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June 1997

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Station

Site Mapping, Geophysical Investigation, and Geomorphic Reconnaissance at Site 9 ME 395 Upatoi Town, Fort Benning, Georgia

by Frederick L. Briuer, Janet E. Simms, Lawson M. Smith

Prepared for U.S. Army Installation, Fort Benning

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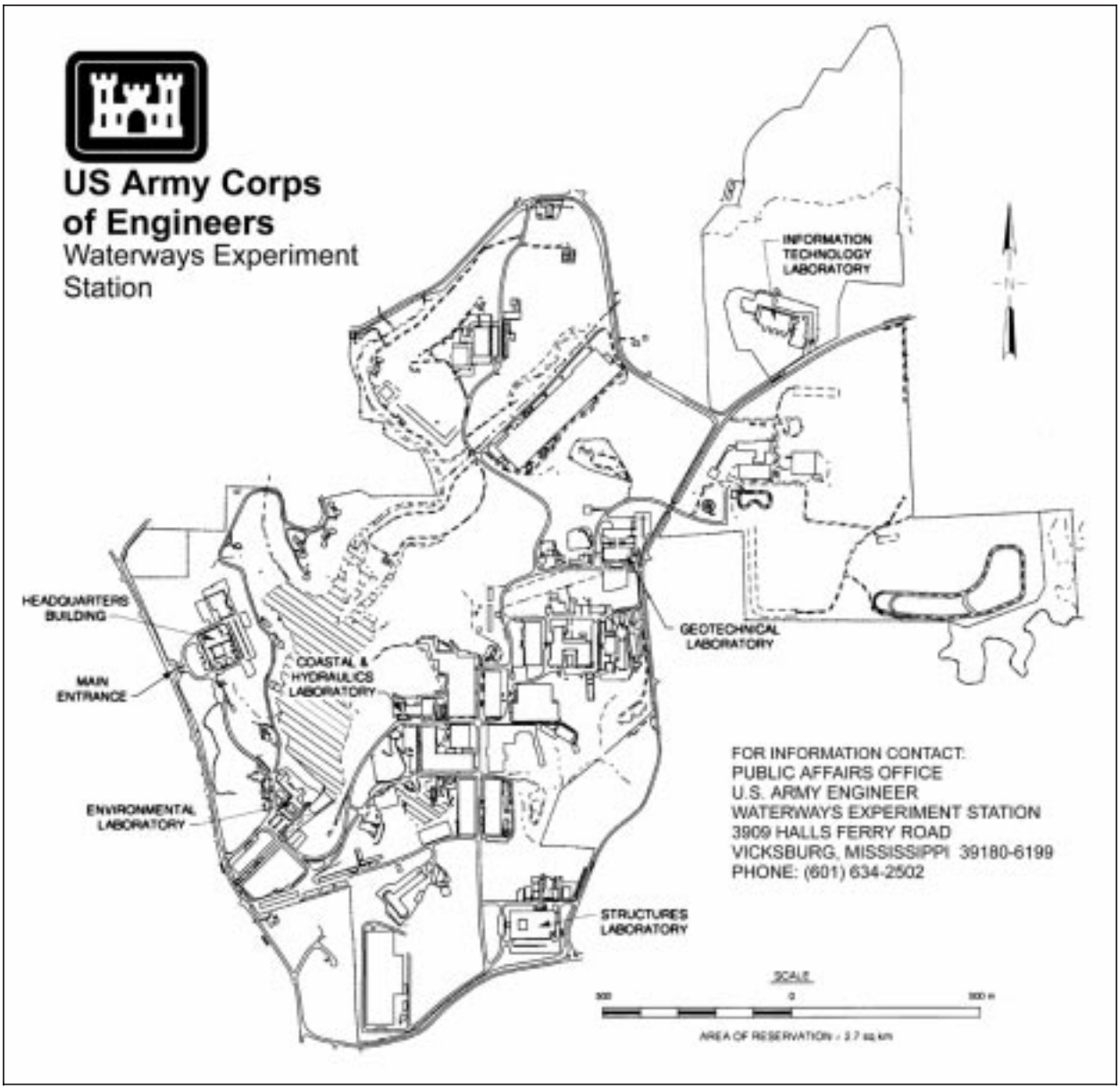
U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Prepared for U.S. Army Installation, Fort Benning
Department of Public Works
Environmental Management Division
Fort Benning, GA 31905



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Preface

This report was a team effort involving interdisciplinary expertise from both the Environmental Laboratory (EL) and the Geotechnical Laboratory (GL) at the U.S. Army Engineer Waterways Experiment Station (WES). Chapters 1 and 4 of this report were written by Dr. Frederick L. Briuer, Director, Center for Cultural Site Preservation Technology (CCSPT), EL. Chapter 2 was written by Dr. Janet E. Simms, Earthquake Engineering and Geosciences Division (EEGD), GL. Dr. Lawson Smith, also of the EEGD, was the author of Chapter 3. Mr. Gary Hebler, a contract student at the CCSPT, supported Drs. Briuer and Simms with the preparation of a geographic information system and helped with editing and preparation of the report. During the course of this work, Dr. John Harrison was Director, EL, and Dr. William F. Marcuson III was Director, GL.

Major funding for this work was provided by the U.S. Army Installation at Fort Benning, with supplemental funding from the Conservation Assistance Program (CAP) for portions of the study involving the use of new and emerging technologies for site mapping. CAP is administered by the U.S. Army Environmental Center, Aberdeen Proving Ground.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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Summary

The inadvertent discovery of a Native American burial at site 9 ME 395 during the course of archaeological field investigations prompted a revision of evaluation and management plans responsive to provisions of the Native American Graves Protection and Repatriation Act and other cultural resource management legal requirements. The Center for Cultural Site Preservation Technology at the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, was tasked by Fort Benning to undertake an interdisciplinary investigation to provide additional information about an eighteenth and early nineteenth century Creek Indian village and burial site. This site has substantial historical documentation identifying it as the Creek town site of "Upatoi." New information was needed to complement what had already been learned about the site. Information, preferably derived from noninvasive and nondestructive methods, was needed to further evaluate the site and serve as the basis for developing a management plan and appropriate consultation effort with the Creek Indian Tribe. The acquisition of information needed to achieve these management objectives was accomplished in a manner demonstrating respect for and minimal disturbance of both the material and mortuary remains of the Creek Indian people.

The interdisciplinary investigation consisted of a site mapping effort using a global positioning system and laser range finding equipment. A geographic information system was used to incorporate appropriate information from site mapping and all other investigations. The site map was taken an iteration beyond the mapping by archaeologists during their initial site evaluation efforts. Other investigations included a geomorphological reconnaissance and a geophysical survey consisting of electromagnetic, magnetic, and ground penetrating radar investigations. In addition, depth-to-resistance measurements using a steel probe were taken throughout the site.

The particular conjunctions of evidence derived from the above suite of techniques and methods clearly indicate a relatively simple but distinct stratigraphic superimposition of cultural deposits containing a significant number and variety of geophysical anomalies. The results of the geophysical prospection indicate a highly patterned distribution of subsurface materials and features that include at least six probable burials and three probable holes or pits stratigraphically earlier in time. Some 20 probable or possible metallic objects were mapped throughout the site. A high percentage of these probable metallic objects were found in direct association with the probable burials. The use of a geographic

information system proved to be an excellent tool for better integrating the combined results of all investigations. Conjunctions of evidence from the various perspectives indicate a pattern and distribution of probable buried artifacts and features that is surprisingly consistent with the independent and earlier archaeological observations based on surface evidence, subsurface shovel testing, and very limited test pit excavation.

The results of this combined research suggest that future archaeological field studies to evaluate cultural resources in similar environmental settings within the Fort Benning region would greatly benefit from a mixed strategy that selectively employs cost-effective, rapidly executed, and nondestructive, interdisciplinary techniques that complement traditional archaeological fieldwork and demonstrate important patterns of observations that might otherwise easily go undetected. The study indicates that investigations short of full-scale data recovery and mitigation can be highly resourceful means to extract as much useful information as possible from relatively low-impact site evaluation efforts. The results of this study clearly raise the level of significance of the Upatoi village by presenting sound evidence, including archival, archaeological, geophysical, and geomorphic information, that indicates the site is not simply a limited activity site containing an isolated burial, but probably one of the most important, potentially protectable Creek village and probable mortuary sites in the southeastern United States.

1 Introduction

The Center for Cultural Site Preservation Technology at the U.S. Army Engineer Waterways Experiment Station (WES) was approached by Dr. Christopher Hamilton, cultural resource manager for U.S. Army Installation at Fort Benning, Georgia, for assistance with a problematic cultural resource site, in regard to compliance requirements under the National Historic Preservation Act, Executive Order 11593, the Archaeological Resources Protection Act, and especially, new provisions in the Native American Graves Protection and Repatriation Act (NAGPRA). The Fort Benning cultural resource management program was well under way with the completion of several archaeological surveys and evaluation projects designed to bring the installation into compliance with the first three of the above-mentioned statutory requirements when archaeologists, during the course of subsurface investigations associated with a survey and evaluation of compartments K-6 and K-7, unexpectedly uncovered Native American human remains. This discovery immediately required compliance with several very explicit treatment, reporting, consultation, and protection measures specified in NAGPRA.

The discovery of burials during archaeological subsurface investigations prompted Dr. Hamilton to revise his program and interject a special high-priority project to supplement current survey and inventory work being performed by the archaeological contracting firm of Southern Research. The WES was asked to supplement existing archaeological investigations of the burial site 9 ME 395. The WES project would complement the work accomplished by Southern Research by executing a global positioning survey (GPS) and laser rangefinder mapping. In addition, the WES team would construct a 5-m grid as the basis for a geophysical survey conducted by Dr. Janet Simms and a geomorphological reconnaissance conducted by Dr. Lawson Smith. Appropriate field data from all investigations would be prepared in a geographic information system (GIS) to supplement ongoing archaeological survey and evaluation efforts and to provide integrated information in a GIS format for future research and management purposes.

This project undertaken by WES contributes supplemental information that complements archaeological field and archival research conducted by Southern Research, which has allowed Fort Benning to better meet the requirements to evaluate, protect, and consult with appropriate Native American groups concerning the responsible management of a site recommended as eligible for inclusion

in the National Register of Historic Places. As a consequence of the expeditious management actions involving protection, reporting, and consultation, Fort Benning is one of the first, if not the first, military installation to demonstrate comprehensive compliance with all administrative requirements associated with the unexpected discovery of Native American burial remains during the course of a Federal action. Using state-of-the-art technology to complement traditional archaeological survey and evaluation procedures has resulted in a comprehensive and defensible informational base. This knowledge allows managers to comply with the complex provisions of the law in ways that are compatible with successful execution of the installation mission.

Cultural Resource Management Background

As of October 1993, Elliot et al. (1996) reported that approximately 22 percent of Fort Benning had been surveyed for cultural resources. A series of field and analytical projects dating back to the 1950s, and particularly from the last decade, has resulted in the recording of over 800 historic and prehistoric archaeological sites on the Fort Benning Installation. Approximately one-fourth of this inventory has been nominated or assessed as eligible or potentially eligible for inclusion on the National Register of Historic Places (36 Code of Federal Regulations, Part 60). Most recently, intensive survey and assessment by Southern Research has focused on compartments K-6 and K-7 in the northeastern extreme of the installation (Elliot et al. 1996). The purpose of this most recent effort was to comply with requirements of sections 106 and 110 of the National Historic Preservation Act. This compliance involved giving appropriate consideration to the cultural resources in these compartments, in view of expected impacts due to logging activities deemed necessary to remedy serious infestations of the Southern pine beetle. The survey of compartments K-6 and K-7 also responded to National Historic Preservation Act requirements for considering other potential installation impacts and long-term stewardship requirements.

The initial field survey of site 9 ME 395 in 1995 involved 31 shovel tests that resulted in recovery of 51 artifacts from as deep as 44 cm. The majority of artifacts were found within 30 cm of the surface. The artifact assemblage contained aboriginal ceramics and other historic period materials, such as glass and an English spall type gunflint, all indicative of Historic Creek affiliation. The artifacts from shovel testing at 9 ME 395 and other sites in the immediate vicinity were entirely consistent with an earlier suggestion by Braley (1981) that the general area was quite likely the location of the historically well-documented late eighteenth/early nineteenth century Creek town site of Upatoi.

Further archival investigation by Southern Research categorically narrowed the location of the Upatoi town site to the vicinity of site 9 ME 395. In particular, a land plat map for a Georgia state survey of District 10 dating to 1827 indicated lot numbers, place names, and other cartographic information that placed the Creek town site near site 9 ME 395. The 1827 map indicates a council house and four other dwellings in the southeast quadrant of lot 252 (Elliot et al. 1996, pp 256-257). This particular lot is located in compartment K-6 of Fort Benning, and there are no other indications on the 1827 map of other Creek towns that

could correspond to any other complexes of recorded sites in the vicinity. The cartographic and other archival information suggests that the Creek site was still occupied as late as 1827. On the basis of this particular conjunction of field and archival evidence, Southern Research included site 9 ME 395 on its list of sites recommended for further subsurface evaluation.

Archaeological Description

Site 9 ME 395 was subjected to further subsurface excavation beginning in October 1995. An additional 35 shovel tests helped delineate the site's boundaries, which are well defined with the exception of the northeastern edge, where a single negative shovel test separates 9 ME 395 from site 9 ME 394. Quite likely, these two sites are actually the same site.

On the basis of artifact quantities recovered from shovel tests, suggesting highest artifact density in the southwestern quadrant of the site, six 2- by 2-m test pits were excavated in this area. One of the excavation units intersects or touches upon a large oval-shaped depression purported to be a bulldozer cut for stacking and preparing logs for hauling. There is clearly a trail coming directly to this depression, suggesting a hauling operation (see Figure 1). One cannot, however, dismiss the possibility that the depression might also be associated with the historic council house.

Elliot et al. (1996) reported that the excavations resulted in the recovery of more than 2,500 artifacts, including chipped and ground stone tools and debitage, fire-cracked rock, daub, animal bone, and a ceramic assemblage dominated by pottery types characteristic of Historic Creek sites. A variety of metal artifacts (including brass, lead, and silver) were recovered, along with gun flints typical of the late eighteenth and early nineteenth century. By comparison, there were very few Archaic or Woodland artifacts in the assemblage.

The excavation of six test pits, each 2 m on a side, revealed a stratigraphy that in general could be described as at least four strata, all compressed within 34 to 45 cm from the surface. The uppermost stratum was in general a darker fine sandy loam, probably disturbed extensively from plowing and ongoing bioturbation such as root action and animal burrowing. Underlying this plow zone was a less dark and less fine-grained sandy loam with mottles of yellow sandy loam. A third general stratum appeared to be a transitional zone that graded to a lighter color and a loam of higher clay content. The Southern Research team defined a fourth general stratum of reddish brown, more compact sandy clay devoid of cultural material except where intrusive archaeological features may have penetrated this lowest layer.

Features defined in the excavation units included a charcoal or smudge pit, a charred corn cob, burn features, and a large, oval, basin-shaped subsurface feature located on the slope of the purported bulldozer depression. A variety of well-defined post molds indicated that one or more structures stood in the area of the six excavation units.

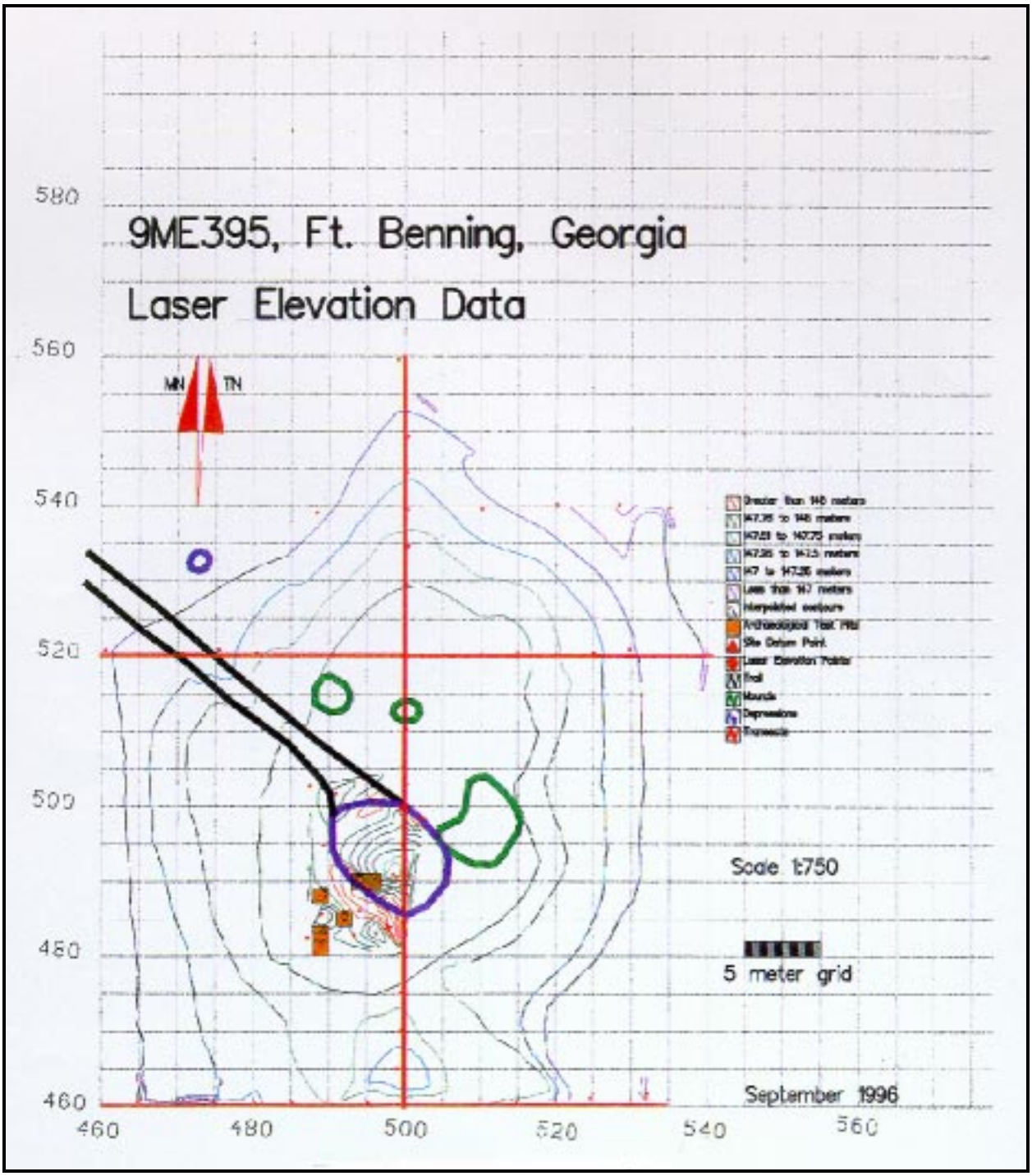


Figure 1. Site 9 ME 395 contour map

A rectangular feature oriented east/west contained an infant or young child burial with fairly elaborate grave goods. Fragmentary remains of teeth, cranial, and some postcranial elements indicated an infant or child less than 7 years of age. Grave goods found with the child included wood and fabric fragments, a diabase celt fragment, chert debitage, a bottle glass unifacial tool, plainware and Chattahoochee brushed ceramics, an iron-backed creamware gorget, two brass

buckles, and 81 spherical glass beads. Several silver artifacts were also found among the grave goods, including 12 conical beads, two arm bands, and two wrist or hair bands. One of the silver arm bands was engraved with a maker's mark and dated 1789. Subsequent archival investigation by Southern Research suggested that the silver arm band with the engraved date was very likely a commemorative peace offering. These items were distributed to certain Creek chiefs by U.S. Government officials who represented President George Washington at a peace conference held in New York in August 1790.

Elliot et al. (1996, p 63) have proposed that site 9 ME 395 be considered for inclusion in the National Register of Historic Places under a thematic nomination. Its significance is argued on the basis of a need for considering flexibility in defining site boundaries, to potentially include a complex of other Historic Creek period sites in the upper reaches of Upatoi Creek. Not enough is presently known about the relationship between the entity recorded as site 9 ME 395 and other cultural resources in that vicinity to preclude other recorded sites from also being elements of the Upatoi town. Clearly the density, diversity, and integrity of artifacts, features, and probable structural remains associated with a little-known period of Creek history attests to the research potential of the site and environs under Criterion D and other National Register criteria (36 CFR Part 60). The obvious importance of the site has also suggested potential National Historic Landmark status and could also, under Federal Law, be considered eligible for designation as a Sacred Place (Parker and King 1990).

Initial Fieldwork

Between 28 and 30 November 1995, Dr. Frederick L. Briuer, Director of the Center for Cultural Site Preservation Technology, and Mr. Thomas Berry, surveyor with the WES Environmental Laboratory, conducted fieldwork necessary for preparing site 9 ME 395 for all subsequent investigations. Initial preparations included site mapping to supplement the earlier mapping efforts by Mr. Dean Wood of Southern Research. In particular, the existing site map based on impressionistic contours and limited measurements was upgraded. Earlier mapping consisted of a datum with north-south and east-west grid lines as laid out by the Southern Research field crew to achieve vertical and horizontal control for all shovel tests as well as excavation units that were completed in that effort.

Global positioning survey

The site was expeditiously remapped using the Trimble Pathfinder Pro XL Global Positioning System mounted on a Prosurvey 1000 laser ranger (Photo 1). A 12-channel Pro XL unit and a TDC1 data logger were used for establishing a base station. An 8-channel Pro XL unit with a TDC1 was used as a rover. The site data, as well as the north-south and east-west grid lines and estimated site boundary, were recorded as GPS point and line data. For comparative purposes the system was operated using Fort Benning base station data as well as base station data from a first-order survey point found in the vicinity of the installation. Establishing a new base station allowed for postprocessing of data using

differential correction. The upgraded map was demonstrated to be accurate to within less than 1 m. The Fort Benning base station GPS system used by the Environmental Management Division, Directorate of Public Works, was found to be consistent with WES data. However, the system lacked the same submeter accuracy of points gathered using differential correction on a first-order survey point with both horizontal and vertical control. The GPS data gathered onsite earlier by Mr. Wood were also found to be consistent, but not as accurate. The GPS used by Southern Research was found to be quite adequate for locating various center points of sites during archaeological site survey.

Photo 1. GPS/laser ranger

Laser range finding survey

The hand-held, eye-safe Prosurvey 1000 laser range finder was then used to rapidly collect horizontal and vertical distance measurements for improving the contour mapping and for quickly laying out a 5-m grid of plastic pin flags in anticipation of the geophysical survey and geomorphic reconnaissance of the site (see Figure 1). The device uses a pulsed time of flight to accurately determine ranges, rather than phase measurements commonly used by electronic distance measurement devices. The system emits an ultrashort pulse of laser light from a gallium arsenide laser diode. The Prosurvey 1000 comes equipped with an integrated flux-gate digital compass and inclinometer and an integral 16-bit, 8-MHz processor to determine range, bearing, and elevation. These data are provided to external computers or data loggers through a standard RS-232 serial port installed in the unit. A display gives the user a readout of range, bearing, and angle information through the aiming lens. The laser ranger requires minimum setup and is designed for rapid one-person operation. The system is based on a simple point-and-shoot procedure that records targets without the need of a second person holding a pole and prism in the conventional manner, but can also be used with a prism target. The data are recorded in an electronic format capable of easy conversion to a GIS. In addition to these mapping efficiency considerations, the instrument costs a fraction of the expense of the total station transit.

In mapping the site, special attention was given to the area of the large depression thought possibly to be a bulldozer cut and/or remnant of a Creek tribal council house as described in early survey plats of the region. Several cross sections were measured through the depression with the laser range finder to upgrade the quality of mapping in this particularly sensitive feature immediately adjacent to the subsurface excavation units completed by Southern Research.

The site required an estimated 2-person-day effort for the clearing of vegetation that would have seriously impeded geophysical investigation. Initial vegetation clearing was done with hand tools. One day was expended by an equipment operator using a mechanical bush hog provided by the Environmental Management Division for clearing the worst of the remaining vegetation. The site could not have been adequately prepared for the geophysical survey the following week without the assistance of Dr. Hamilton, who assisted with the work and provided the mechanical equipment for site clearing. Mr. Wood also graciously assisted with the fieldwork and shared critical information from his own fieldwork and analysis.

Photo 2. Probing

Probing and site mapping

Reestablishing the site grid offered the opportunity to map other observations such as roads and other unusual features including obvious depressions and mounds. The grid was used as the basis for collecting geophysical measurements in that phase of the fieldwork and was also the basis for plotting 204 probes to depth of resistance. For subsurface probing across the site, a 1-m-long steel-tipped probe was used (Photo 2). An improved contour map depicts the grid system, probe locations and new site observations (Figure 1).

Geographic information system integration

A final objective of the project was to establish a GIS database as an interpretation and evaluation tool for integrating previous archaeological data, as well as new field observations described above and any new data generated by geomorphological reconnaissance and comprehensive geophysical survey. The GIS database was set up in the ARC/INFO system in the Environmental Laboratory at WES. It is worth noting that using GPS and laser range finder equipment in tandem and integrating the resulting data into a GIS is an excellent way to rapidly map and prepare a site requiring accurate three-dimensional plotting. This is clearly a more rapid and efficient method than conventional surveying and site mapping using a transit or alidade. Besides requiring fewer people to set up and operate, downloading the data into a GIS database precludes the time-consuming, laborious, and error-prone digitizing of hard-copy map data into an electronic format. The GIS database established for site 9 ME 395 ought to be considered as a prototype or pilot case study for supporting and complementing future cultural resource management projects for the installation, especially projects where expeditious fieldwork will be necessary.

Developing the GIS coverages

The archaeological survey grid set up over site 9 ME 395 in the field was replicated in the GIS database using ARC/INFO's “Generate” command. GPS

locational and laser elevation data collected in the field by Mr. Tommy Berry were used to project the newly formed grid coverage into the 1,000-m Universal Transverse Mercator coordinate system used by Fort Benning. With the grid in place, a point coverage was created overlaying the grid transects. Points located on transects where shovel tests and/or probes were made were assigned values based on the results of these investigations. Shovel tests that uncovered cultural material were assigned positive values; tests that did not were assigned negative values. The depth to resistance was measured using a 1-m steel probe and tape. These values were plotted at appropriate intersections on the 5-m grid.

The laser elevation and depth-to-resistance point coverages were analyzed and triangulated to form interpolated contour coverages using ARC/INFO's “Tin” package. These consistently placed measurements allowed for concise contour interpolations. On the other hand, laser elevation readings were taken only along certain transects and around the site's central depression. This uneven distribution of point locations caused a severe skewing of the contour interpolations. Those interpolations considered too unreliable were deleted and replaced by manually digitized contours based on the investigators' hand-drawn site maps and field assessments.

Most of the ARC/INFO coverages created for this project were exported out of ARC/INFO and copied onto two 3-1/2-in. diskettes. Most of these exported files were small and required no alteration for downloading. However, the depth-to-resistance contour coverage was too large to fit on a diskette unaltered, and it was necessary to use the PKZIP shareware to deflate the export file to a manageable size. PKUNZIP can be used to restore the file once it is downloaded onto a computer's hard drive.

Metadata describing the origins, accuracy, and content of the coverages were developed using Tri-Services Standards, Part 3, “Spatial Data Standards,” and other Federal metadata standards. These metadata were copied onto a 3-1/2-in. diskette as WordPerfect 6.0 files (one file per coverage). Hard copy of the metadata files was also provided to accompany the disks.

2 Geophysical Investigation

Background

Between 4 and 8 December 1995, a geophysical investigation consisting of magnetic, electromagnetic, and ground penetrating radar surveys was conducted at site 9 ME 395 by Dr. Janet Simms of the WES Geotechnical Laboratory, with assistance from Dr. Briuer.

Fort Benning is located near the Alabama-Georgia state line just south of Columbus, GA (Figure 2). The 73,655-km^2 installation was established in 1918 and presently provides basic training for soldiers preparing to become infantry personnel. The survey area is located in a section used for training and maneuvers in the northeastern quarter of Fort Benning.

Objectives

Based on previous investigations, there is a very high probability that site 9 ME 395 could contain a considerable density and diversity of buried cultural material associated with the well-documented prehistoric and historic Creek Indian occupation. It is also highly probable that there are additional human burials on the site. For cultural resource management purposes, it was desirable to quickly and cost-effectively learn as much as possible about the site and determine the accurate location of subsurface archaeological remains in a noninvasive and nondestructive manner. Three geophysical methods—magnetic, electromagnetic, and ground penetrating radar—were used to identify the location of possible burials, the council house, and other possible buried archaeological structures or features.

Geophysical Test Principles and Field Procedures

Electromagnetic survey

The electromagnetic (EM) method is used to measure terrain conductivity. The conductivity of a material is dependent on the degree of water saturation, the types of ions in solution, the porosity, the chemical constituents of the soil,

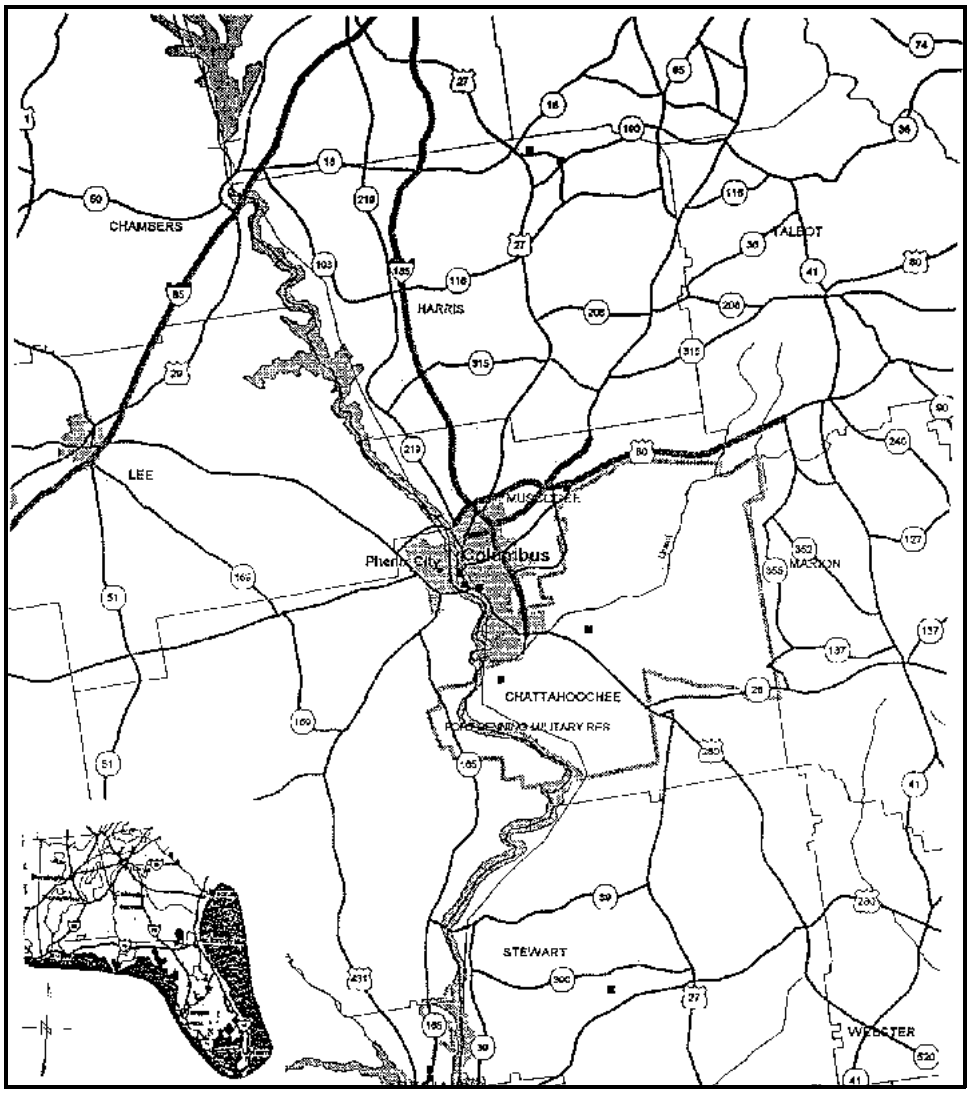


Figure 2. General location of Fort Benning (not to scale)

and the physical nature of the soil. Due to these factors, conductivity values can range over several orders of magnitude.

The EM system consists of a transmitter and receiver coil separated by a fixed distance. An alternating current, commonly in the 1- to 20-kHz range, is passed through the transmitter coil, thus generating a primary time-varying magnetic field. This primary field induces eddy currents in the subsurface conductive materials. These currents are the source of a secondary magnetic field, which is detected by the receiver coil along with the primary field. Under a fairly wide range of conditions, the measured component that is 90 deg out of phase (quadrature component) with the primary field is linearly related to the terrain conductivity (Keller and Frischnecht 1982, Dobrin 1976, Telford et al. 1973). Conductivity is measured in units of millimhos per meter (mmho/m) or, in the SI system, millisiemens per meter (mS/m). Two components of the in-

duced magnetic field are measured by the EM equipment. The first is the quadrature phase component, sometimes referred to as the out-of-phase or imaginary component, which gives the ground conductivity measurement. Disturbances in the subsurface caused by compaction, soil removal and fill activities, or buried objects may produce conductivity readings different from those of the background values, thus indicating anomalous areas. The second component is the inphase or real component, which is the ratio of the induced secondary magnetic field to the primary magnetic field. The inphase component is primarily used for calibration purposes; however, it is significantly more sensitive to large metallic objects and therefore very useful when looking for buried metal (Geonics Limited 1990). The inphase component is measured relative to an arbitrarily set level and assigned units of parts per thousand.

A Geonics EM-38 ground conductivity meter was used for this investigation (Photo 3). The EM-38 has a transmitter-receiver coil separation of 1 m and operates at a frequency of 13.2 kHz, which gives an effective depth of investigation of approximately 1.5 m (Geonics Limited 1990). The instrument can be operated in either a horizontal or vertical dipole orientation, each having different depths of investigation. For this study, the data were collected with the instrument at ground level and the dipoles vertically oriented (coils oriented horizontally and co-planar), which provides the maximum depth of signal penetration. Due to the design of the instrument, it is necessary to perform a separate survey to collect each data component (conductivity and inphase).

Photo 3. EM38

Ground penetrating radar survey

Ground penetrating radar (GPR) is also an electromagnetic method. However, it differs significantly from the induction EM methods described above and warrants a separate discussion. At the lower frequencies (kilohertz range) where EM induction instruments operate, conduction currents (currents that flow via electrons in a metallic matrix or ions in solution) dominate, and energy diffuses into the ground. At the higher frequencies (megahertz range) which GPR uses, displacement currents (currents associated with charges that are constrained from moving any distance) dominate, and energy propagates into the ground as a wave.

GPR is used to image the subsurface. The subsurface image is obtained by transmitting an electromagnetic pulse (which propagates into the earth where it undergoes refraction, reflection, scattering, and dispersion) and then measuring the return signal. The frequencies employed in GPR typically range from 10 to 1,000 MHz. Contrast in the dielectric permittivity at layer boundaries causes the EM wave to be reflected and refracted. The dielectric permittivity is the proportionality factor relating the displacement current to the energy. Since electromagnetic fields consist of both electric and magnetic fields, any properties of the geologic material which affect either of these fields will also affect the propagation of the EM wave in the subsurface. Generally, the electrical properties of the soil and rock have a greater influence on the EM wave propagation than do the magnetic properties. Soil conductivity is a major factor in determining if GPR can be used successfully at a site. High-conductivity soils, such as those with a high clay content and moisture content, can significantly attenuate the EM signal and render GPR virtually useless.

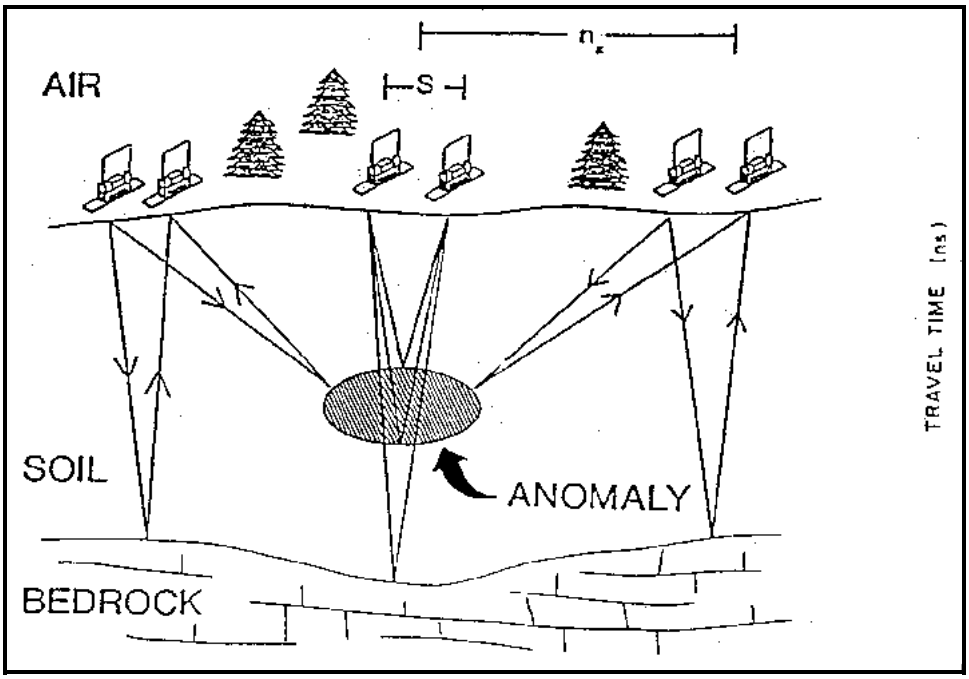
A Sensors & Software, Inc., pulse EKKO IV system modified for high-speed data-acquisition capabilities and employing 200-MHz antennas was used to collect the GPR data. The antennas were mounted on a hand-pulled cart, with a wheel odometer attached to provide antenna position information (Photo 4). The survey was performed in reflection mode where the transmitter and receiver antennas were kept a fixed distance apart, and both antennas were simultaneously moved along the survey line. The time (in nanoseconds) required for the EM wave to travel through the subsurface and return to the receiver (Photo 5) was recorded at each sample station. The received signal is plotted against two-way travel time at each sample station along the survey line. Figure 3 illustrates the reflection mode and the corresponding GPR response for the anomaly shown.

Photo 4. GPR cart with transmitter and receiver antennas

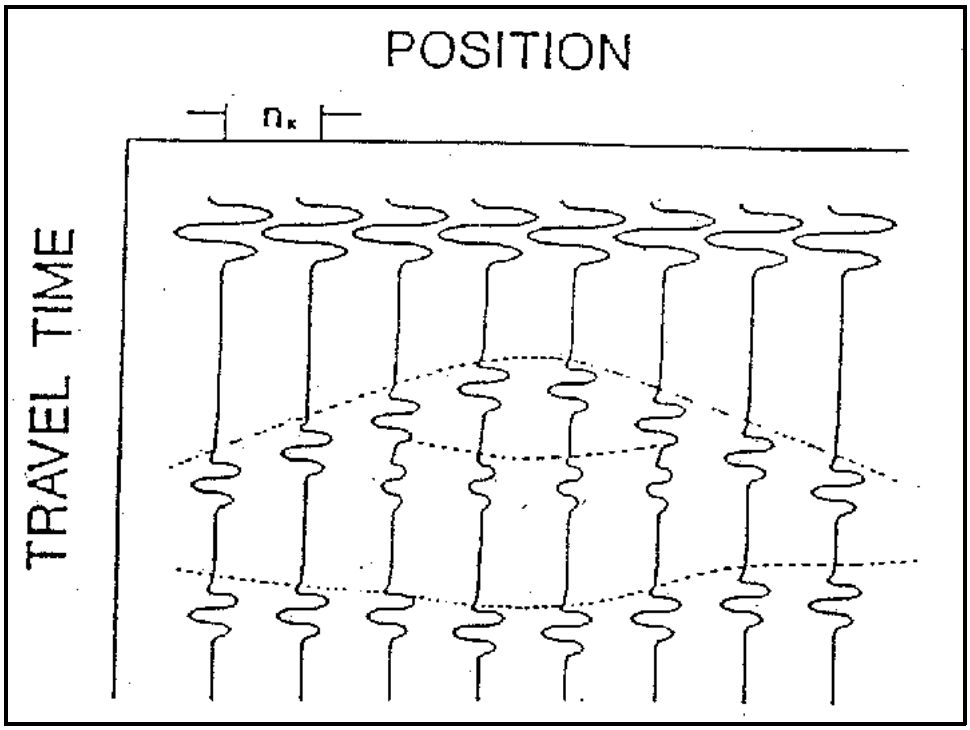
Magnetic survey

A magnetic survey measures changes in the earth's total magnetic field caused by variations in the magnetic mineral content of near-surface rocks and soils or iron objects. These variations are generally local in extent. The magnetic response is attributed both to induction by the magnetizing field and to remanent

Photo 5. GPR receiver



Schematic illustration of common-offset single-fold profiling



Format of a GPR reflection section with radar events shown for features depicted

Figure 3. Illustration of reflection mode GPR and corresponding radar section for anomaly shown (after Annan 1992)

magnetization (Parasnis 1986). Remanent magnetization is permanent magne tization and depends on the thermal and magnetic history of the body; it is

independent of the field in which it is measured (Breiner 1973). Induced magnetization is temporary magnetization that disappears if the material is removed from the inducing field. Generally, the induced magnetization is parallel with and proportional to the inducing field (Barrows and Rocchio 1990).

A GEM GST-19T proton precession magnetometer (Photo 6) was used to collect the magnetic survey data. This magnetometer is equipped with two sensors separated by 56 cm. Each sensor contains a hydrogen-rich fluid as a source for the protons. The proton precession magnetometer is based on the principle that protons will precess freely in the presence of the earth's magnetic field. The hydrogen-rich fluid is subjected to an external magnetic field applied in a direction approximately perpendicular to the earth's field. The proton's moment will align in the direction of the resultant field between that of the external magnetic field and earth's magnetic field. When the external field is removed, the magnetic moment of the proton will precess about the earth's field until it returns to its original alignment with the earth's magnetic field. The proton precesses at an angular frequency that is proportional to the magnetic field. Therefore, by measuring the frequency at which the protons precess, the strength of the local magnetic field can be determined.

Photo 6. Proton precession magnetometer

The GEM magnetometer is capable of measuring both the magnetic total field and the magnetic gradient. The gradient is obtained by simultaneously measuring the total field using both sensors and dividing the difference of the two values by the sensor separation distance. The value of the magnetic gradient can be positive or negative depending on whether the total field measured by the lower sensor is greater or less than the total field measured by the upper sensor. The gradient measurement has the advantage of being insensitive to magnetic storm effects and diurnal variations. It also increases the resolution of local magnetic anomalies by filtering out the regional magnetic gradient (Breiner 1973).

Any material having a magnetic component will contribute to the total magnetic field measured by the magnetometer. If an object is present such that its magnetization is great enough to perturb the ambient magnetic field, it will appear as an anomaly on the magnetic data plot. The size, depth of burial, magnetic susceptibility, and remanent magnetization of the object affect the ability of the magnetometer to detect the object. For a given susceptibility and remanent magnetization, as the size of the object decreases and depth of burial increases, the magnitude of the anomaly decreases; eventually the anomaly will be undetectable.

The magnitude of a magnetic anomaly generated by a feature of interest at a prehistoric archaeological site is generally on the order of tens of nanoteslas or less. This is in contrast to a historic site where iron-bearing metal may be present; these objects can produce an anomaly tens to hundreds of nanoteslas in magnitude. Features that have been subjected to high temperatures, such as hearths, kilns, pottery, and fired brick, produce a magnetic anomaly high. Magnetic anomaly lows are generally associated with areas where the soil has been physically disturbed. Examples of activities that disturb the soil and can produce a measurable anomaly are cultivating, digging of graves, and foot or animal traffic.

Field methods

An 80- by 80-m grid flagged at 10-m spacings was prepared by members of the research team prior to conducting the geophysical investigations. Nonconductive polyvinyl chloride pin flags were used to preclude interference with the geophysical survey. The center of the grid was arbitrarily designated station (500E, 500N). Within a 20- by 40-m area of particular interest, pin flags were placed at 5-m intervals so that more detailed measurements could be made. EM-38 readings were taken at 5-m intervals over the entire grid and at 2.5-m spacings within the finer gridded section. The EM-38 data were collected in both the quadrature (conductivity) and inphase mode. A data logger connected to the instrument was used to store the data during the surveys and, at the conclusion of each survey, the data were transferred to a field computer for later plotting.

The magnetometer was operated in “walking mode,” with measurements taken at 0.5-sec intervals as the operator proceeded at a slow walking pace along the survey grid; approximately four measurements per meter were acquired. The sensors were mounted on a staff with the lower sensor approximately 1 m above the ground surface. The magnetic data were collected along survey lines spaced 10 m apart over the entire grid and along 2.5-m spaced lines within the 5-m flagged area. The data were downloaded to a field computer at the end of each survey.

The GPR data were collected along north-south and east-west survey lines within the area of particular interest. A nominal antenna frequency of 200 MHz was used. The transmitter and receiver antenna were mounted 0.5 m apart on a hand-pulled cart. The antennas were oriented normal to the survey direction. A wheel odometer was attached to the cart to monitor antenna position. The cart was pulled slowly along the survey line to allow data collection at 5-cm intervals. The data were recorded on a field computer for later processing.

Geophysical Results and Interpretation

Data presentation

The area is described as an upland knoll located on an alluvial terrace (Savrda 1995). The soil strata in the first 50 cm below the ground surface consist of

sandy loam over sandy clay. The maximum area surveyed measures approximately 90 m square and has a large, shallow depression located near the center of the survey area (Figure 4). The depression lies within an area of special interest, which is bounded by coordinates 485–505E, 470–510N. The locations of shovel tests and excavation units completed by Southern Research prior to the geophysical survey are also shown in Figure 4. Disturbance of the soil in the area of the test pits could affect the quality of the GPR data in that area.

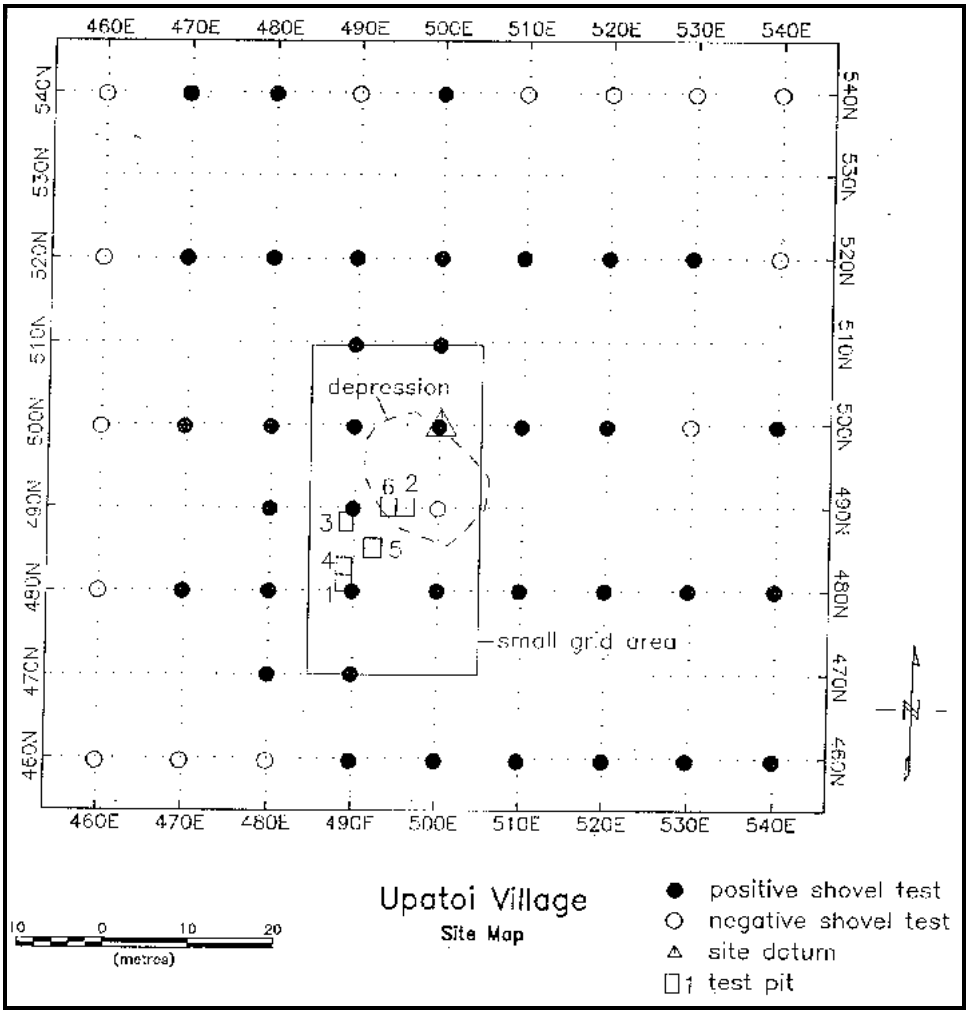


Figure 4. Site map of survey area

The EM-38 and magnetic data are presented as contour plots. Anomalies are identified as areas that differ significantly in value from the average or background value. On contour plots, anomalies are indicated by a concentration of contour lines and, on color plots, by the “hot” (pink) and “cold” (blue) colors. The pink colors indicate high anomalous values whereas the blues indicate low anomalous values. Anomaly detection is dependent not only on the type and size of material buried and the depth of burial, but also on the contrast between the soil and buried material.

The GPR data are presented as travel time versus distance along survey line. The time axis, in nanoseconds, is located on the left side of the plot; depth, in meters, is on the right. The depth scale is based on a subsurface layer velocity of 0.1 m/ns. This velocity was determined from the results of a common midpoint sounding performed at the site.

Two aspects of the GPR field data plot require some explanation. The first notable feature is the lack of coincidence between zero time and zero depth. This offset is a result of the separation of the transmitter and receiver antenna. The first arrival at the receiver is the reflection from the direct wave traveling from the transmitter to the receiver, not the reflection from the ground surface. The time span between zero time and zero depth is the two-way travel time of the direct wave. The second point of initial confusion is the depth scale, in particular at very shallow depths where the scale is obviously nonlinear. The depth is determined based on the velocity of the media. Because the transmitter and receiver antenna are separated by a finite distance and the transmitted pulse has a lobe-shaped radiation pattern, the ray of the transmitted pulse that arrives at the receiver does not strike the subsurface interface at normal incidence, but at an acute angle. The depth scale is corrected for nonnormal incidence of the transmitted path.

Conductivity and inphase data

The conductivity data collected at 5-m intervals over the entire grid are presented in Figure 5. The site is characterized by an average conductivity of 3 mS/m. An area of higher conductivity is apparent along the western boundary between (460–470E, 480–540N). This high appears to be caused by variations in soil conditions. A small, localized anomaly high is centered at (525E, 465N) and may have some correlation, at the corresponding location, with the inphase anomaly high (Figure 6) in the southeast section of the grid. However, the small range of variation in the inphase data suggests that the inphase anomaly high is caused by variations in the magnetic susceptibility of the soil rather than a metallic object. The conductivity and inphase data collected at a 2.5-m spacing (Figures 7 and 8, respectively) over the smaller area of particular interest do not reveal any significant features. The magnitude of the data values collected using a smaller grid spacing is similar to that at the 5-m spacing, even in the area of the depression.

Magnetic data

Several anomalies are present in the magnetic total field and gradient data (Figures 9 and 10, respectively) that were collected over the entire grid. The elongation of the anomalies in the east–west direction is due in part to having a small station interval (four measurements per meter) relative to the survey line spacing (10 m), and the combined effect of closely spaced subsurface features. The anomalous areas are outlined by rectangles in Figures 9 and 10 and listed in Table 1. The localized conductivity anomaly (525E, 465N) may be caused by the same source as the magnetic anomaly in the same proximity. No correlation is seen between the magnetic data and the inphase anomaly high (Figure 6) in

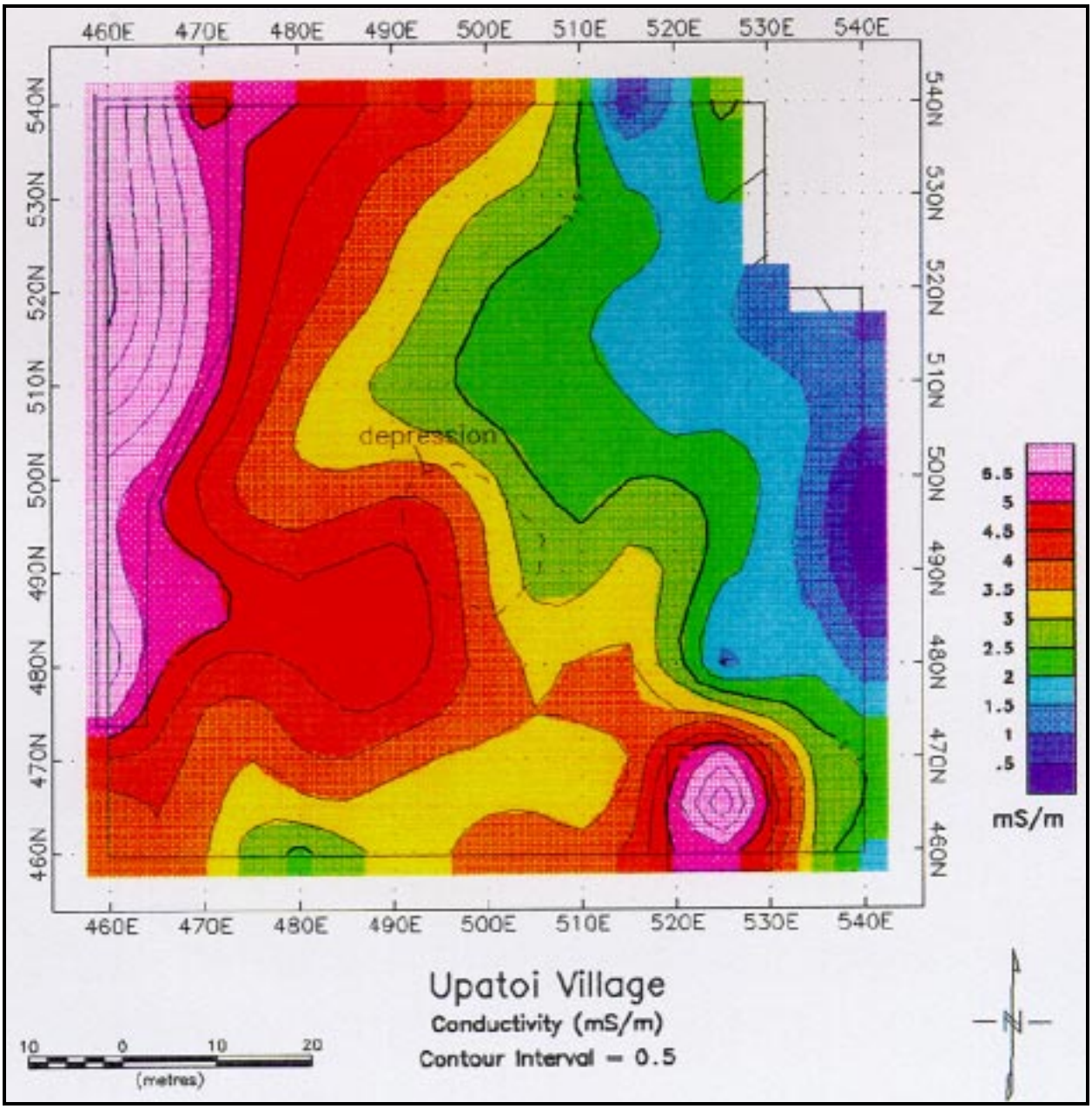


Figure 5. Results of conductivity survey performed over entire survey grid (5 m survey line spacing)

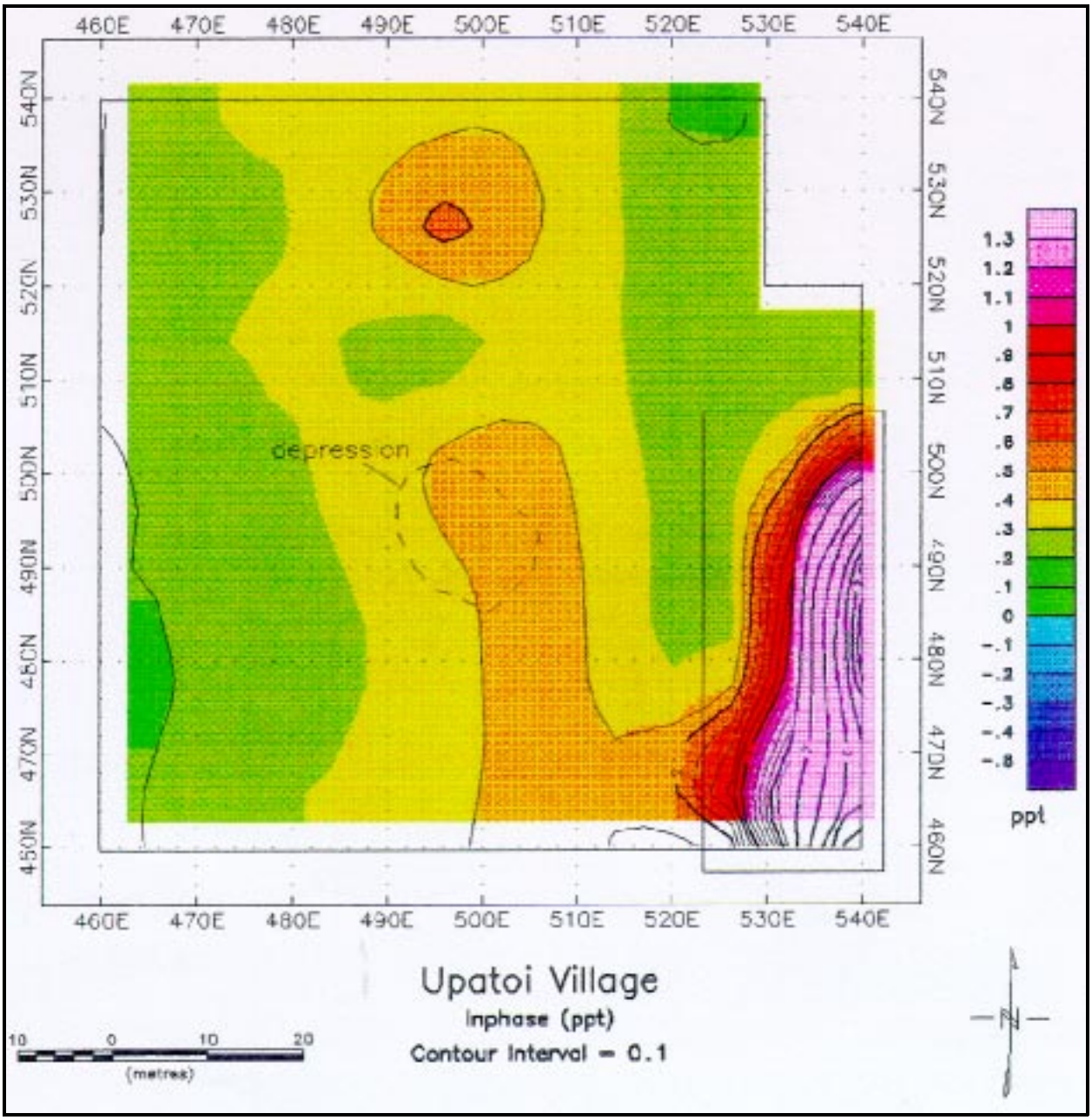


Figure 6. Results of inphase survey performed over entire survey grid (5 m survey line spacing)

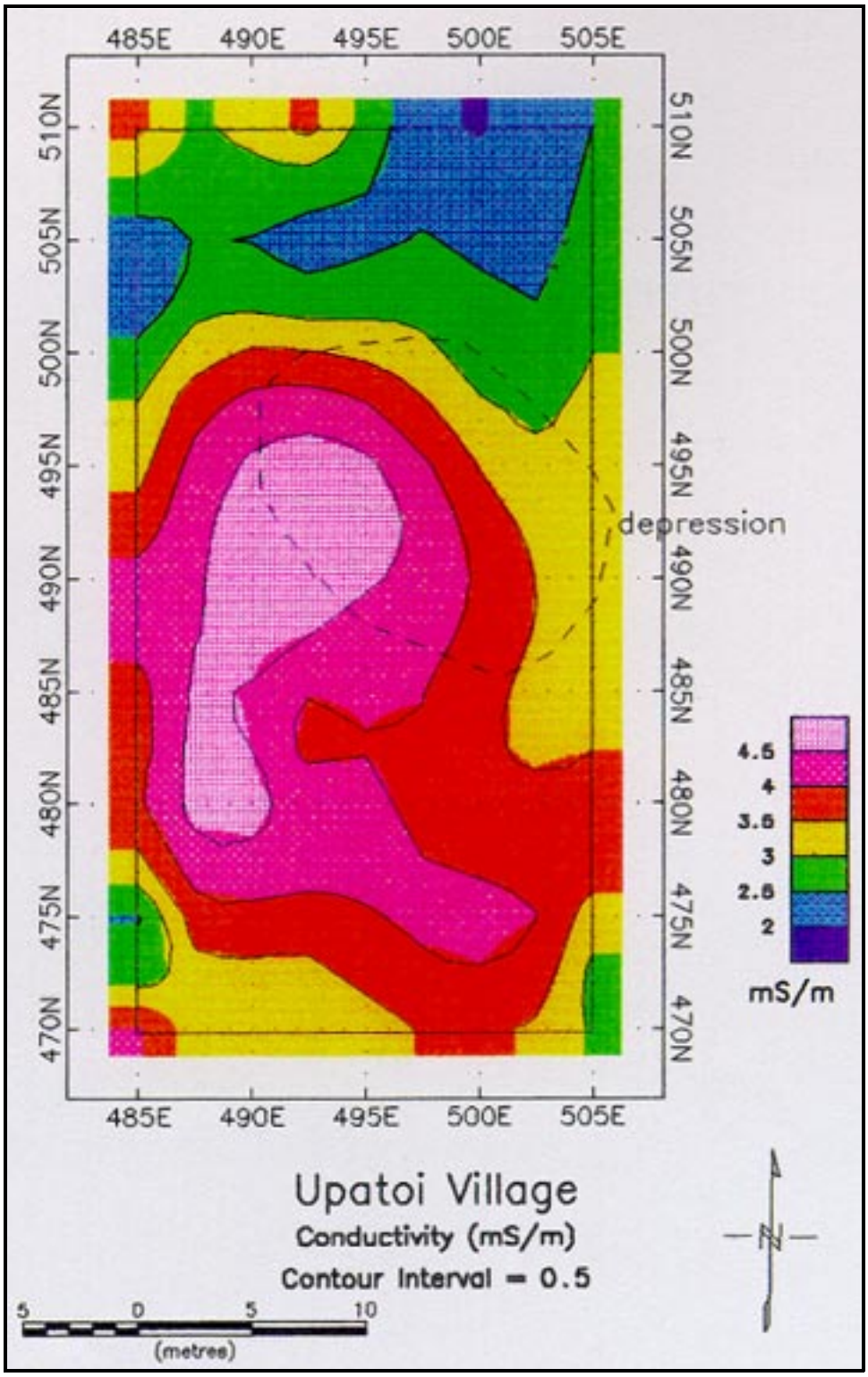


Figure 7. Results of conductivity survey performed over portion of survey grid (2.5 m survey line spacing)

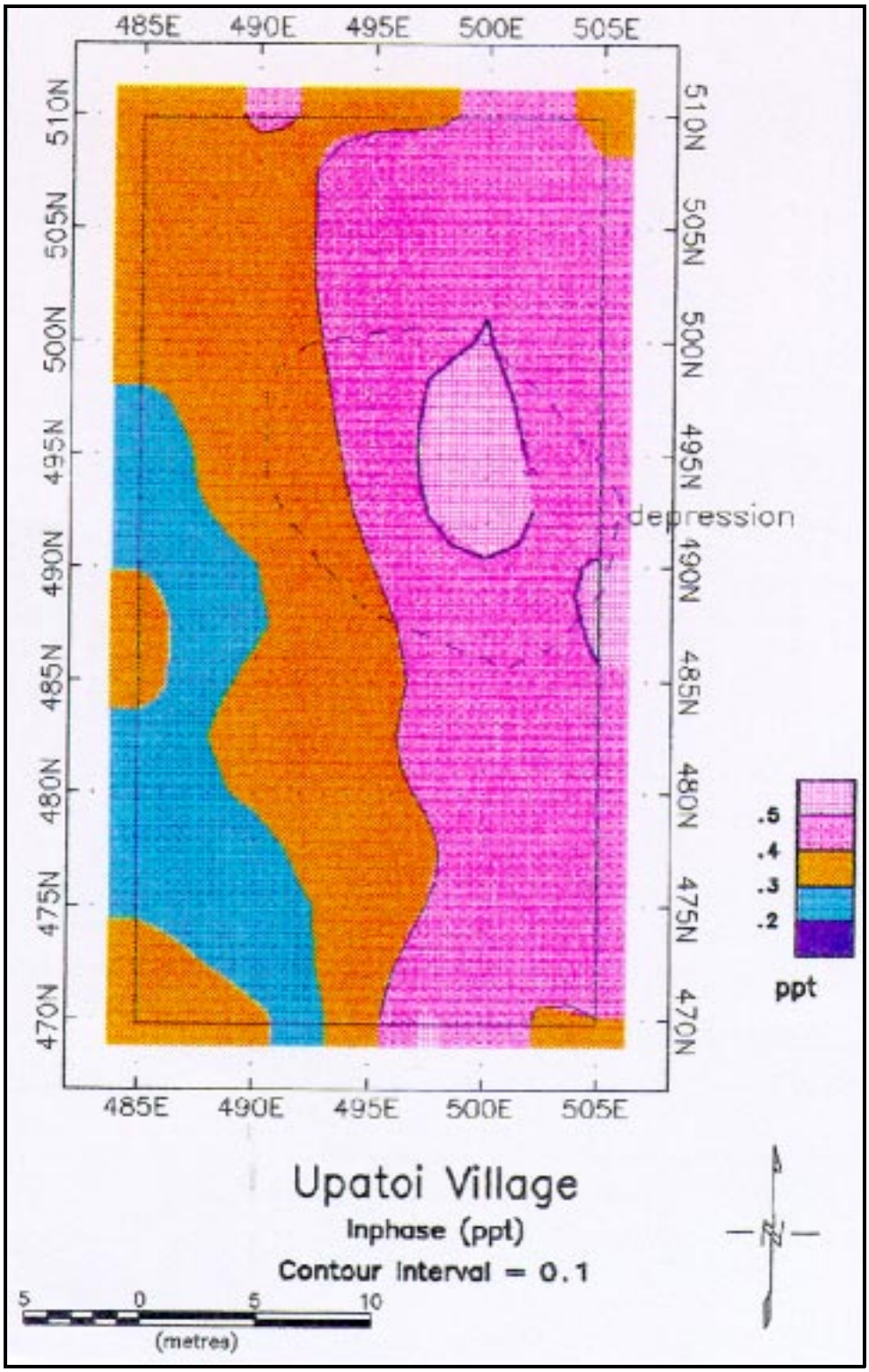


Figure 8. Results of inphase survey performed over portion of survey grid (2.5 m survey line spacing)

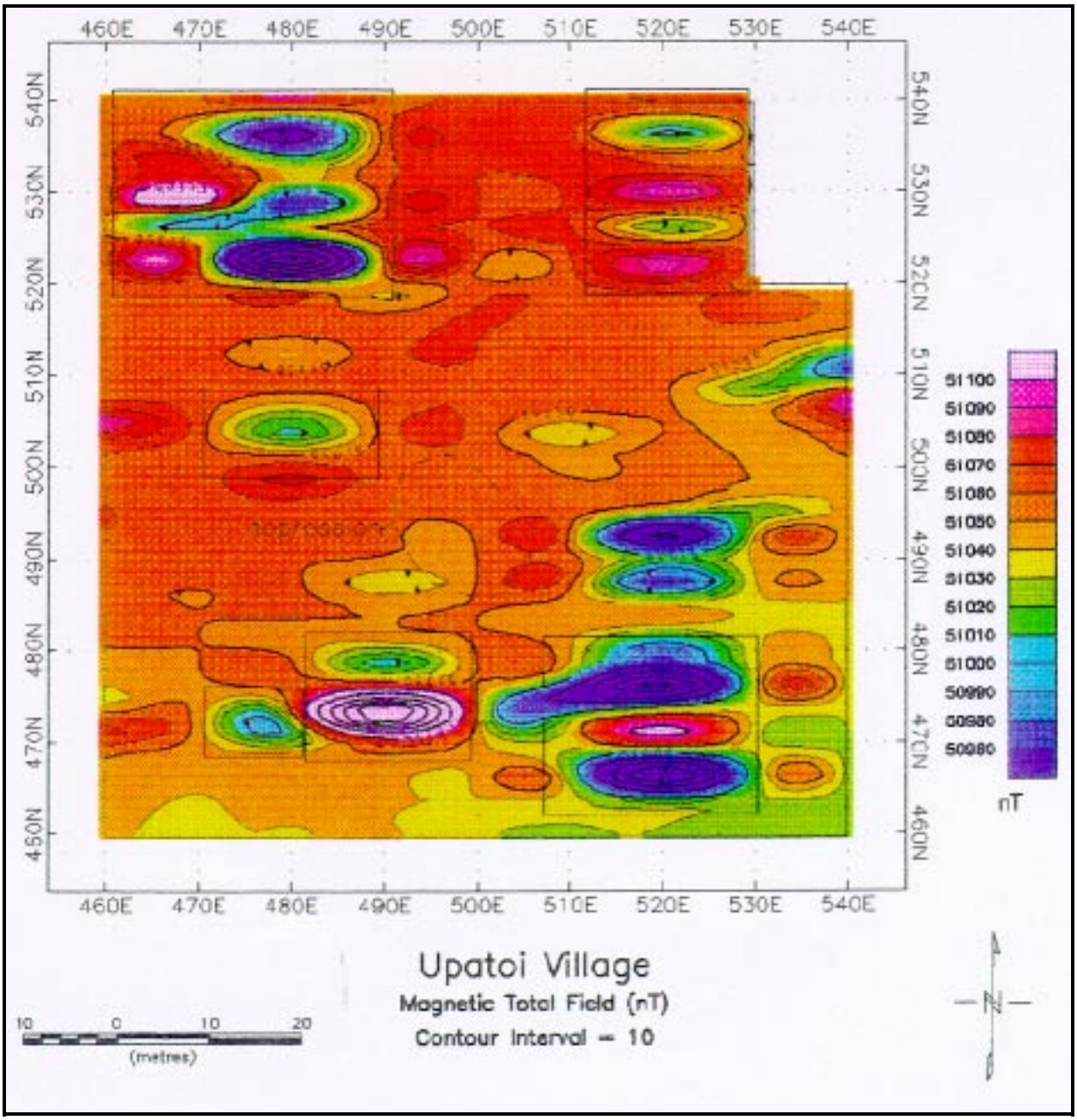


Figure 9. Results of magnetic total field survey performed over entire survey grid (10 m survey line spacing)

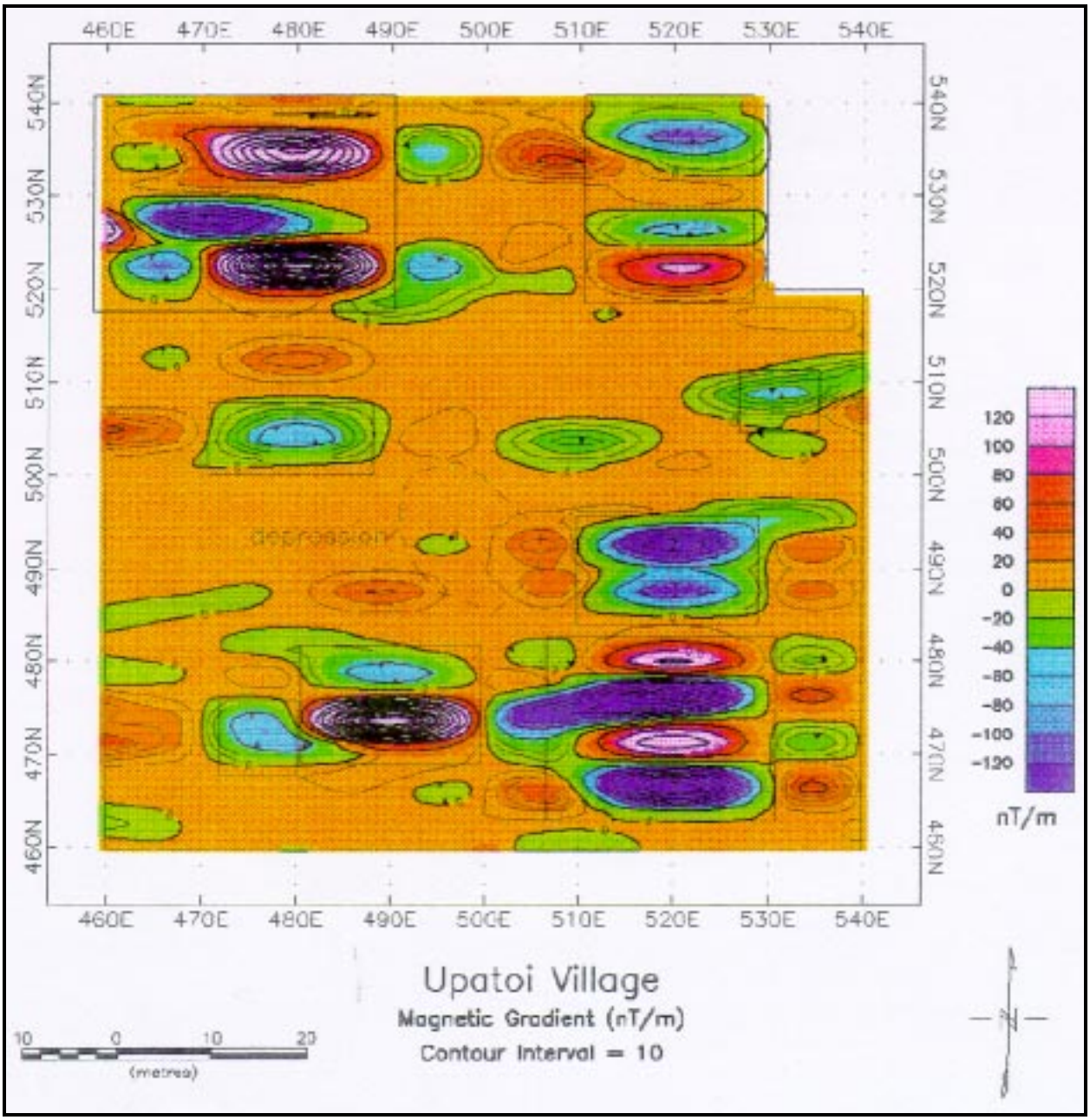


Figure 10. Results of magnetic gradient survey performed over entire survey grid (10 m survey line spacing)

Table 1
Magnetic Anomalies, Entire Grid (10-m Survey Line Spacing)

Anomaly Location	Magnetometer		Anomaly Description
	Total Field	Gradient	
(470E, 528N)	X	X	High/low total field, low gradient. Possible ferrous metallic object.
(476E, 472N)	X	X	Low total field and gradient. Possible soil disturbance or ferrous object.
(480E, 504N)	X	X	High/low total field and gradient. Possible fire-related material[1] or ferrous object.
(480E, 522N)	X	X	High/low total field and gradient. Probable ferrous metallic object.
(480E, 535N)	X	X	Low total field, high gradient. Probable ferrous metallic object.
(490E, 476N)	X	X	High/low total field and gradient. Probable ferrous metallic object.
(520E, 470N)	X	X	High/low total field and gradient. Probable ferrous metallic object.
(520E, 478N)	X	X	Low total field, high/low gradient. Probable ferrous metallic object.
(520E, 488N)	X	X	Low total field and gradient. Probable ferrous metallic object.
(520E, 492N)	X	X	Low total field and gradient. Probable ferrous metallic object.
(520E, 524N)	X	X	High/low total field and gradient. Probable ferrous metallic object.
(520E, 536N)	X	X	Low total field and gradient. Possible ferrous metallic object.
(530E, 508N)		X	Low gradient. Possible soil disturbance or ferrous metallic object.

[1] Fire-related material could include hearths, kilns, pottery, etc.

the southeast section of the grid, which further supports the premise that the in-phase anomaly is caused by variations in the magnetic susceptibility of the soil rather than ferrous metallic material. The magnetic data (Figures 11 and 12) collected along 2.5-m spaced survey lines in the smaller survey area allow the separation of individual anomalies that generated the large anomaly at (490E, 475N) in Figures 9 and 10, and also reveal other anomalies that were not detected using a 10-m line spacing. Table 2 lists the locations of the magnetic anomalies that are outlined in the total field (Figure 11) and gradient (Figure 12) data. The source of the majority of anomalies identified in the magnetic data is most likely ferrous metallic material. The magnitude of the anomalies (>100 nT) is greater than what would be expected if any of the anomalies were caused by soil disturbance activities (digging, foot traffic, etc.).

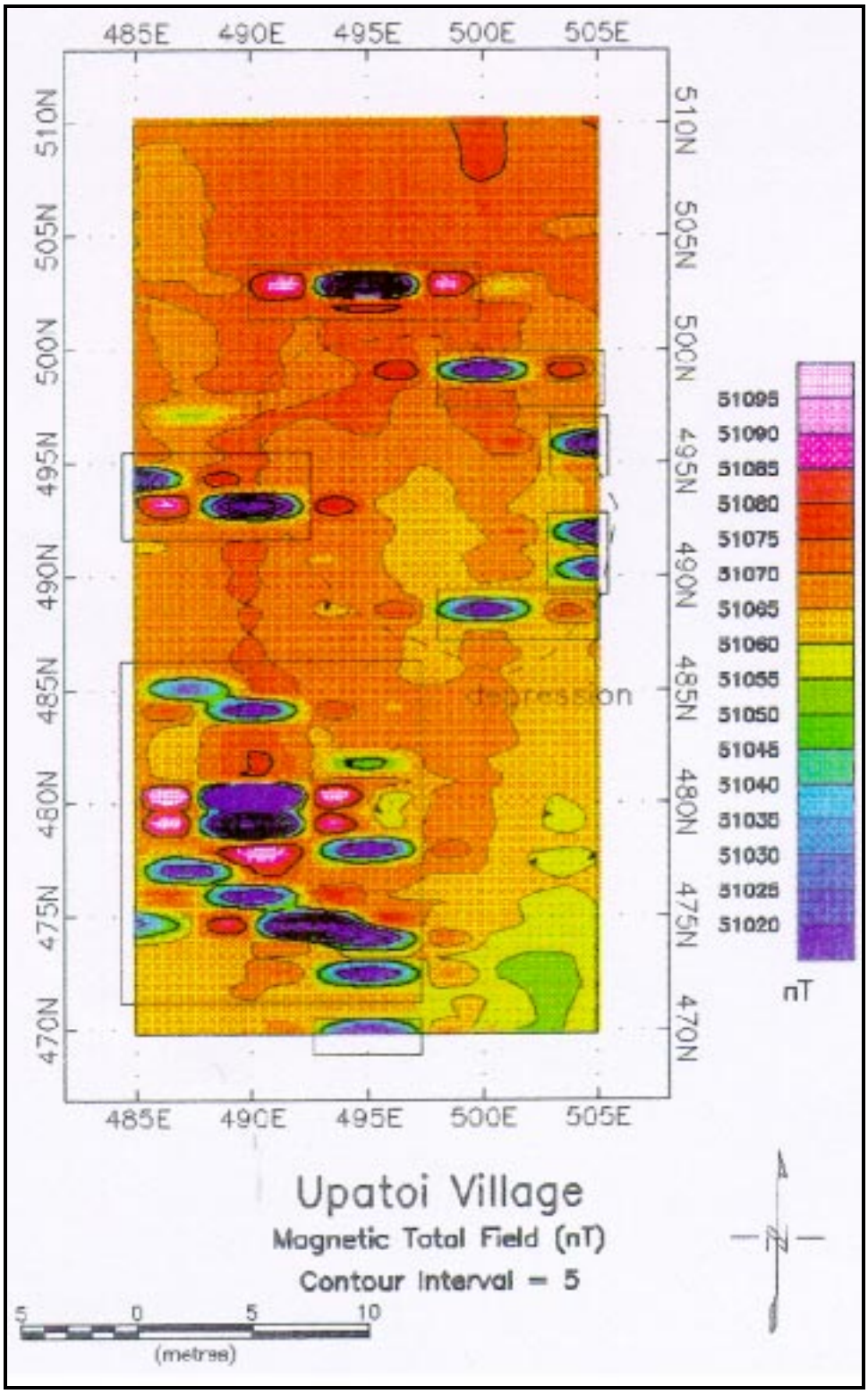


Figure 11. Results of magnetic total field survey performed over portion of survey grid (2.5 m survey line spacing)

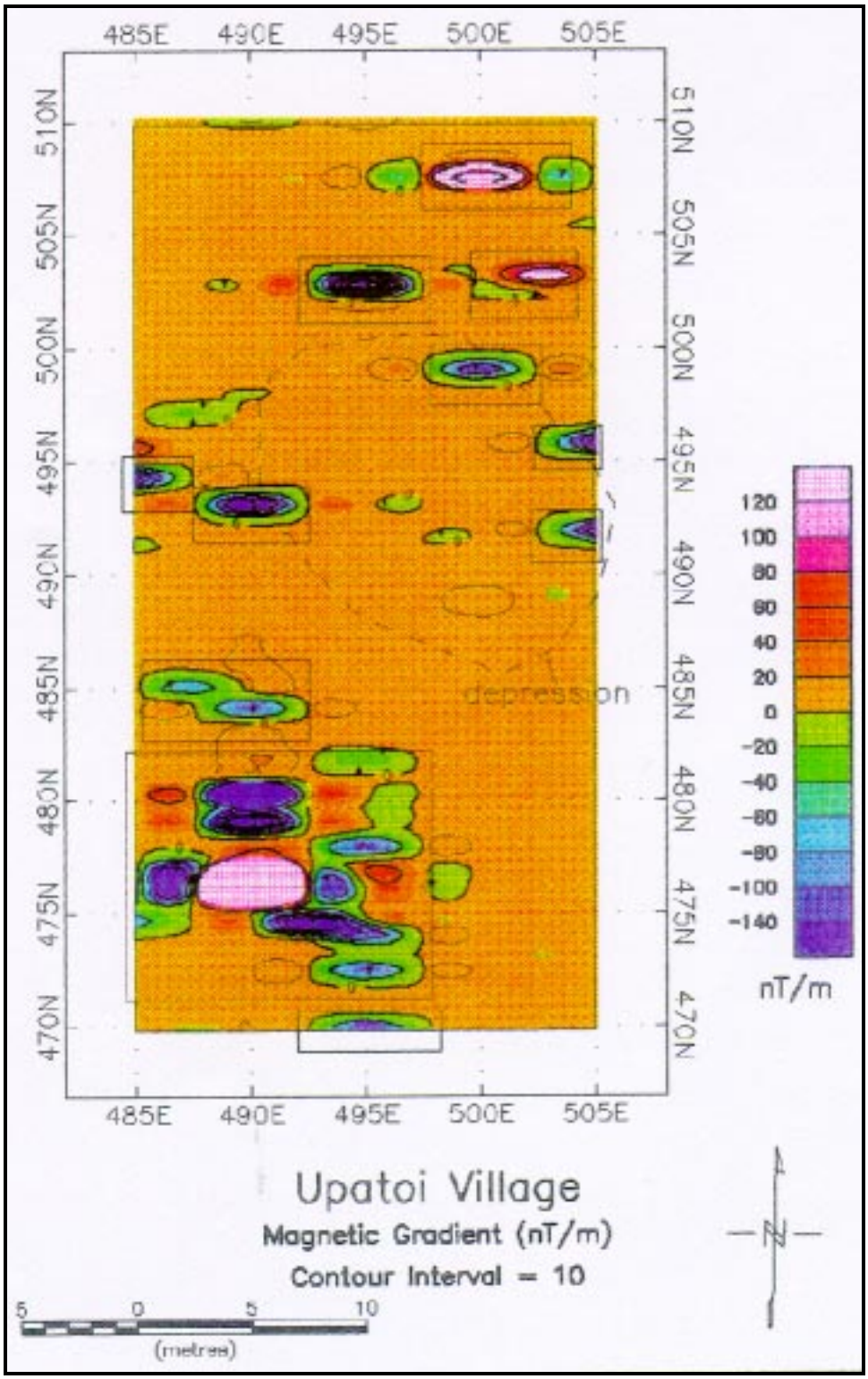


Figure 12. Results of magnetic gradient survey performed over portion of survey grid (2.5 m survey line spacing)

Table 2
Magnetic Anomalies, Partial Grid (2.5-m Survey Line Spacing)

Anomaly Location	Magnetometer		Anomaly Description
	Total Field	Gradient	
(485E, 475N)	X	X	Low total field and gradient. Possible ferrous metallic object.
(485E, 494N)	X	X	Low total field and gradient. Possible ferrous metallic object.
(487E, 477N)	X	X	Low total field and gradient. Possible ferrous metallic object.
(487E, 485N)	X	X	Low total field and gradient. Possible soil disturbance or ferrous metallic object.
(487E, 497N)	X	X	Moderately low total field and gradient. Possible soil disturbance.
(490E, 476N)	X	X	Low total field and high gradient. Probable ferrous metallic object.
(490E, 479N)	X	X	Low total field and gradient. Probable ferrous metallic object.
(490E, 480N)	X	X	Low total field and gradient. Probable ferrous metallic object.
(490E, 484N)	X	X	Low total field and gradient. Probable ferrous metallic object.
(490E, 493N)	X	X	Low total field and gradient. Probable ferrous metallic object.
(492E, 475N)	X	X	Low total field and gradient. Probable ferrous metallic object.
(495E, 470N)	X	X	Low total field and gradient. Possible ferrous metallic object.
(495E, 472N)	X	X	Low total field and gradient. Probable ferrous metallic object.
(495E, 478N)	X	X	Low total field and gradient. Probable ferrous metallic object.
(495E, 482N)	X	X	Moderately low total field and gradient. Possible soil disturbance.
(495E, 503N)	X	X	High/low total field and gradient. Probable ferrous metallic object.
(500E, 488N)	X		Low total field. Possible ferrous metallic object.
(500E, 499N)	X	X	Low total field and gradient. Probable ferrous metallic object.
(500E, 508N)		X	High gradient. Possible ferrous metallic object.
(502E, 503N)		X	High/low gradient. Possible ferrous metallic object.
(505E, 490N)	X		Low total field. Possible ferrous metallic object.
(505E, 492N)	X	X	Low total field and gradient. Probable ferrous metallic object.
(505E, 496N)	X	X	Low total field and gradient. Probable ferrous metallic object.

GPR data

The low soil conductivity provided a good environment for performing ground penetrating radar. The GPR data reveal three major subsurface reflectors at depths of 0.5 to 0.7 m (10 to 13 ns), 1.2 m (22 ns), and 2 m (40 ns). In some of the deeper time sections, a broad anticlinal feature is present. Anomalous features identified in the GPR data indicate activities caused by inhabitation and/or geologic processes that occurred at two different time periods. These features

will be noted on specific GPR records discussed later in the text. The GPR survey consisted of nine lines oriented north-south and eight east-west. The locations of the GPR lines are shown in Figure 13. The north-south survey lines generally run between stations 470N and 510N, and the east-west lines between 485E and 505E. Typical features observed on a GPR record are (1) continuous reflector, (2) discontinuous or disturbed reflector, (3) hyperbolic reflection, and (4) no resolution. These four features are identified on the GPR record in Figure 14. A continuous reflector generally represents the results of a slow geologic process, such as a stratigraphic layer, sediment-filled depression, or other geologic structure. A disturbed reflector can be caused by several factors, including human and animal activity or geologic processes. Objects or structures, either naturally occurring or man-made, of finite size in a given direction can generate a hyperbolic GPR reflection. Examples of naturally occurring structures are boulders, tree roots, and logs, whereas man-made structures include pipes, cables, and graves. The region of no reflection on a GPR record represents where the transmitted GPR signal has been attenuated to a level such that no features below that point in the subsurface are discernible.

The north-south GPR profile lines are discussed first. Figure 14 is the GPR record collected along Line 482.5E. Two anomalous features are identified: a strong hyperbolic reflection at 475N, depth 0.8 m, and a disturbed area at 497N, depth 1.0 m. The hyperbolic reflection marks the location of a possible burial. This reflection may be overshadowing a deeper feature at 1.7-m depth. The label given each anomaly is for future reference. Profile Line 485E is shown in Figure 15. The hyperbolic reflection at 475N, depth 0.75 m, may be associated with the same feature seen on Line 482.5E. A possible hyperbolic reflection is located at 494.5N, depth 0.5 m, and two disturbed areas between 499–501N and 504– 506N, both at about 1-m depth. One anomaly, which may be another burial, is seen on Line 490E at 474N, depth 1 m (Figure 16). The hyperbolic reflection at 474N, depth 0.8 m, on Line 492.5E (Figure 17) could be part of the similar feature on Line 490N. The region between 475–480N appears disturbed, but seems to be more of a geologic nature than man-made. A thin hyperbolic reflection is present at 485.5N, depth 1.2 m, and is probably caused by a small object. A point of disturbance is located at 492N and could indicate where a hole has been dug. Two prominent anomalies are apparent on Line 495E (Figure 18). The first is a hyperbolic reflection located at 474N, depth 0.6 m, which could be caused by a grave, and the second is at 496–497N, depth 2 m. The continuous nature of the strata overlying the second anomaly indicates that this feature occurred at an earlier time period than the anomaly at 474N. The feature at 496– 497N could have been formed by failure of the sedimentary layer, or it could be a hole, pit, or trench that later filled with sediment. Lines 500E (Figure 19) and 507.5E (Figure 20) exhibit no anomalous features. The GPR data collected along Lines 510E and 512.5E are in two sections because a fallen tree prevented continuous collection of the data. Figure 21 is the GPR profile along Line 510E. The anomalous feature at 472N, depth 2 m, appears to be a hole. The deeper, anticlinal structure can be seen in this section centered below 493N at a depth of 4.5 m. This deep reflector is the only prominent feature on Line 512.5E (Figure 22). The location, depth, and possible feature of each anomaly discussed is summarized in Table 3. The possible features noted as burials at locations 474N and 475N between Lines 482.5– 495E could be a trench.

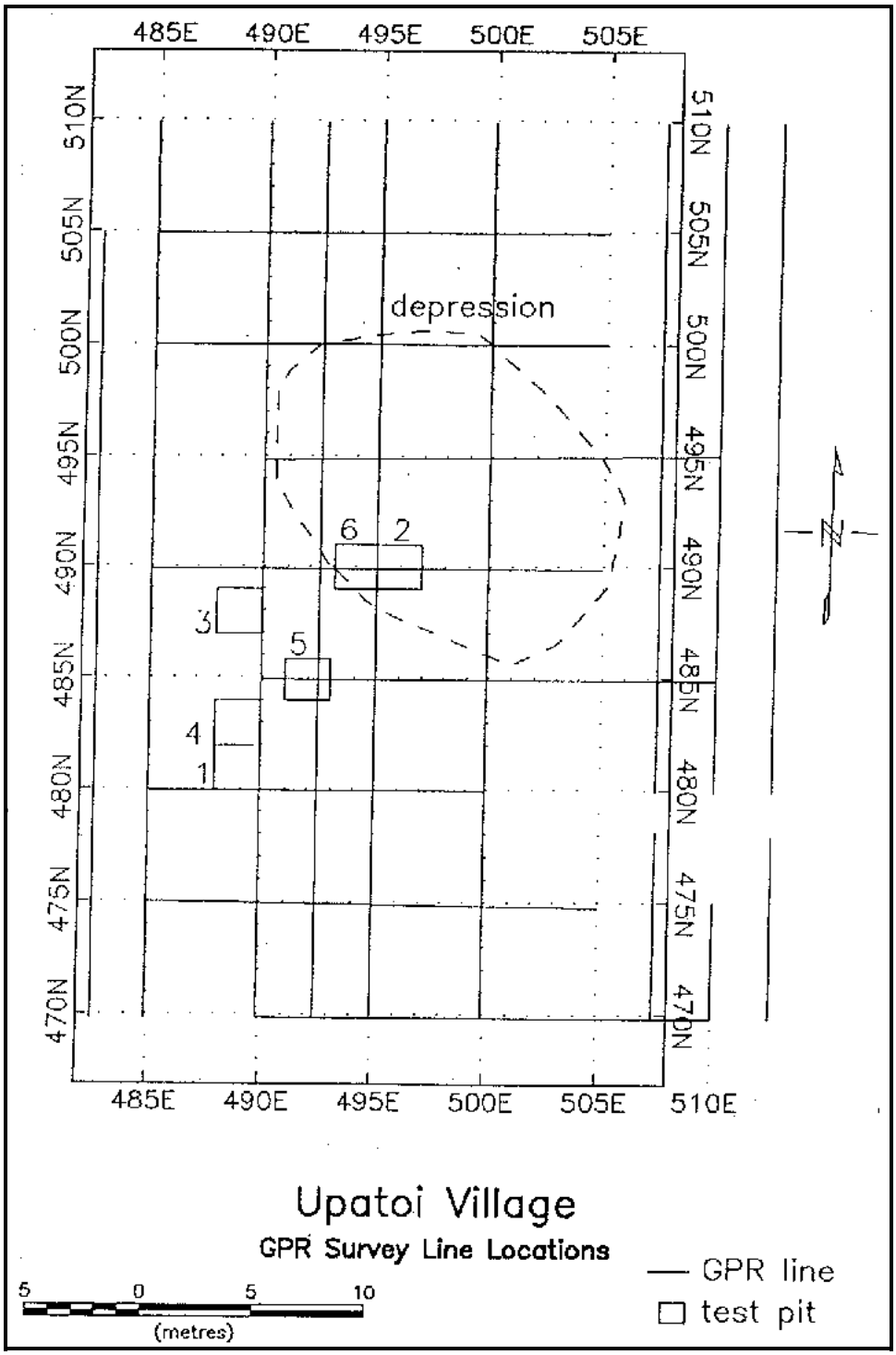


Figure 13. Location of GPR profile lines

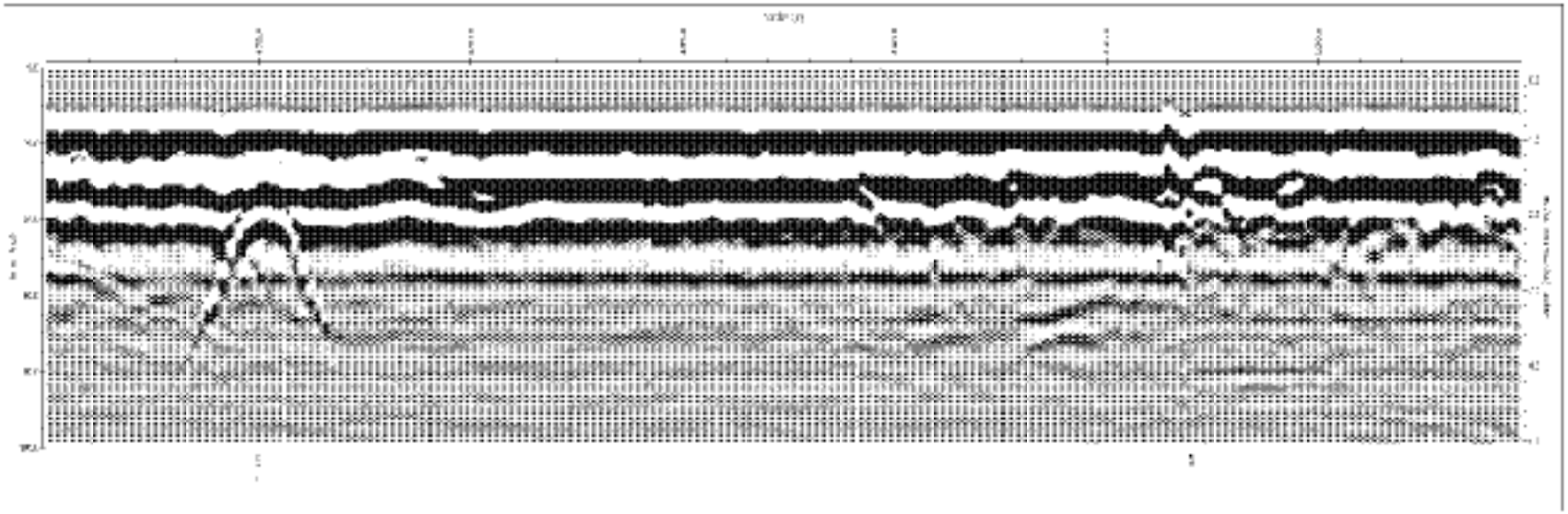


Figure 14. GPR profile Line 482.5E, with labels to identify anomalies G1-G3 and four typical features that can be observed on GPR sections

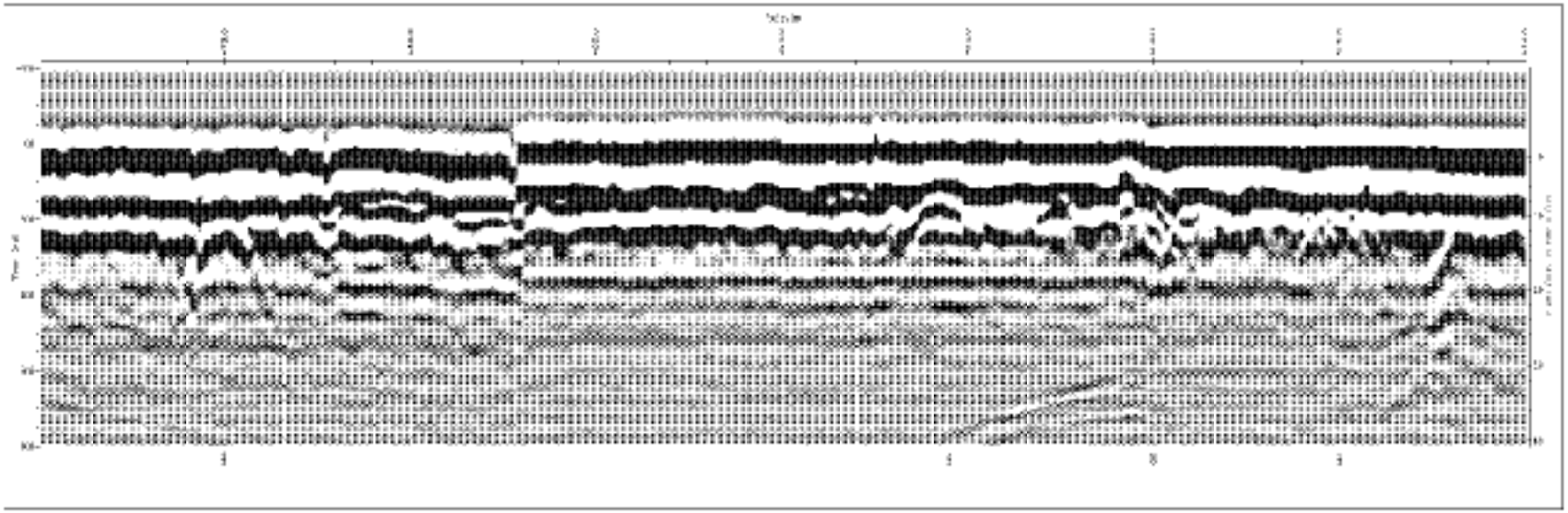


Figure 15. GPR profile Line 485E with anomalies G4-G7 identified

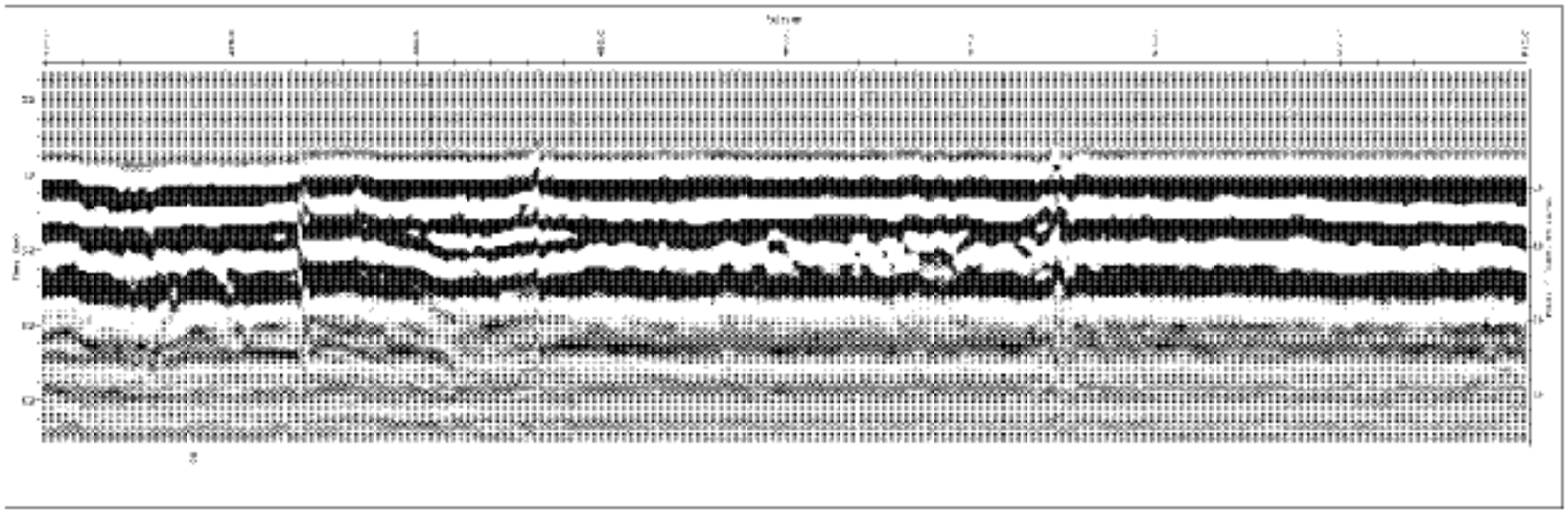


Figure 16. GPR profile Line 490E with anomaly G8 identified

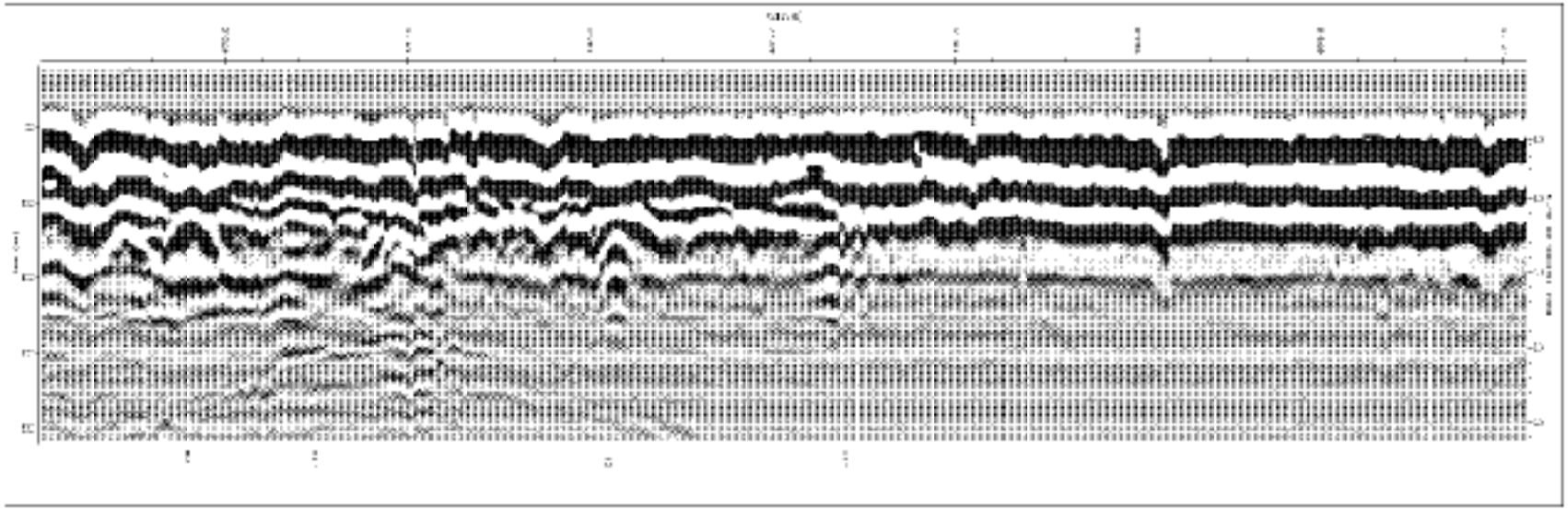


Figure 17. GPR profile Line 492.5E with anomalies G9-G12 identified

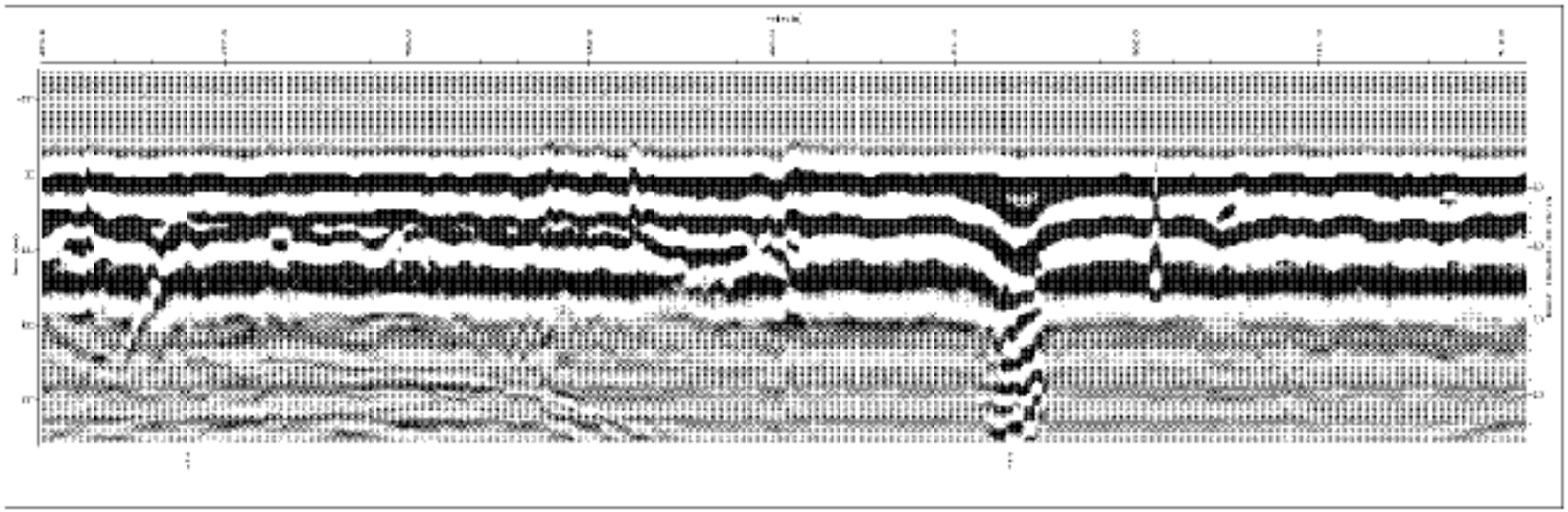


Figure 18. GPR profile Line 495E with anomalies G13 and G14 identified

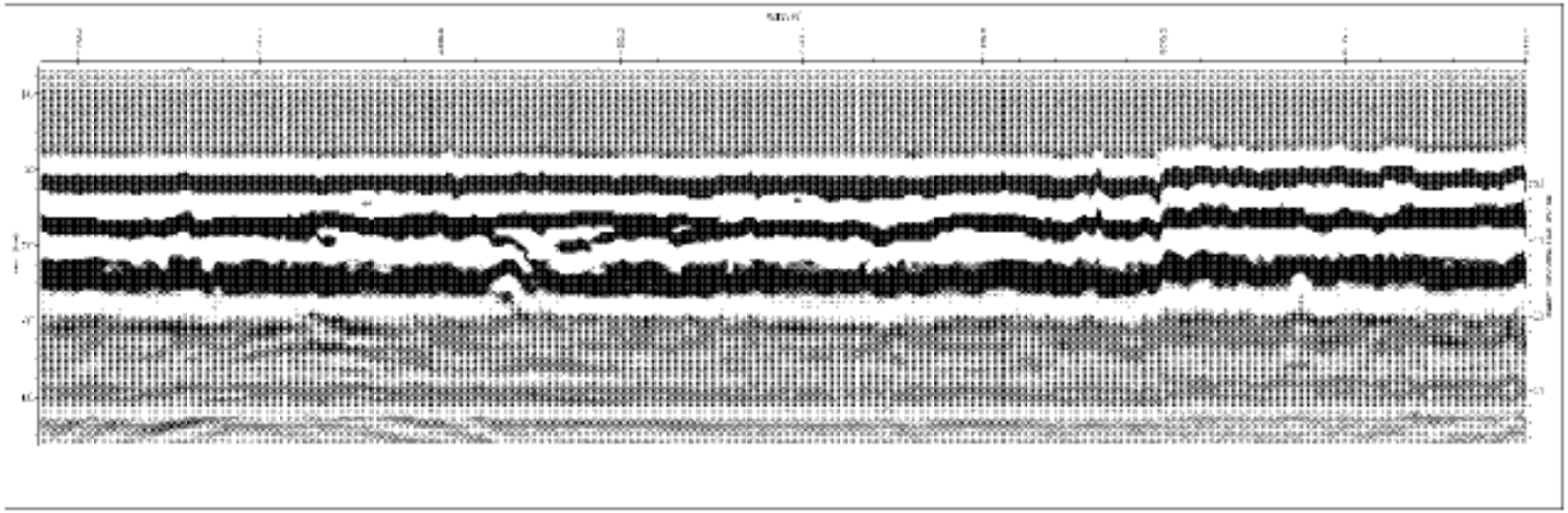
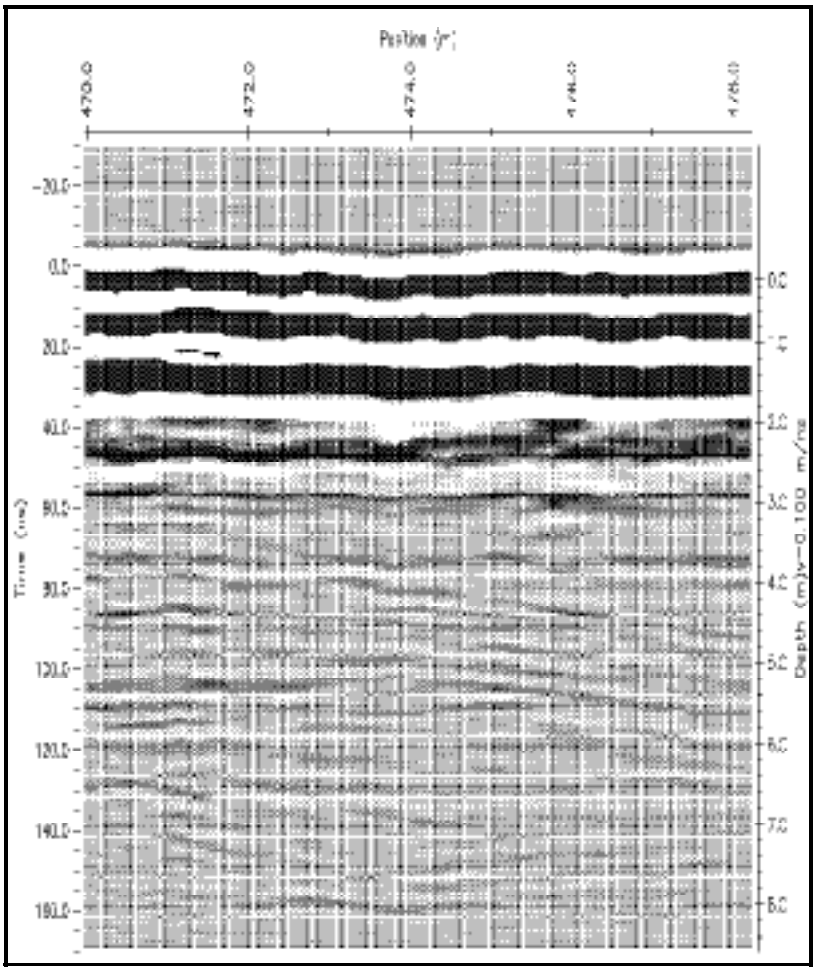


Figure 19. GPR profile Line 500E



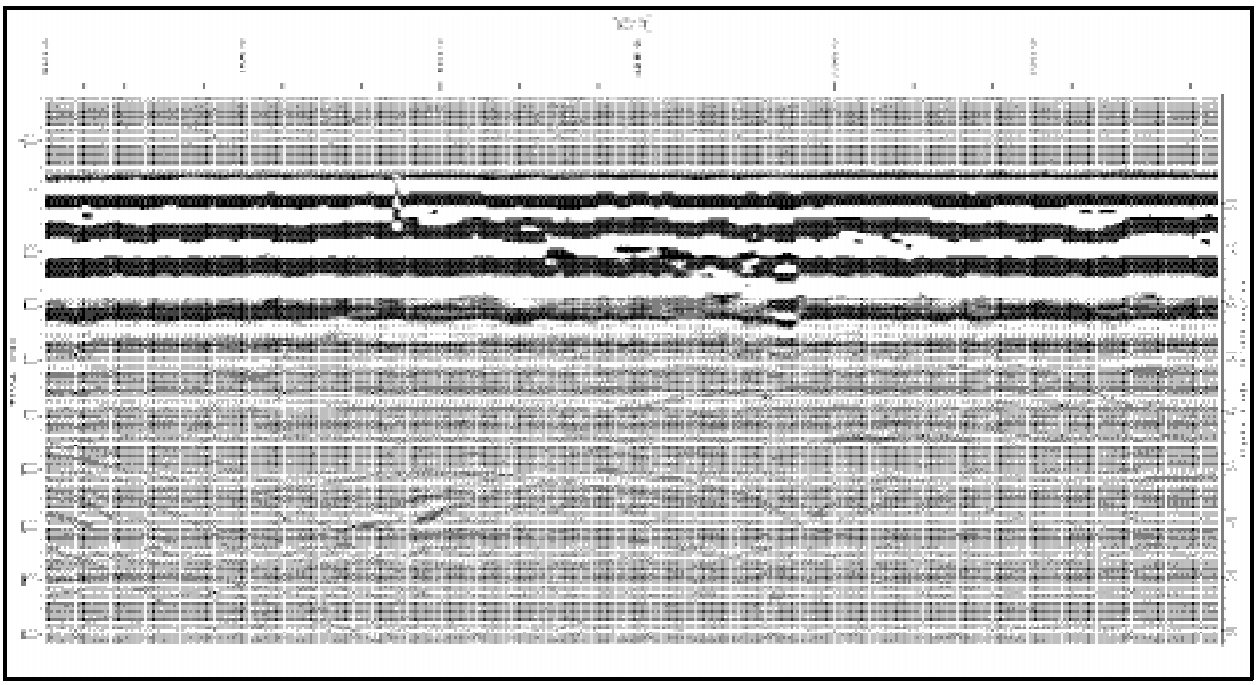
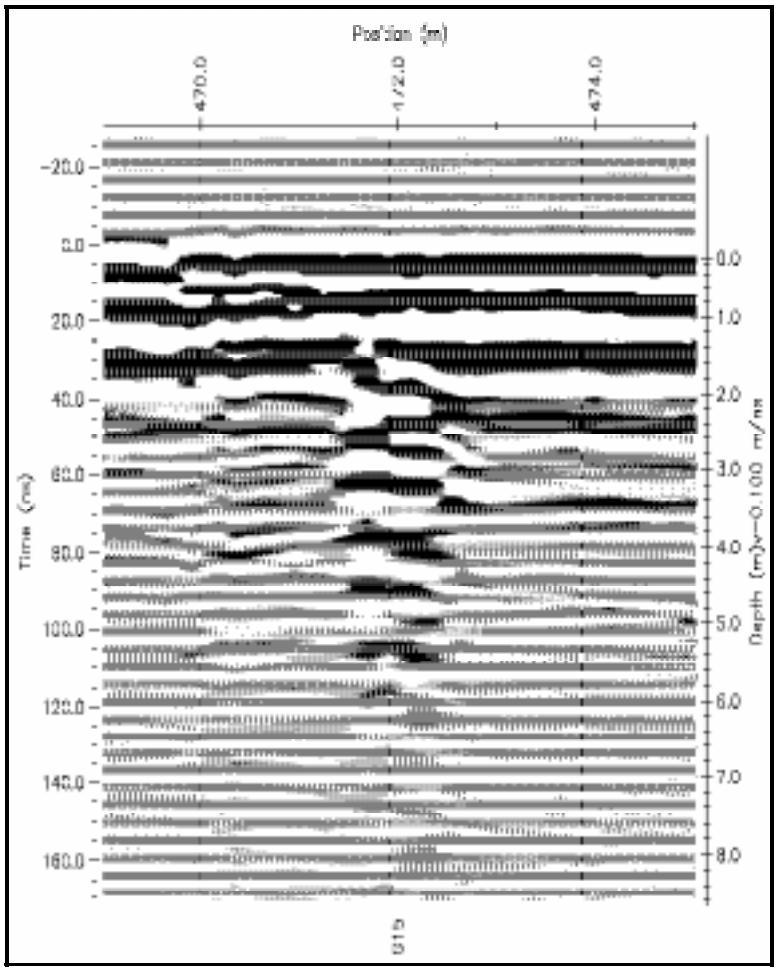


Figure 20. GPR profile Line 507.5E



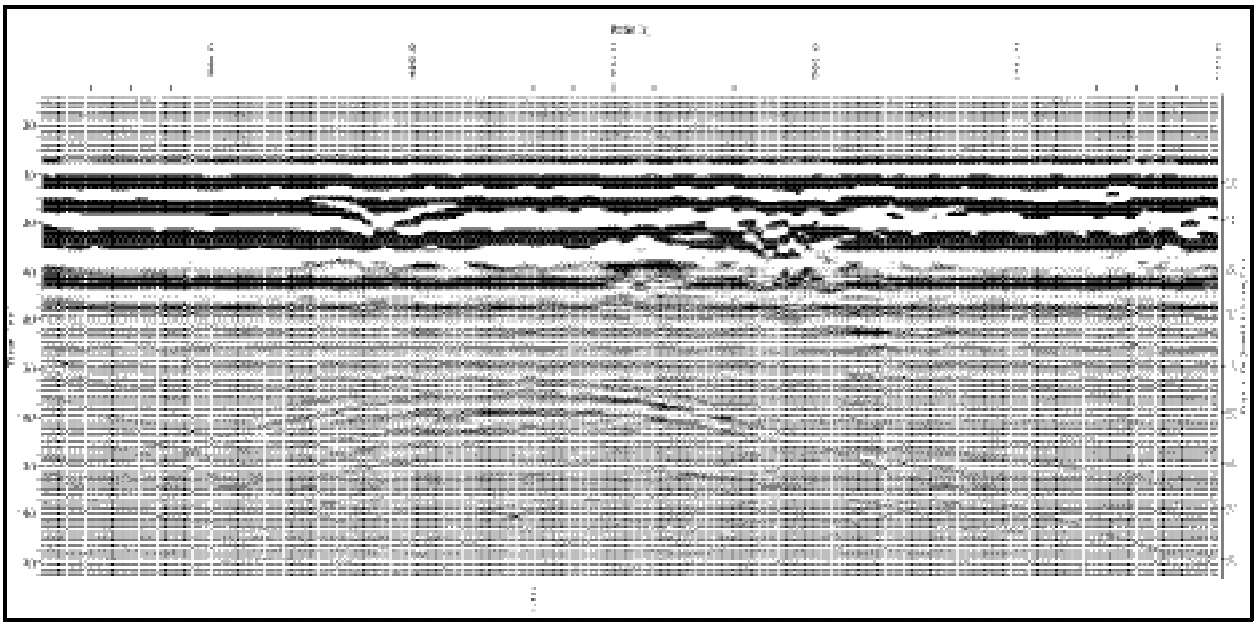
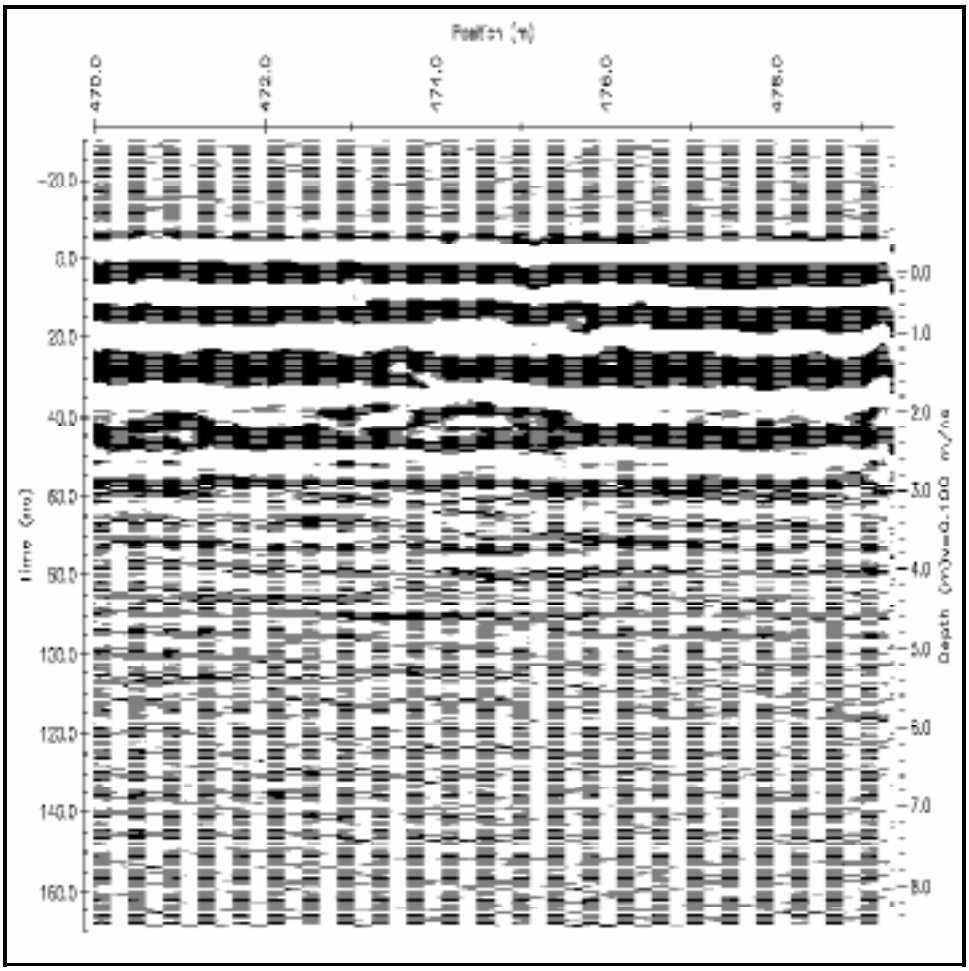


Figure 21. GPR profile Line 510E with anomaly G15 and geologic feature G16 identified



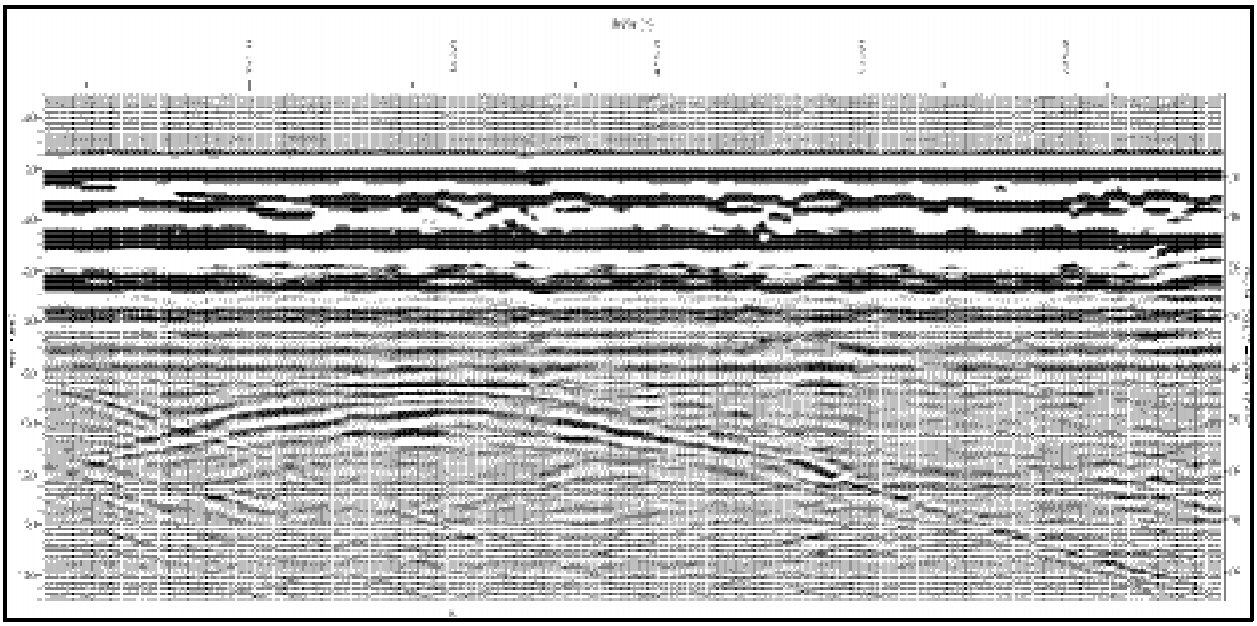


Figure 22. GPR profile Line 512.5E with geologic feature G17 identified

Table 3
GPR Anomalies, North-South Profile Lines

Line	Anomaly Location	Reference Label	Depth, m	Anomaly Description	Possible Feature
482.5E	475N	G1	0.8	Hyperbola	Burial
	475N	G2	1.0	Hyperbola (?)	Object
	497N	G3	1.7	Disturbed	
485E	475N	G4	0.75	Hyperbola	Burial possibly associated with G1
	494.5N	G5	0.5	Hyperbola (?)	Burial (?)
	499–501N	G6	1.0	Disturbed	
	504–506N	G7	1.0	Disturbed	
490E	474N	G8	1.0	Hyperbola	Burial
492.5E	474N	G9	0.8	Hyperbola	Burial possibly associated with G8
	475–485N	G10	1.0–1.8	Disturbed	Geologic
	485.5N	G11	1.2	Hyperbola	Small object
	492N	G12	1.4	Disturbed	Hole
495E	474N	G13	0.6	Hyperbola	Burial possibly associated with G9
	497N	G14[1]	2.0	Disturbed	Hole, pit, trench
510E	472N	G15[1]	2.0	Disturbed	Hole, pit
	493N	G16	4.5	Strong reflector	Geologic deep structure
512E	490N	G17	4.2	Strong reflector	Geologic deep structure

[1] Possible earlier occupation horizon.

The east-west GPR profile lines are presented in Figures 23–30. The anomaly located at 501E, depth 0.5 m, on Line 470N may be caused by a buried object (Figure 23). Another possible grave is located at 491.5E, depth 0.6 m, on Line 475N (Figure 24). Note the greater width of this hyperbolic reflection compared to one on a north-south profile line (Figure 14), which suggests that the feature is oriented east-west. This anomaly may be associated with G8 or G9. Three anomalies, one of which is questionable, are seen on Line 480N (Figure 25). The first is a disturbance at 486.5E, depth 1.3 m, and another is a possible burial at 490.5E, depth 0.9 m. The anomaly in question is located at 493E. It is caused in part by the irregular ground surface, but there may be a deeper source at approximately 1-m depth. Figure 26 is the GPR record collected along Line 485N. The hyperbolic reflection at 502.5E, depth 1 m, could be caused by a grave. A possible anomaly is located at 487.5E, depth 1.3 m, on Line 490N (Figure 27). The disturbance between 493–495E is where archaeological test pits 6 and 2 are located. Line 495N (Figure 28) shows a disturbed area between 500.5–503.5E, depth 2 m, that may represent a pit containing small objects. The

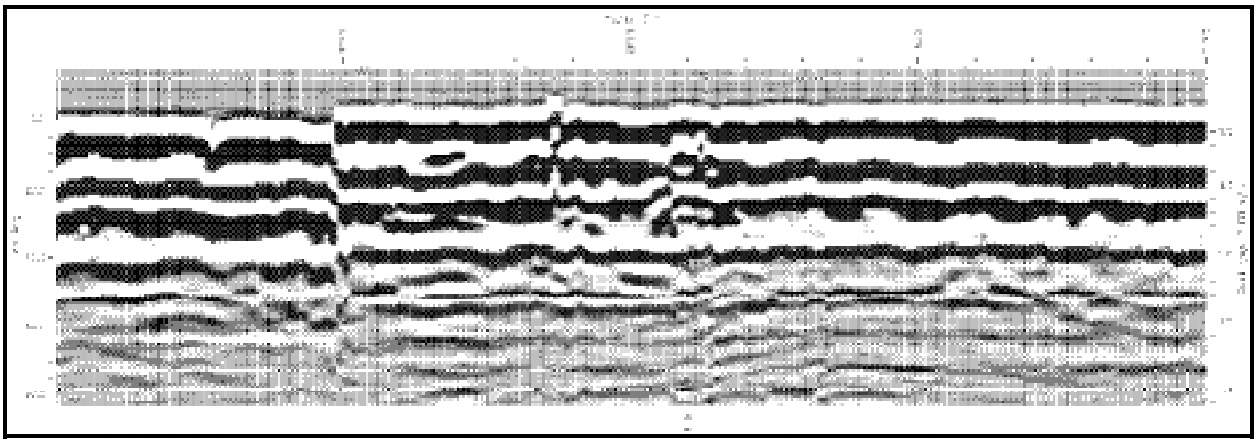


Figure 23. GPR profile Line 470N with anomaly G18 identified

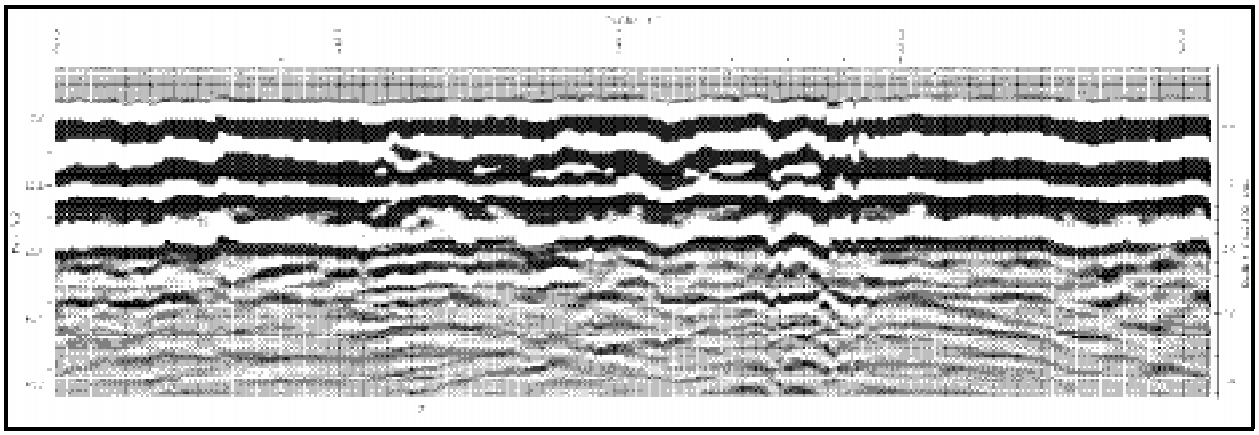


Figure 24. GPR profile Line 475N with anomaly G19 identified

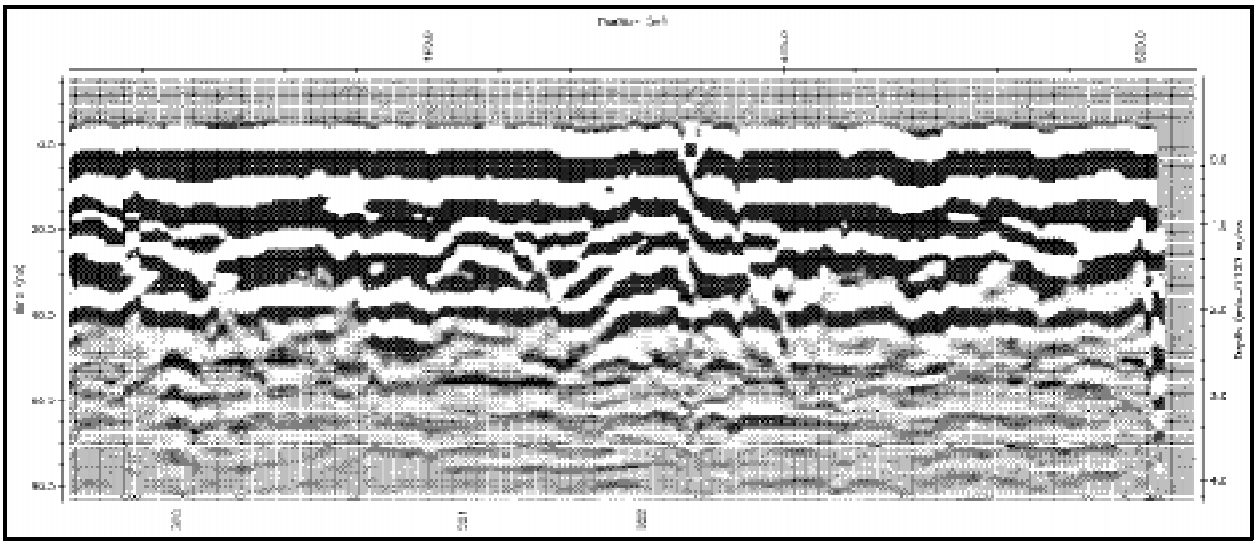


Figure 25. GPR profile Line 480N with anomalies G20-22 identified

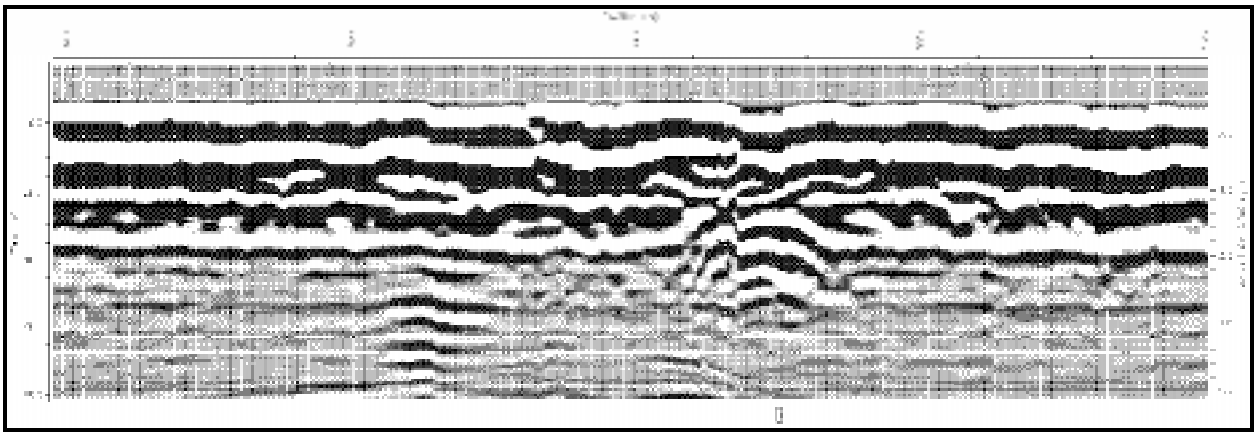


Figure 26. GPR profile Line 485N with anomaly G23 identified

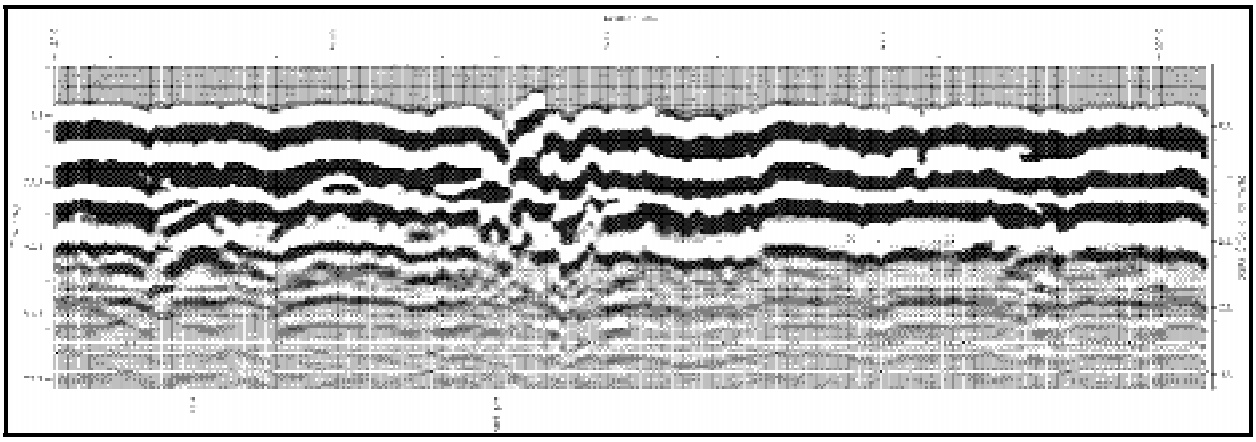


Figure 27. GPR profile Line 490N with anomaly G24 identified

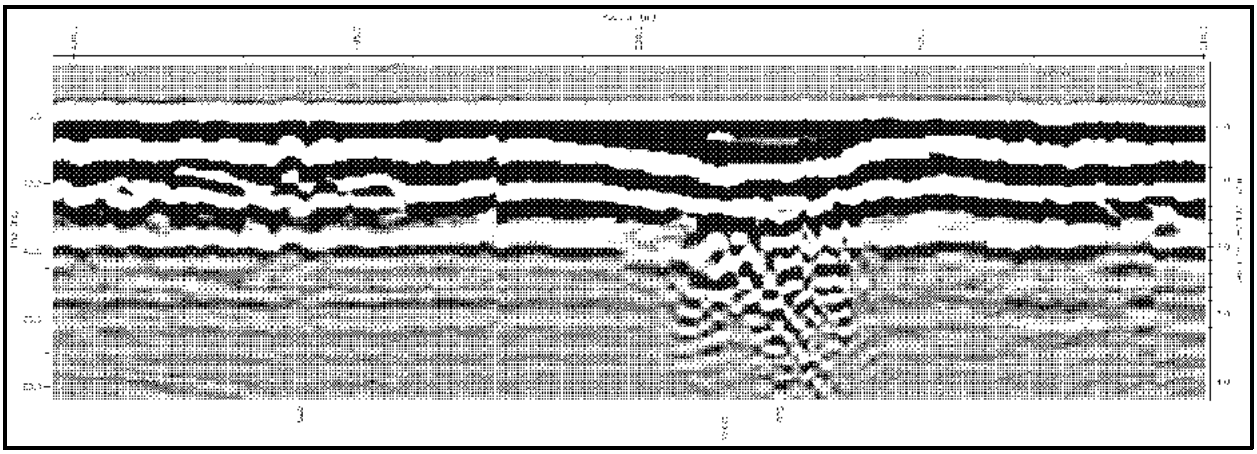


Figure 28. GPR profile Line 495N with anomalies G25 and G26 identified

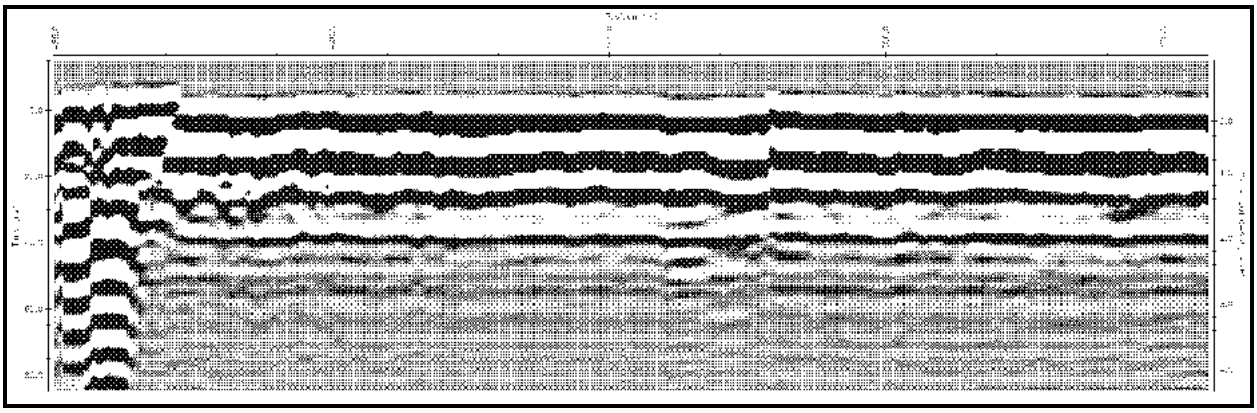


Figure 29. GPR profile Line 500N

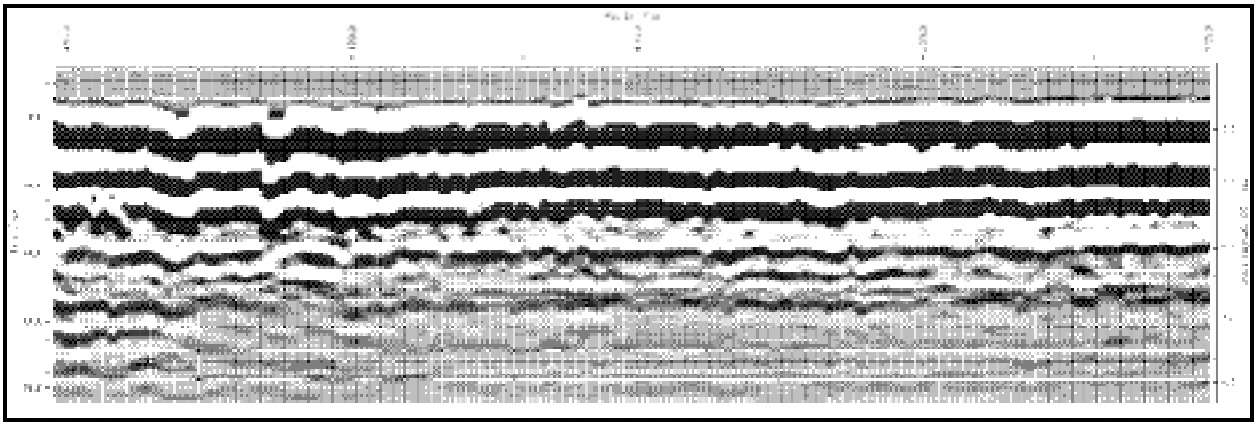


Figure 30. GPR profile Line 505N

section between 490–496E of the stratigraphic layer at 1.5-m depth is slightly disturbed compared with other sections of this reflector. Lines 500N (Figure 29) and 505N (Figure 30) exhibit no anomalous features. A summary of the anomalies identified on the east-west GPR profile lines is given in Table 4.

Summary of results

The locations of anomalies identified in all data sets are shown in Figure 31. The majority of anomalies are within the area bounded by (480–510E, 470–510N). Within this smaller area, the anomalies are concentrated in the area of higher conductivity values seen in Figure 7. Note that the higher conductivity values in Figure 7 are not anomalously high when compared with the conductivity data collected over the entire grid (Figure 5). The GPR anomalies in bold type (G1, G4, G5, G8, G9, G13, G19, G21, G23) represent possible burials. Although there are nine GPR anomalies that mark possible burials, two or more of the anomalies may be caused by a single burial, e.g. G1/G4 and G8/G9/G19. A magnetic anomaly is generally associated with the possible burials. Three of the

Table 4
GPR Anomalie s, East-West Profile Lines

Line	Anomaly Location	Reference Label	Depth, m	Anomaly Description	Possible Feature
470N	501E	G18	0.5	Hyperbola (?)	Object
475N	491.5E	G19	0.6	Hyperbola	Burial possibly associated with G8 or G9
480N	486.5E	G20	1.3	Disturbed	
	490.5E	G21	0.9	Hyperbola	Burial
	493E (?)	G22	1.0	Disturbed	
485N	502.5E	G23	1.0	Hyperbola	Burial
490N	487.5E (?)	G24	1.3	Disturbed	
495N	490–496E	G25	1.5	Disturbed	
	500.5–503.5E	G26[1]	2.0	Disturbed	Pit or trench with small objects

[1] Possible earlier occupation horizon.

four GPR anomalies that appear to be holes or pits are located within the depression (G12, G14, G26). Stratigra phic evidence suggests that the fourth anomaly, G15, and anomalies G14 and G26 were emplaced during an earlier time period than the other GPR anomalies.

Conclusions

Results of the geophysical investigation conducted at site 9 ME 395 showed that the majority of geophysical anomalies are concentrated within a smaller region of the survey area bounded by the coordinates (480–510E, 470–510N). The conductivity and inphase data do not reveal any anomalous areas that corresponded with anomalies in the other data sets. The anomalies present in the EM data are likely caused by variations in the local soil conditions. Numerous magnetic anomalies were identified. The magnitude of these anomalies (>100 nT) suggests that ferrous metallic material is the source.

The GPR data exhibit several interesting features. Six possible burials were identified, four of which had a magnetic anomaly associated with them. The depth of these six subsurface features ranged from 0.5 to 1.0 m. The geophysical data do not confirm the location of the council house. No correlation was observed between the location of the large depression and that of the geophysical anomalies. Three GPR anomalies that appear to be holes or pits were identified on separate GPR sections at a depth of 2.0 m; two of the anomalies are located within the depression. The GPR records show that there is no disturbance of the strata overlying these three anomalies. The continuity of the overlying strata indicates that these features were created at an earlier time period than the possible burials, which are located at shallower depths.

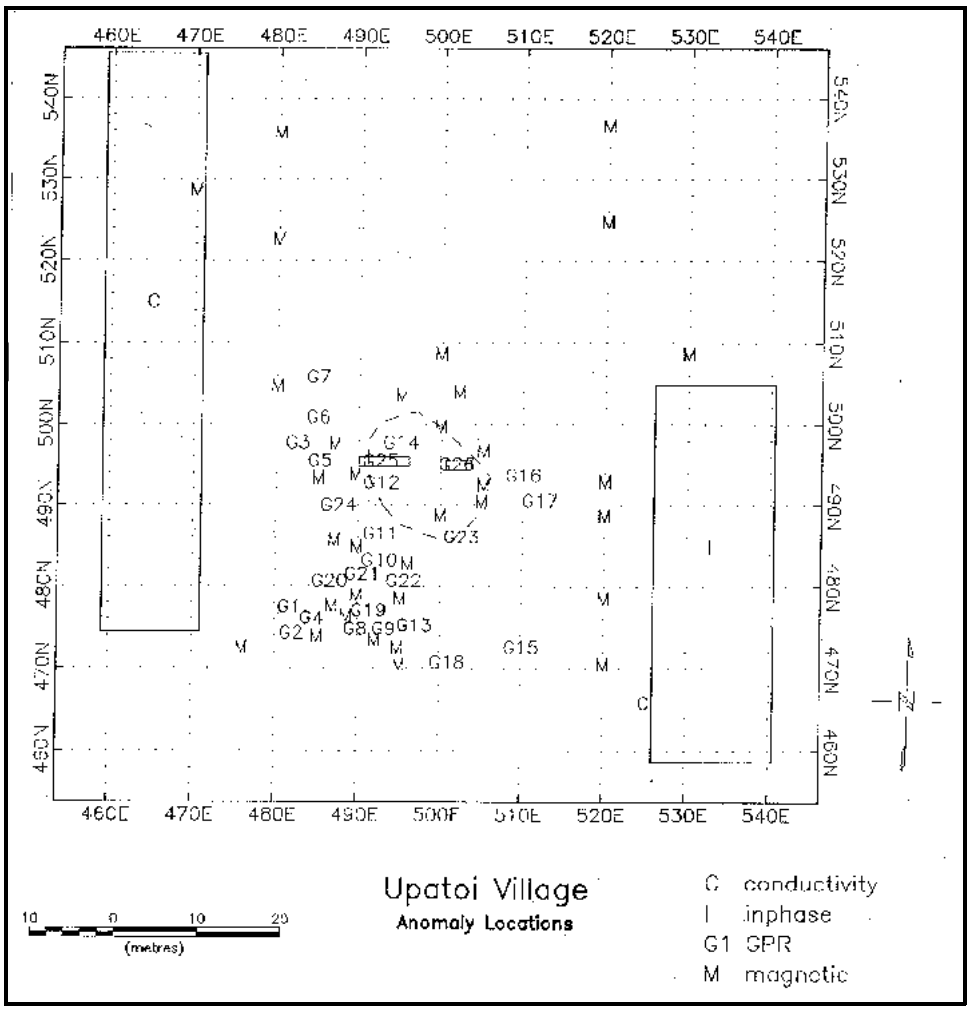


Figure 31. Locations of anomalies identified in all data sets

Preliminary archaeological investigations of the Upatoi Village site discovered a wide variety of prehistoric and historic artifacts, features, and a Creek burial. Test pits unearthed the location of post holes and buried features thought to be associated with one or more structures and possibly a council house. This geophysical investigation has identified several new features/areas that are probably of archaeological importance. Use of geophysics allowed a large area of site 9 ME 395 to be expeditiously investigated. Conjunctions of various geophysical evidence indicate which areas of the site are more likely to contain significant archaeological material and possible buried features that, in the absence of more expensive, destructive, and time-consuming archaeological excavation, might have gone undetected.

3 Geomorphological Reconnaissance

A geomorphological reconnaissance of site 9 ME 395 in the northeastern corner of Fort Benning, Georgia, was conducted with two objectives: (a) to provide relevant information for use in the subsequent geophysical survey of the site, and (b) to provide information useful in the evaluation of the site with respect to the occurrence and significance of historic and prehistoric cultural resources. In the following paragraphs, the methods used and interpretations developed by the geomorphological reconnaissance are described.

Methods

Prior to the field reconnaissance, a review of immediately available materials was conducted. These materials included the "Report on the Geomorphology of Compartments K-6 and K-7, Fort Benning Georgia" (Savrda 1995); the Upatoi 1:24,000 U.S. Geological Survey topographic quadrangle; field notes from Southern Research of field investigations at the site;[1] and the "Fort Benning Georgia, Terrain Analysis" (U.S. Army, Fort Benning, Georgia 1976).

On 28 November 1995, a field visit to the site was conducted. While at the site, observations were made of local topography, geographic setting, shallow soils (soil pits and natural subsurface exposures), observable geologic features, and the relationship between gross vegetation patterns and soils. Additionally, the results of field investigations conducted by Southern Research several months prior were discussed with Mr. Dean Wood at the site, including the spatial distribution of the results of subsurface testing. While in the vicinity, site 9 ME 42 was also examined rudimentarily.

Interpretation

Site 9 ME 395 is located on the edge of a terrace overlooking a floodplain. This is a landscape setting that has been found to be important to both prehistoric

[1] Personal Communication, 1996, Dean Wood, Archaeologist, Southern Research, Ellerslie, GA.

and historic human occupation. Furthermore, the site is situated near the boundary between the Coastal Plain Sand Hills and the highly weathered soils of the Georgia Piedmont. The landscape setting is illustrated in Figure 32, a topographic cross section of the landscape in the vicinity of site 9 ME 395 with landforms identified and shallow stratigraphy postulated. The topography of the area is profiled from Upatoi Creek to the south, across the site to the uplands of the Piedmont north of the site.

The landscape of the area is primarily the product of the erosion of weakly indurated coastal plain deposits (sands, silts, and clays of the Eutaw and Tuscaloosa Formations) and highly weathered Piedmont crystalline rocks (Phoenix City Gneiss) by the streams of the area. The fluvial terrace upon which site 9 ME 395 is located was originally part of a broad sandy floodplain of Upatoi Creek or its ancestor stream. As the stream continued to incise the landscape, the floodplain was also incised, leaving the former active floodplain (now no longer subject to frequent inundation) as a terrace. The geographic extent of the terrace has subsequently been reduced by the erosional development of Kendall Creek and its tributaries as they developed their floodplains.

As the local streams developed the hillslopes, terraces, and floodplains of the area, they left behind a complex of fluvial deposits whose probable distribution is illustrated in Figure 32. The landforms encountered across the landscape are delineated on the bottom of the profile. Although these fluvial deposits may appear similar (gravelly or clayey sand), they are the product of different streams active over different time spans. Consequently, the significance of the fluvial deposits to cultural resources management is highly variable.

The sandy soils of the Tuscaloosa Formation, upslope (north) of the site should be culturally sterile at depth (due to their substantial age), with the exception of shallow (30-cm) materials in the plow zone. The surficial soils of the terrace (upon which the site is located) were probably deposited several tens of thousands of years ago and should contain the cultural record in the upper 30 to 50 cm (with the exception of human burials or other intrusive features). At the base of the terrace escarpment is a colluvial slope produced by the erosion of material from the terrace escarpment. This colluvial zone has been forming since the lateral impingement of Kendall Creek as it developed its floodplain (probably several thousand years ago). Both historic and prehistoric materials may be stratified in this deposit. The floodplain of Kendall Creek may contain cultural materials in the uppermost 150 cm of strata buried by vertical accretion of flood sediments over the last several thousand years.

During the field reconnaissance, the limits of the area to be geophysically surveyed were identified. These limits were based on the probable distribution of historic burials and other large features that could be detected geophysically. The factors considered in the determination of the limits of the survey were microtopography (as an indicator of surficial processes and the suitability of the specific location for use) and the results of the shovel tests and excavation units. Survey limits were confined to the top of the terrace, in particular the depression and areas where positive shovel tests were recorded. The sloping sides of the site were interpreted as being eroded during the historic period and probably too steep for intensive use or burial.

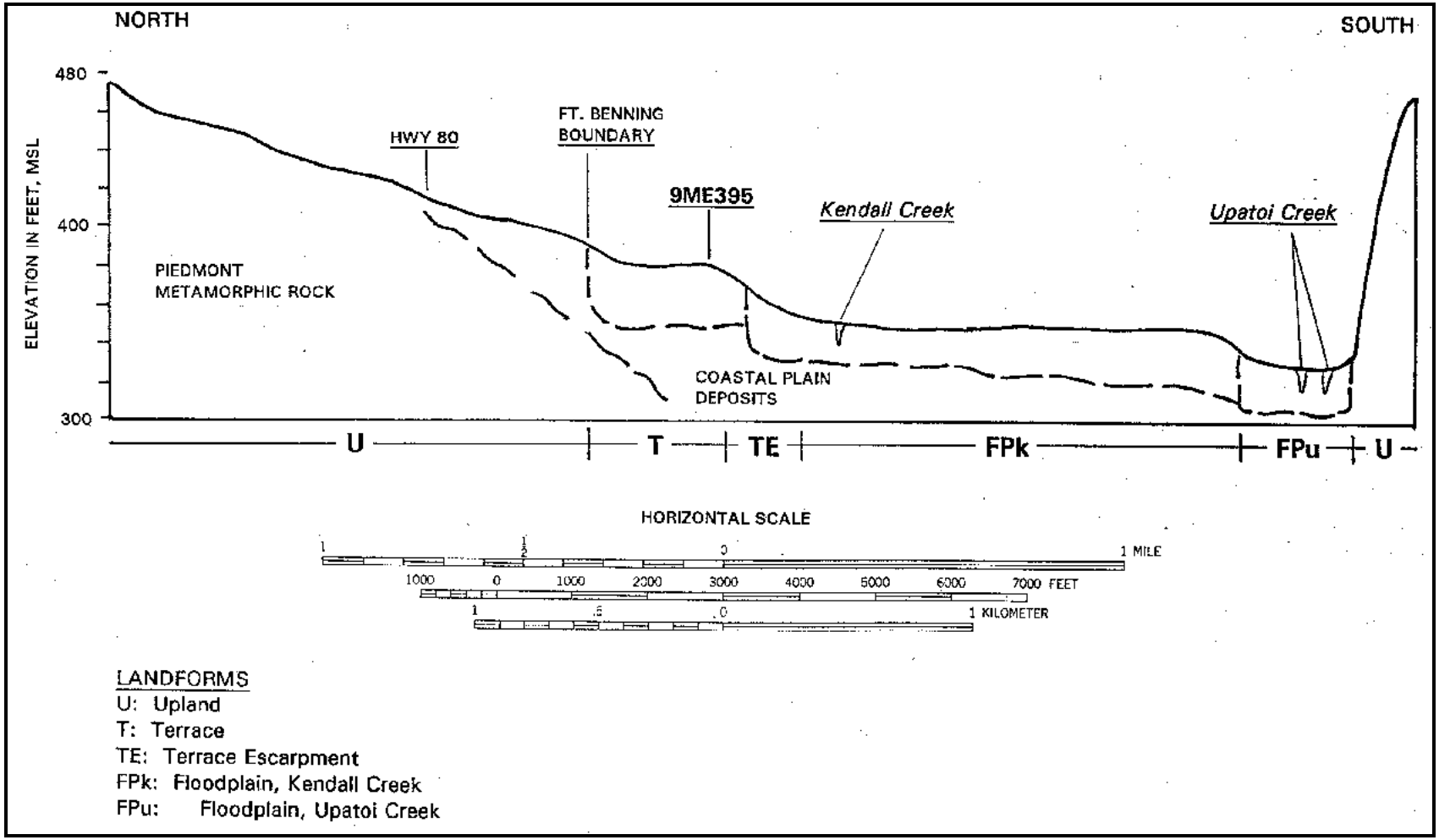


Figure 32. Landscape setting of Site 9 ME 395

Several relevant geomorphological characteristics of the site should be considered during the detailed evaluation of the site. These characteristics significantly influence the value of the site to both prehistoric and historic exploitation in terms of the availability of natural resources, site suitability for structures, and protection from natural hazards. These geomorphological characteristics are as follows: (a) the landscape setting of the site is a terrace adjacent to the escarpment between a floodplain and two types of uplands; (b) the natural geomorphic processes that most likely were active during both prehistoric and historic occupation of the site were those that would concentrate the cultural record within the upper 70 cm of the soil column; (c) the surficial soils of the site are relatively old (probably tens of thousands of years), geomorphically stable, easily excavated, and well drained; and (d) the amount of bioturbation (by rodents, tree throws, roots, etc.) is substantial in the upper 70 cm of the soil. It is also important to note that the specific landscape setting of the site is relatively common in the area, indicating that the specific location of site 9 ME 395 is not unique and that additional concentrations of (especially) prehistoric cultural artifacts may occur in the area.

Field observations of soil strata at the site indicate that there are two fundamental soil horizons within the upper 2 m of subsurface material at the site. As mentioned above, the sandy coastal plain soils are highly and deeply weathered throughout the immediate area of the site. Strong weathering of the sandy sediments has resulted in an orange to red clayey-sandy soil. The upper 50 to 70 cm of the soil has been highly bioturbated (mixed) by various organisms, resulting in the brownish-tan coloring of the soil by increased organic matter and the leaching of clay into the subsoil beneath. The significance of these two soil strata to cultural resources management at the site is substantial. The upper soil unit should contain almost all of the cultural record, with the exception of deep excavations such as burials. Because of the complete overturning of the upper soil strata by bioturbation processes, relatively recent cultural artifacts may be found at the same subsurface elevation and mixed in with considerably older artifacts. The basal orange-red clayey sand should be culturally sterile with the exception of deep features mentioned above.

4 Integrated Results and Program Recommendations

Integrated Results

The archaeological information based on six (2- by 2-m) excavation units indicates a clear but simple stratigraphy that is consistent with independent observations from a geomorphological and geophysical perspective. The detailed stratigraphic profiles recorded by archaeologists are compatible with Dr. Smith's conclusions regarding subsurface observations and geomorphic processes that explain the evolution of the landform on which the site is located. The estimated boundaries of the landform from a geomorphic perspective closely approximate the archaeological definition of the site in space. Based on cultural observations, primarily from shovel testing but amplified by limited subsurface excavation, there is a clear relationship between areas of artifact occurrence and topography that is probably a function of the active erosion of an ancient and stable surface. Artifact occurrence dramatically drops off as a function of steep slopes subject to active erosion, especially in the recent geological past.

Geophysical data indicating depth of disturbed features as well as indications of a large number and variety of buried anomalies well distributed throughout the site are also consistent with the stratigraphy based on archaeological and geomorphological inference. There is nothing in the geophysical data relevant to buried stratigraphy, particularly in segments of undisturbed sediments, that is incongruent with the archaeological and geomorphological observations about stratigraphy. Although the depth of the cultural deposit is not expected to exceed 1 m anywhere, in most places it is only about 30 to 70 cm. There is still ample geophysical evidence of superimposition of buried anomalies and subsurface disturbances to support the concept of a relatively simple stratification of all areas of the site, not just where profiles were drawn or where subsurface indications were in evidence to an experienced geomorphologist.

Figure 33 shows where the site was sampled with a 1-m steel probe. The results of the probing support the conclusions regarding a stratigraphy composed of an upper layer of less compact sandy loam overlying a more compact, higher clay content parent material with an undulating surface between 0.5 and 1 m in depth. The probe data indicate a depth to resistance of less than 85 cm in most places. This is not inconsistent with other stratigraphic indications.

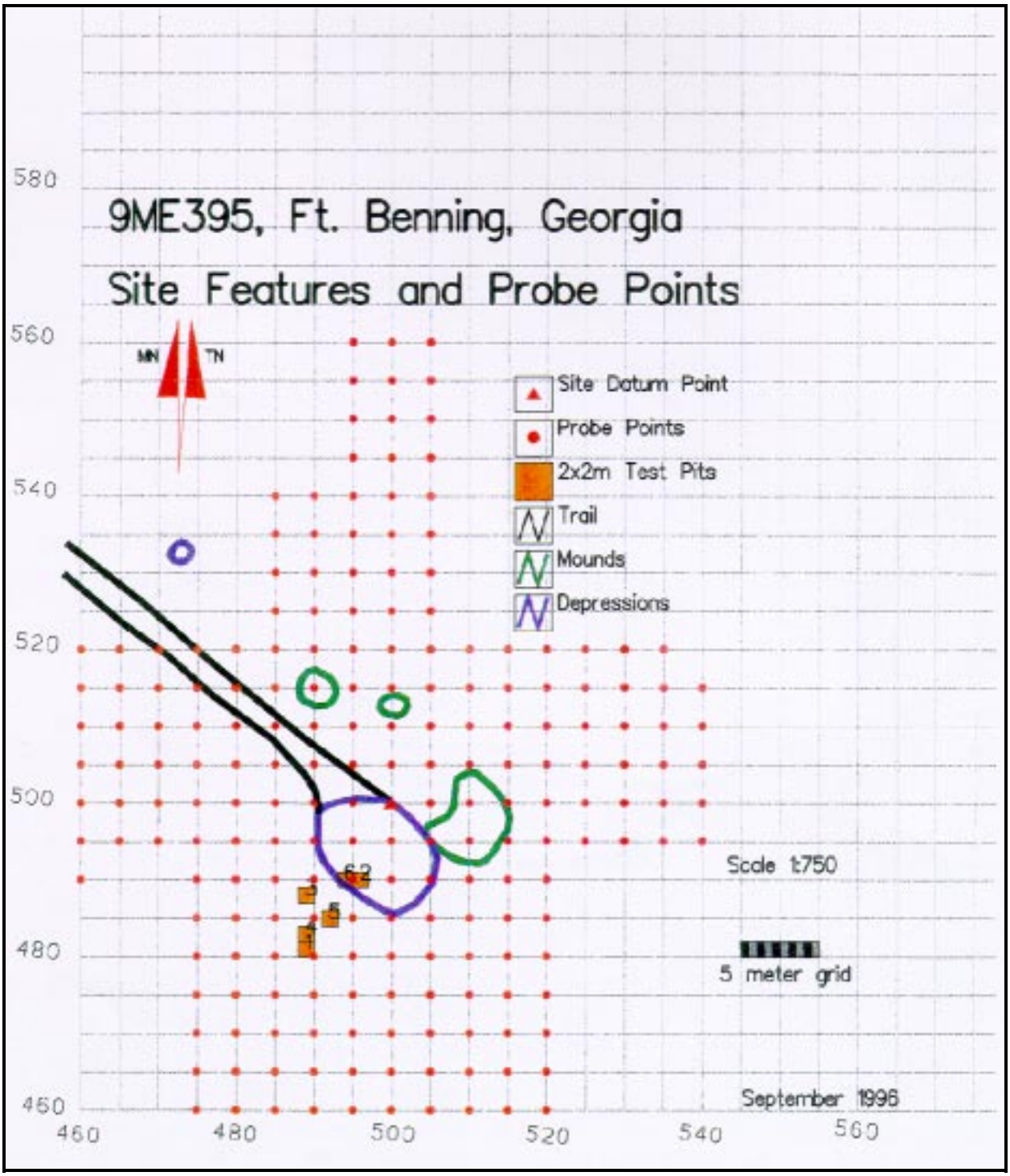


Figure 33. Site feature and probe positions

Shallow depth to resistance is indicated in areas where relatively recent logging trails probably compacted the surface. It is obvious that the current trail and depression are related to the probing data (see Figure 34). The pattern of the depth-to-resistance data suggests that excavated material from the depression probably was compacted by fairly recent logging activities involving heavy equipment and or vehicular traffic. The probing data show a line of compaction following the present-day trail running from northwest to southeast in the center of the site. The probing data also show a fork in the center of the site where an old logging trail intersects and runs east-west. This older logging trail is overgrown with brush and only faintly discernible today.

There is also some indication that the three mounds mapped on the site are relatively recent disturbances, and therefore less compacted than surfaces surrounding them. There is no indication in the geophysical data to suggest that the depth-to-resistance data are likely to be a function of eighteenth or early nineteenth century activities associated with the construction or use of a council house. Given the obvious relationships between modern surface features and the probing data, it is likely that modern logging activities are the probable cause for the compaction of soils surrounding the depression (Figure 34). An alternative hypothesis is that the loggers may have been reusing an older road and council house depression. It would seem to be an extraordinary coincidence that the logging trail and compacted soils resulting from this modern activity would have been exactly adjacent to an archaeological depression by chance alone. The pattern in the probe data may be a function of both modern and much earlier human activity.

Taken together, the topographic, geomorphological, geophysical, and probing data support the basic conclusions of the archaeologists regarding shovel test results and how the pattern of shovel test information was used to further sample the site. The reliability of shovel test samples taken on a grid 20 m north-south and 10 m east-west is at best an open question. To conclude on the basis of this sample that six excavation units would best be placed in a particular portion of the southeastern quadrant of the site to achieve a maximum return of information from a limited excavation sample would also seem to be a problematic conclusion. Perhaps one of the most significant conclusions in this research is that a suite of independent technologies involving several thousand nondestructive measurements and observations across the site have in general supported the archaeologists' interpretation based on a restricted and limited subsurface sample. The decision to open up excavation units in the southeastern quadrant of the site based on the pattern of positive shovel tests is basically consistent with the results of this study. Future investigations, involving both archaeological and geophysical perspectives integrated in a GIS, offer an excellent opportunity to maximize information return from limited subsurface excavation by considering far more information than sparse surface remains and patterns of positive and negative shovel tests.

Figure 35 summarizes the geophysical data by creating a green polygon enclosing an obvious cluster of geophysical anomalies and a smaller red polygon enclosing the area of the greatest density of geophysical anomalies. The two polygons were drawn by simple inspection. A green line was drawn around that area of the site where geophysical anomalies seemed to obviously cluster.

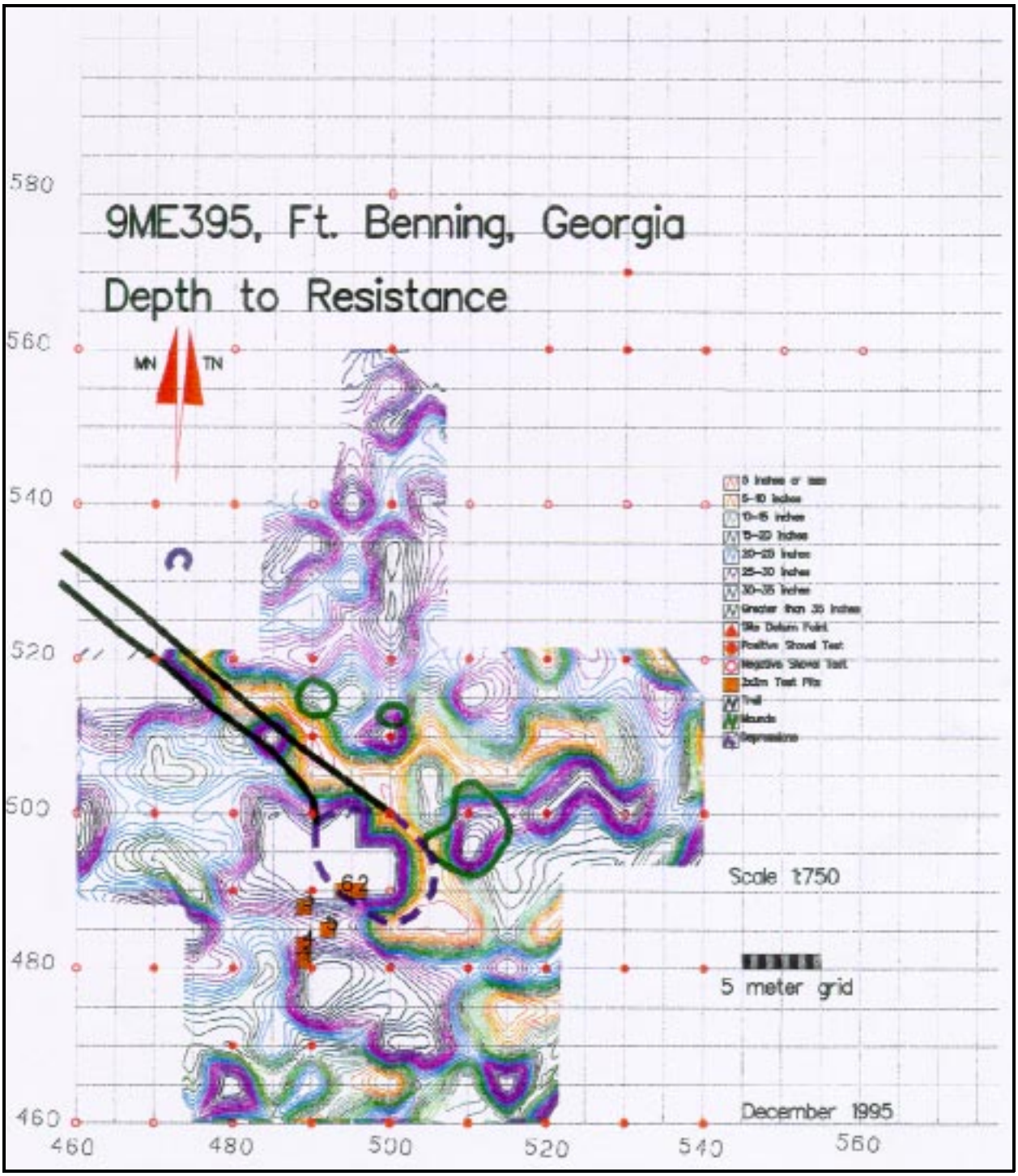


Figure 34. Contour map of Site 9 ME 395 with features and probe locations

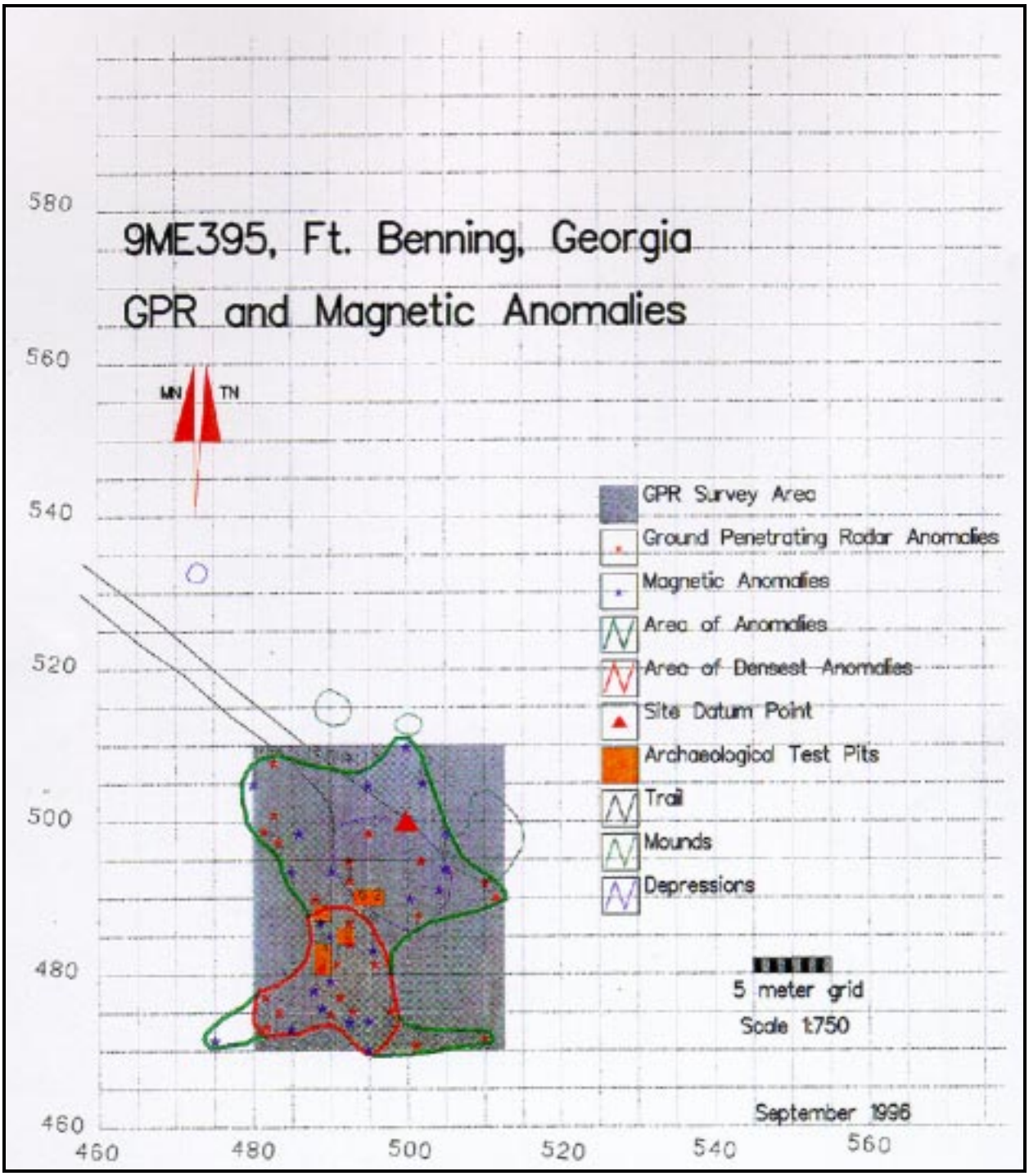


Figure 35. Pattern of geophysical anomalies

Obvious disparate outliers were eliminated. A red line was then drawn inside the green polygon that connected those anomalies with the tightest clustering. The creation of these new units of analysis, informative of spatial clustering of geophysical anomalies, could be done less informally in the future by taking advantage of the analytical power of the GIS. For example, the green polygon could be drawn by connecting all geophysical anomalies with overlapping 5-m buffers. By the same token, a more concentrated set of anomalies could be formally defined by overlapping smaller buffers 2.5 m in size. The archaeological excavation sample that was selected is surprisingly well placed based on these observations. Some improvement would be achieved, however, by spreading the excavation units out somewhat in order to get more subsurface representation in the upper green polygon and perhaps one or two units in the lower red polygon.

Tables 5-9 summarize probe data by grouping the measurements into eight intervals of increasing depth to resistance. Being able to quickly generate Tables 5-9 is one of the distinct advantages of having put the field data into a GIS. Table 5 shows a summary of depth-to-resistance measurements for the entire site. Table 6 summarizes the probe data for the green polygon only, while Table 7 shows measurements for only the red polygon. Table 8 combines depth indications for both the red and green polygons. Table 9 summarizes the depth-to-resistance measurements for all areas of the site outside the red and green polygons. These data indicate that those areas of the site with the greatest concentration of geophysical anomalies also have indications of the greatest number of deep probes. Those areas of the site with the preponderance of geophysical anomalies have the highest percentages of probes in the deepest category. Areas outside the red and green polygons (area of few anomalies) indicate only 16 percent of the probes fall in the deepest category (Table 9). In the red polygon 30 percent of the probes are in the deepest category (Table 7). Areas within the green polygon show 44 percent of the probes in the deepest category (Table 6). Probes in the red and green category combined show 41 percent of the probes in the deepest category. These data suggest that a correlation exists between density of geophysical anomalies and ease of penetration with a steel probe. A corollary to this conclusion suggests that parts of the site with few geophysical anomalies show a shallower depth to resistance.

Table 5
Summary of Probe Data—Total Site Area (204 Probes)

Depth, cm	Number (out of 204)	Percentage of Total
Less than 12.7	9	4.4
12.7 - 25.4	21	10.3
25.4 - 38.1	8	3.9
38.1 - 50.8	37	18.1
50.8 - 63.5	46	22.6
63.5 - 76.2	27	13.2
76.2 - 88.9	13	6.4
Greater than 88.9	43	21.1

Table 6
Summary of Probe Data—Green Polygons (27 Probes)

Depth, cm	Number (Out of 27)	Percentage of Total
Less than 12.7	2	7.4
12.7-25.4	5	18.5
25.4-38.1	1	3.7
38.1-50.8	2	7.4
50.8-63.5	4	14.8
63.5-76.2	1	3.7
76.2-88.9	0	0
Greater than 88.9	12	44.4

Table 7
Summary of Probe Data—Red Polygons (10 Probes)

Depth, cm	Number (Out of 10)	Percentage of Total
Less than 12.7	0	0
12.7 - 25.4	0	0
25.4 - 38.1	0	0
38.1 - 50.8	3	30
50.8 - 63.5	1	10
63.5 - 76.2	2	20
76.2 - 88.9	1	10
Greater than 88.9	3	30

Table 8
Summary of Probe Data—Green and Red Polygons (37 Probes)

Depth, cm	Number (Out of 37)	Percentage of Total
Less than 12.7	2	5.45
12.7 - 25.4	5	13.5
25.4 - 38.1	1	2.7
38.1 - 50.8	5	13.5
50.8 - 63.5	5	13.5
63.5 - 76.2	3	8.1
76.2 - 88.9	1	2.7
Greater than 88.9	15	40.55

Table 9
Summary of Probe Data—Site Area Outside Polygons (167 Probes)

Depth, cm	Number (Out of 167)	Percentage of Total
Less than 12.7	7	4.2
12.7 - 25.4	16	9.5
25.4 - 38.1	7	4.2
38.1 - 50.8	32	19.2
50.8 - 63.5	41	24.5
63.5 - 76.2	24	14.4
76.2 - 88.9	12	7.2
Greater than 88.9	28	16.8

Perhaps the human activity that occurred in the past, involving several subsurface disturbances such as human interment, excavations for structures, post holes and pits, has modified the natural deposit such that probing now will indicate a deeper, more disturbed deposit. An alternative hypothesis is that humans were simply using the deepest most easily penetrated parts of the natural landform in the first place. In either case, the correlation suggests that a low-cost, low-technology, minimally disturbing exploratory probing technique can be used to help independently define those areas of a site where the greatest number of geophysical anomalies will also be likely to occur. At the very least, such data can provide one more line of independent evidence for deciding where to place the more expensive subsurface excavations to optimize the return of information. Future investigations using probing in conjunction with geophysical prospection and a GIS could look at the data with a more formal and rigorous strategy using statistical tools.

The results of this study have significant payoff, not only in terms of achieving increased sampling efficiency and deciding where best to excavate, but also a wide variety of subsurface anomalies throughout the site. These subsurface anomalies include a considerable number of metallic objects and other subsurface disturbances, some superimposed. These anomalies are distributed throughout the site and are not restricted to the area of principal archaeological excavation. The results of this investigation also indicate six buried features that suggest other probable Native American burials. Three anomalies indicate subsurface pits where burials cannot be entirely ruled out. Site 9 ME 395 may prove to be one of a very few protectable Creek Indian burial sites in the southeastern United States.

Site 9 ME 395 is not unique from an archaeological or geomorphic perspective. Other sites similar in many respects to this site can be expected elsewhere on the Fort Benning Installation. The physical characteristics of the site have been shown to be excellent for employing geophysical prospection. The interdisciplinary nature of this investigation has also demonstrated the feasibility and applicability of other field and analytical projects similar to this one in the

future. The results of this investigation clearly suggest that future site evaluation projects should consider incorporating patterns of information from noninvasive methods prior to selecting areas of sites that must be hand-excavated using conventional destructive methods. By working back and forth between traditional archaeological excavation and cost-effective nondestructive methods for rapidly gathering independent data sets over large areas, results are possible that maximize return of reliable information and minimize unnecessarily destructive and expensive site evaluation projects required by Federal law.

Recommendations

Time constraints and limited resources on this project required a decision to sample selectively. A greater areal coverage was accomplished with the soil conductivity and magnetometry because of the rapid nature of undertaking these surveys and the desirability of completing these surveys first. The goal was to consider the results of the conductivity and magnetometry measurements before focusing on a sample for GPR survey. Therefore, the GPR survey was accomplished over a more restricted area in view of the scheduling and time constraints involved. The GPR results, in particular the clustering of anomalies, including those indicating probable burials on the periphery of the southeastern quadrant of the site, all suggest that further GPR surveying in that area is very likely to extend the site and number of probable burials beyond the area of current investigation.

There is nothing in the results of the suite of investigations to indicate that investigators have gained closure on the full extent of the site or area of probable burials in the southeastern quadrant. To gain a better understanding of the extent and contents of this site, it is recommended that the GPR survey be extended into the area of probable additional burials and other subsurface archaeological remains. It is also recommended that selective archaeological excavation be undertaken to ground truth the strong indications of additional burials. Excavation should be minimal and only to the extent necessary to remove enough of the surrounding matrix to verify the existence of at least one additional burial as indicated in the GPR data. Any interment encountered should be left undisturbed and should be reburied as soon as practicable. One example of ground truthing should be sufficient reason to validate GPR burial indications. Without some ground truthing, it will be impossible to ascertain if site 9 ME 395 contains anything more than an isolated single burial. It is recommended that such a project be fully coordinated beforehand with the appropriate tribal representatives, to secure and document their consent and endorsement.

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13. ABSTRACT *(Maximum 200 words)*

An interdisciplinary team was tasked to support archaeologists in evaluating an historic Creek Indian village and cemetery site located on Fort Benning, Georgia. The investigations demonstrated that conditions at the site were excellent for the use of nondestructive methods of site investigation. The suite of technologies that was employed provided extensive information about the nature and distribution of subsurface archaeological remains throughout the site, including the precise location and stratigraphic context of additional probable burials. A mix of new and emerging technologies was employed, including laser range finding, global positioning systems, soil conductivity, electromagnetometry, ground penetrating radar, geographic information systems, and geomorphological inference. The use of nondestructive technologies greatly complemented the archaeological and historical investigations, and led to conclusions and inferences that would not have been attainable using conventional archaeological techniques alone. Results of this study provide managers at Fort Benning with the comprehensive informational basis to support the significance of the National Register property, with a management plan commensurate with the importance of the site. Clearly, the study has application to other situations where information can be acquired rapidly and efficiently, in a manner that is highly cost effective and sensitive to Native American concerns for the appropriate treatment of human remains.

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