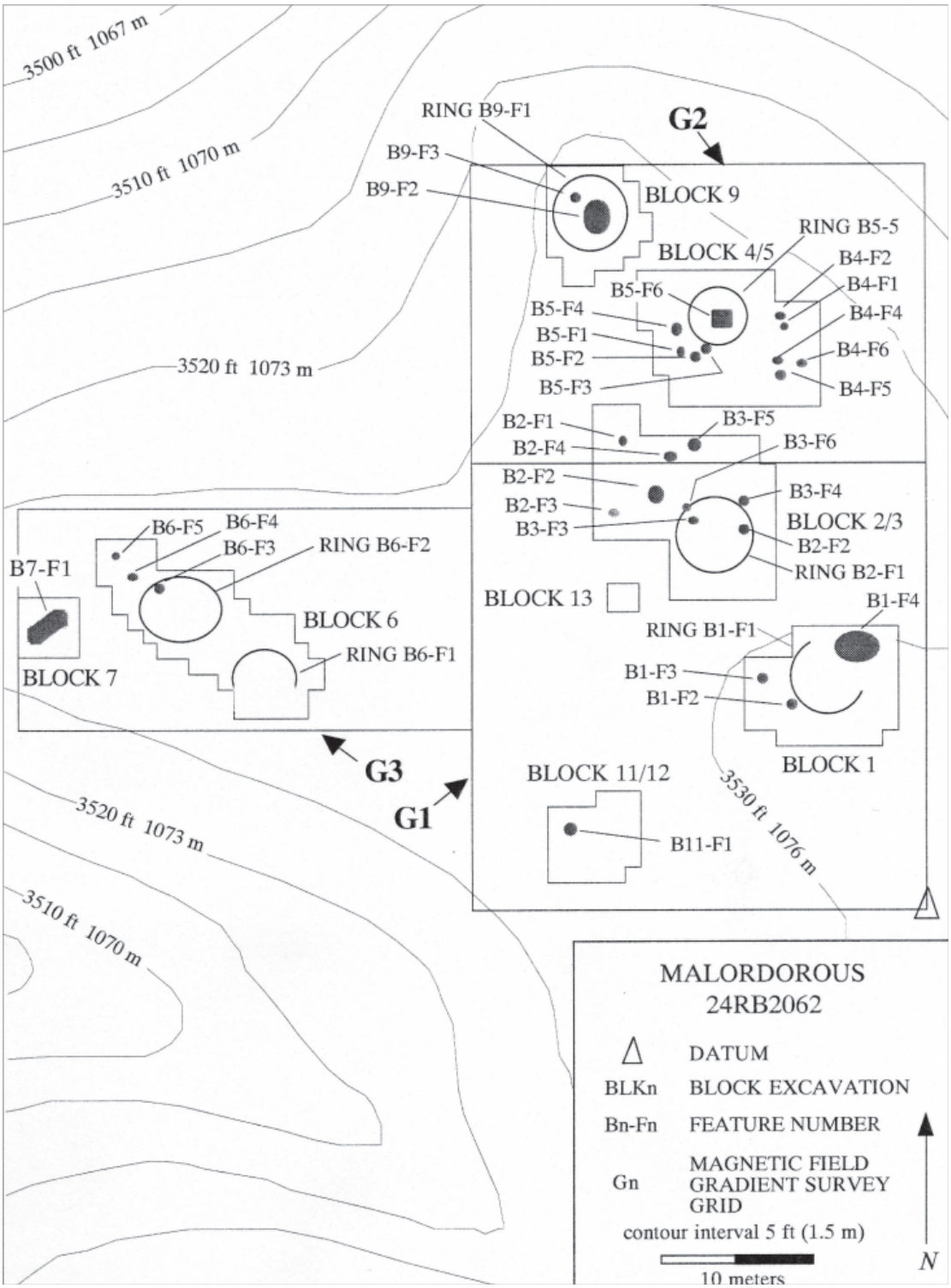


Figure 8. Site plan of the Malodorous site (24RB2062).

Figure 9. Feature B5-F5, an example of stone ring features from the Malodorous site.

survey results. Five stone rings were identified by cultural patterning of naturally occurring thermally-altered rock. A sixth ring was discovered during excavation that was not apparent in the geophysical survey data, suggesting that it was composed mainly of unaltered local rock.

CONCLUSIONS

Geophysical methods have been most typically employed on large, complex sites. However, they can be an extremely effective approach to studying more ephemeral sites as well. The relative simplicity of the sites under consideration has made geophysical interpretation unusually straightforward when compared to sedentary sites where a high density of features and complex stratigraphy may be present.

In spite of its success in these cases and many others like them, successful employment of any geophysical method requires careful consideration of many factors in order to be successful. Soils, geology, surface conditions, vegetation and terrain, feature type, size, composition, and depth, modern impacts, and many other factors must be considered to determine 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 archaeological features are expressed geophysically.

On a fundamental level, archaeological features must contrast sufficiently with the surrounding matrix to be detected and recognized when appropriate methodologies are applied. The physical composition, depth, and geometry of the feature must be considered in the context of its surrounding matrix. More accurate characterizations of subsurface conditions will lead to better feasibility assessment and survey design. When physical samples can be obtained, laboratory testing can be invaluable. For example, a feature might be easily detected in a magnetically quiet setting, but completely undetectable in the presence of metal debris or igneous cobbles. Many sedimentary rocks are essentially undetectable, and different soils vary widely in their response to heat. On the other hand, conditions that preclude magnetic survey may be very favorable to other geophysical methods that measure unrelated physical properties.

While the specific combination of features and environment occurring on the sites under consideration has resulted single-method investigations that have been highly successful, this should not be considered typical of archaeological sites generally. The use of multiple methods is generally recommended, especially on more complex sites than those considered here. Not only does it increase the likelihood of success with at least one method, but it can greatly enhance interpretability. Because each geophysical method responds to different properties, multiple data sets are generally complementary rather than redundant.

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

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

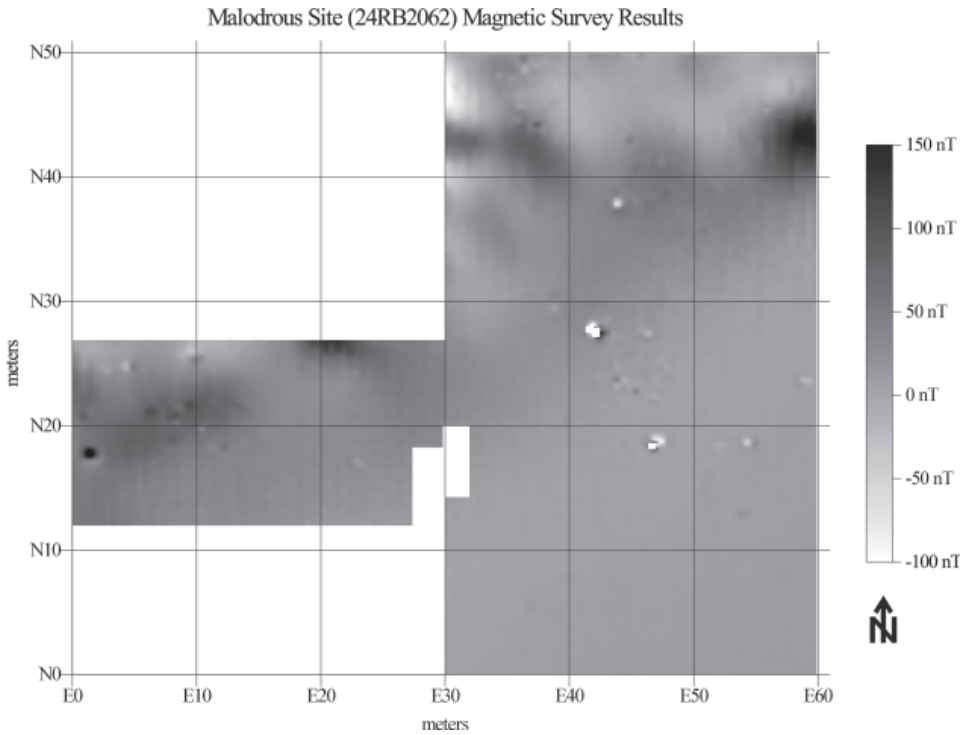


Figure 10. Malodorous site magnetic survey results.

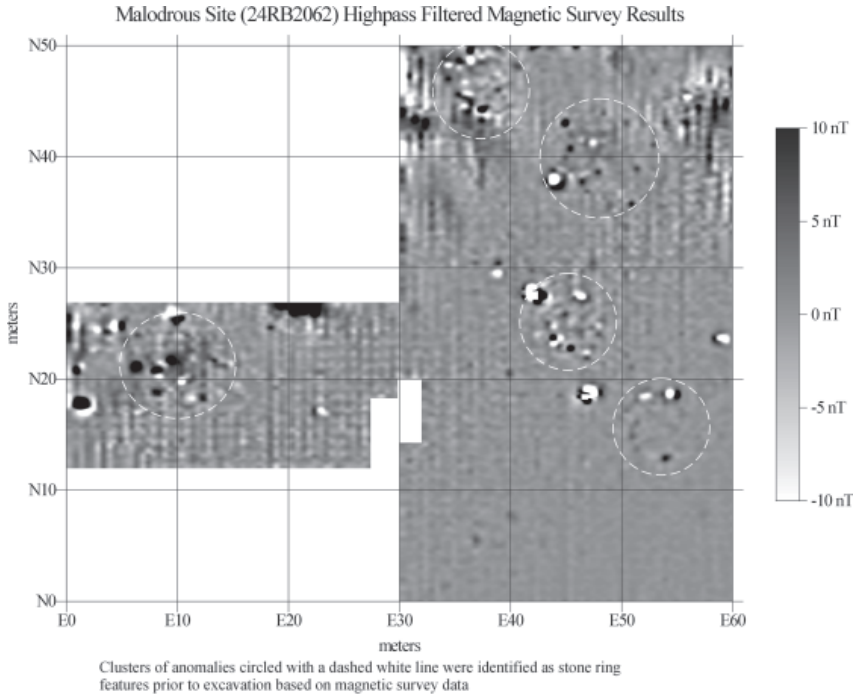


Figure 11. Malodorous site magnetic survey data after statistical filtering.

- Ground truthing (on-the-ground testing)
- Refine interpretations
- Excavation
- Model site context integrating excavation, geophysical, environmental and other available data

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 for future research. More critical, and often overlooked, is the effect of metal artifacts left on sites by archaeologists themselves. Steel pinflags, nails, datums, and other items 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. Steel pinflags are particularly problematic. Ubiquitously used, often lost, and difficult to find after the plastic flag has degraded or fallen off, the steel wire creates a surprisingly large magnetic anomaly. The inconvenience and expense of plastic pinflags will be found to be well worth the benefits. It is hoped that these considerations will be reflected in standard archaeological practices in the near future.

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