ABSTRACT

A ground-penetrating radar survey was conducted at the Monroe Crossroads Battlefield site at Fort Bragg, North Carolina, to determine possible locations of subsurface archaeological features. An electromagnetic survey also was conducted at the site to verify and augment the ground-penetrating radar data. The surveys were conducted over a 67,200-square-foot grid with a grid point spacing of 20 feet.

During the ground-penetrating radar survey, 87 subsurface anomalies were detected based on visual inspection of the field records. These anomalies were flagged in the field as they appeared on the ground-penetrating radar records and were located by a land survey. The electromagnetic survey produced two significant readings at ground-penetrating radar anomaly locations.

The National Park Service excavated 44 of the 87 anomaly locations at the Civil War battlefield site. Four of these excavations produced significant archaeological features, including one at an abandoned well.

INTRODUCTION

The Monroe Crossroads Battlefield site is in the Coastal Plain Province of North Carolina (fig. 1). This Civil War battlefield is located on the U.S. Army's Fort Bragg Military Reservation, in the northern part of Hoke County and the northwestern part of Cumberland County. Ongoing studies are being conducted by the U.S. Geological Study (USGS) in cooperation with the U.S. Army at Fort Bragg to identify and delineate the extent of contamination at a number of solid-waste management sites throughout the military reservation. Part of this effort involves the use of ground-penetrating radar and electromagnetic surveys to detect various objects beneath the ground surface.

In 1994, the USGS, in cooperation with the National Park Service (NPS) and the U.S. Army at Fort Bragg, conducted a survey of the Monroe Crossroads Battlefield site using ground-penetrating radar and electromagnetic surveys to assist the NPS in locating subsurface archaeological features at the site before any disturbances related to Fort Bragg activities occurred at the site. This work provided an opportunity to test the new geophysical equipment and to allow the investigators to become familiar with the operation of the equipment and the interpretation of the data before using the equipment at solid-waste management sites. It also was an opportunity to become familiar with signal responses due to the particular geometry of the Middendorf Formation that underlies Fort Bragg. The Middendorf Formation is composed of medium- to fine-grained quartz sands and clayey sands interbedded with discontinuous sandy clay or clay lenses.

Purpose and Scope

This report presents the results of ground-penetrating radar (GPR) and electromagnetic (EM) surveys conducted at the Monroe Crossroads Battlefield site to identify subsurface features that could be related to the Monroe Crossroads farm and battle. The equipment and methods used in the GPR and EM surveys are discussed, along with the procedures used to determine potential archaeological features based on anomalies in the geophysical records. Locations of GPR anomalies at the study site are presented, as well as results of excavations by the NPS that revealed important archaeological features at GPR anomaly locations.

Site History

The Monroe Crossroads site is in a region that has been used for farming since the mid-18th century (Ross, 1965). In 1832, Charles Monroe became the owner of a 500-acre tract that encompassed the present study site (D.D. Scott and W.J. Hunt, Jr., National Park Service, written commun., 1993). The area has become known as Monroe Crossroads because of its proximity to an intersection of Longstreet and Blues Roads northeast of the farm. It is also referred to as Solemn Grove in historical descriptions of the farm (Barrett, 1963).

In 1865, during the Civil War, a brief but heated battle took place at the Monroe farm. In March 1865, as General William Sherman's Union army entered North Carolina, Confederate cavalry units, under General Wade Hampton, moved to join Confederate Lieutenant General W.J. Hardee's army in Fayetteville, North Carolina. Union cavalry units, commanded by Major General Judson Kilpatrick, were moved to intercept Hampton's troops at Monroe Crossroads (Barrett, 1963). On the night of March 9, Kilpatrick's men camped at the Monroe farm. Learning of this, Hampton tried to capture Kilpatrick's troops on the morning of March 10, and drove the forces into a nearby swamp. However, the Confederate soldiers became disorganized as they tried to take possession of the Union encampment and supplies, and thus gave Kilpatrick's troops time to rally and retake the camp (Barrett, 1963; Ross, 1965). Although there is general disagreement over who won the engagement, the Confederate troops were able to proceed on to Fayetteville (Barrett, 1963 and 1975).

Many of the Confederate dead from the Monroe Crossroads battle are buried in the Longstreet Church Cemetery (fig. 2A). About 30 Union soldiers and at least one Confederate soldier are buried in small cemeteries at the Monroe Crossroads Battlefield site. The farm was sold to Neill S. Blue in 1881 and became part of the Fort Bragg Military Reservation in 1917. These cemeteries have been marked and maintained by Fort Bragg personnel since 1921 (D.D. Scott and W.J. Hunt, Jr., National Park Service, written commun., 1993). Presently, the site is not used by the military, but there is evidence that it was used for military training in the recent past (D.D. Scott and W.J. Hunt, Jr., National Park Service, oral commun., 1993).

Acknowledgments

William Kern, former Acting Chief of the Fort Bragg Environmental Branch, recognized the significance of the Monroe Crossroads battle and initiated the study. Sergeant First-Class Kenneth Belew, former XVIII Airborne Corps Historian, and Specialist Fourth-Class Robert Briggs, former Assistant Historian, provided historical accounts of the battle and a tour of the study area for USGS personnel. This reconnaissance tour of the study area included a discussion of troop movements during the battle and the approximate locations of buildings and other related structures. Staff Sergeant William Dagenhart of the Headquarters Battery 10th Marine Survey/Meteorology Battalion supplied geographic horizontal location data for two reference marks established by the USGS in the study area. Stephen A. Berg (deceased) of the USGS provided most of the technical assistance needed for the design of this study.

GROUND-PENETRATING RADAR INSTRUMENTATION

The GPR survey of the Monroe Crossroads study site was conducted by using the Geophysical Survey Systems, Incorporated, Subsurface Interface Radar System-10 (SIR-10) (fig. 3). The SIR-10 operates by transmitting and receiving electromagnetic wave frequencies that penetrate subsurface material. An electromagnetic pulse is sent from the SIR-10 unit to the transmitter in the selected antenna. The pulse is then converted to a specific frequency determined by antenna size and structure. The signal transmitted from the antenna travels through the subsurface material; the signal then reflects off and is attenuated by the subsurface layers encountered. Next, the signal is picked up by the receiver in the antenna, which transmits it back to the SIR-10 unit. Reflected signals indicate interfaces between layers having different electrical properties. Filters and gains are applied to the radar signal to produce the optimum image for the conditions of the survey site. Processed data are displayed on the color video screen of the SIR-10 and are recorded on magnetic tape for future playback and processing. During data collection, stacked data points are recorded on a thermal plotter to produce a paper record. The records display the subsurface interfaces between material of different electrical properties encountered by the radar signal.

The GPR record displays the two-way travel time of the radar signal in nanoseconds (ns). The range is the total depth of the GPR record in two-way travel time; the range gain is the amplification of the GPR signal with depth. The two-way travel time of the radar signal per foot of depth is calculated from the dielectric constant of the material it passes through by using the following equation (adapted from The Finnish Geotechnical Society, 1992):

$$TT = 2\left(\frac{\sqrt{E_r}}{c}\right)$$

where TT is two-way travel time per unit of depth in nanoseconds per foot (ns/ft),
E_r is dielectric constant, dimensionless, and
c is velocity of radar pulse in free space (0.98 foot per nanosecond) (ft/ns).

The dielectric constant of sediments is dependent upon the composition and degree of saturation of the sediments. The dielectric constant varies from an unsaturated value of 4 to a saturated value of 25 for sediments composed of sand, from an unsaturated value of 9 to a saturated value of 23 for sediments composed of silt, and from an unsaturated value of 4 to a saturated value of 16 for sediments composed of clay (The Finnish Geotechnical Society, 1992). These values were used to estimate the approximate depth of the GPR signal.

ELECTROMAGNETIC INSTRUMENTATION

The EM survey of the Monroe Crossroads study site was conducted by using a Geonics Limited EM31. The EM31 operates by transmitting circular eddy current loops into the subsurface. These current loops induce a magnetic field that is intercepted by the receiver in the EM31 after the magnetic field passes through the subsurface (fig. 4). The signal received by the EM31 is translated into the apparent conductivity of the subsurface in millisiemens per meter (mS/m). The EM31 also measures the inphase component of the return signal in parts per thousand (ppt). The inphase reading is more sensitive to detection of buried metal. In theory, the EM31 has a maximum depth penetration of approximately 18 feet (ft). The EM31 conductivity and inphase values are dependent upon the composition and depth of the subsurface layers. The data from the EM31 are most useful in comparing values, rather than as absolute readings.

DATA ACQUISITION METHODS

Data acquisition for the Monroe Crossroads study site involved four phases. During phase 1, a survey grid was established at the study site. Phase 2 involved the collection of GPR data, locating anomalies in the data, and flagging these anomaly locations in the field. Phase 3 involved the collection of electromagnetic data to verify and augment the GPR data. During phase 4, GPR anomaly locations were surveyed to produce an anomaly map of the study site (fig. 2).

Survey Grid and Monuments

A survey grid was established at the Monroe Crossroads study site by using a Pentax Electronic Total Station survey instrument and a prism. A survey grid origin point was established at the southwest corner of the study site. A baseline for the grid was established by setting the total-station instrument on the survey grid origin point and sighting a line approximately southwest to northeast in alignment with Blues Road (fig. 2). The long axis of the survey grid was completed by setting grid point number 2 on the northeast corner of the study site, 420 ft from the survey grid origin point. Twenty fluorescent pin flags were set at 20-ft intervals between the survey grid origin point and flag number 2 to complete the 420-ft baseline. The total-station instrument was then moved and set up on flag number 2, and a reference angle of 0 degree was set from the back sight of the survey grid origin point. The instrument sight was then turned 90 degrees. and an endpoint for the short axis baseline was set at flag 10. Seven fluorescent pin flags were set at 20-ft intervals between flag number 2 and flag number 10 to complete the 160-ft short axis baseline.

Grid reference points were set at 20-ft intervals by using the two baselines of the survey grid. Pink or yellow-green surveyor's pin flags marked with the appropriate grid point number (fig. 2) were used to mark the grid reference points. The distance between flags was measured with a tape. The completed grid encompassed an area of 67,200 square feet (ft^2).

Two surveying monuments were installed at the Monroe Crossroads study site to serve as permanent location markers which can be used as reference points for future surveys of the site (fig. 2). Both monuments are located on the east side of Blues Road. These location monuments were installed using Howitzer shell casings cemented into the ground. The tops of the shell casings are approximately 2 inches (in.) above land surface.

Ground-Penetrating Radar Survey Data Acquisition

Before data collection began at the Monroe Crossroads study site, various antenna configurations and GPR settings were tested at the site. The antenna configurations selected to collect data at the site were (1) a single 300-megahertz (MHz) antenna and (2) a dual 100-MHz antenna (fig. 3). The 300-MHz antenna contains a transmitter and receiver in one antenna unit. The antenna cable from the GPR unit is attached to the receiver in the antenna; the output signal is transferred from the antenna cable to the transmitter of the antenna by a coaxial cable. The dual 100-MHz antenna configuration contains two antennas that function as a single antenna. One 100-MHz antenna contains a transmitter and the other contains a receiver. The antenna cable from the GPR control unit is attached to the receiving antenna; the output signal is transferred from the antenna cable to the transmitting antenna by means of a fiber-optic cable.

The dual 100-MHz antenna was used to optimize the depth of penetration of the radar signal. This antenna was used in sections of the grid and along Blues Road to determine the potential for deep features that may not have been discernible using the 300-MHz antenna. The 300-MHz antenna produces data having a higher degree of resolution of near-surface features than the dual 100-MHz antenna. As much of the survey grid as possible was surveyed with the 300-MHz antenna.

For this study, the SIR-10 and thermal plotter were installed in a vehicle with a cable leading to the antenna (fig. 3A). The antenna was slowly pulled by vehicle across the ground surface in cleared areas and on roads or was pulled by hand in impassable wooded areas. There were a few areas within the grid that could not be surveyed with GPR because of dense forestation; these areas were surveyed with the EM31. As the GPR antenna was pulled across the ground surface, the operator viewed the SIR-10 video display and thermal plotter record for any indication of anomalies in the data. The signal transmitted from the antenna is projected at approximately a 90-degree angle from the center of the antenna along the direction the antenna is being pulled and at approximately a 60-degree angle from the center of the antenna perpendicular to the direction the antenna is being pulled (fig. 3B). Because of the angle of the transmitted radar signal, anomalies are detected before the antenna is directly over them. These anomalies appeared as hyperbolas in the radar records with the crests of the hyperbolas at the anomaly locations. Ringing, which appears as a repeated vertical pattern on the GPR record, also appears on the radar records at anomaly locations. Anomalies on the radar records indicate a sharp change in electrical conductivity of subsurface features. As these anomalies appeared on the GPR records, flags were placed in the field at the anomaly locations. These GPR anomalies were later surveyed as potential locations of archaeological features.

Electromagnetic Survey Data Acquisition

The EM survey of the Monroe Crossroads study site was conducted along the survey grid and Blues Road using the EM31 and a digital data recorder. The EM31 consists of a main control unit with two fiberglass tubes, one each extending from the front and back of the control unit. One tube contains the EM31 transmitter coil and the other tube contains the EM31 receiver coil. Measurements are displayed on a digital screen on the EM31 control unit. During the EM survey, data from the EM31 are transferred by a cable to the data recorder, which stores the data in a computer file format. Files are later uploaded from the data recorder to a computer for processing and production of line plots of the data.

Before the EM survey of the Monroe Crossroads study site began, the EM31 was calibrated at an established background line. The background line was established at a location that did not have any known cultural features that would affect the EM data. The EM31 inphase was set to read zero ± 0.1 ppt along the background line, and the conductivity readings were recorded.

At the Monroe Crossroads study site, the EM survey was conducted by carrying the EM31 at a walking pace along each line of the survey grid and Blues Road, and recording the data on the data recorder set at a 0.6-second time interval of data collection. Marks were entered into the data recorder files at each grid flag location and at the location of each anomaly detected with the GPR. Data files were uploaded from the data recorder to a computer; the files on the computer were then processed by converting the data-collection time interval to feet of traverse by use of the grid flag marks in the files. The conductivity and inphase values of the data were compared to background values to determine the presence of any anomalies that could indicate the presence of archaeological or other features. Data were then compared to anomalies obtained in the GPR survey to verify and augment the GPR data.

Surveying of Ground-Penetrating Radar Anomaly Locations

Each GPR anomaly flagged at the Monroe Crossroads study site was surveyed using the Pentax Total Station instrument and prism. The total-station instrument was set up over reference mark A (fig. 2B), and a reference angle of 0 degree was set from the back sight of reference mark B (fig. 2B). The reference mark location data were obtained from the Headquarters Battery 10th Marine Survey/Meteorology Battalion (Staff Sergeant William Dagenhart, oral commun., 1994). From the survey instrument position on reference mark A, the horizontal angle and horizontal distance of each anomaly relative to the instrument were stored in a data collector attached to the total station. The data files were later uploaded from the data collector to a computer for further processing. Anomaly location data were converted to latitude and longitude and plotted as shown in figure 2C.

GROUND-PENETRATING RADAR SURVEY RESULTS

The 300-MHz antenna and a range setting of 300 ns proved to be the most useful configuration for the GPR survey within the survey grid. However, the range gains were changed in different parts of the survey grid to adjust for subsurface conditions and to produce the clearest record. The 300-MHz antenna produced records with high resolution of subsurface features to a depth represented by a two-way travel time of about 150 ns (fig. 5). By using the two-way travel time equation presented in this report and the dielectric constants estimated for the sediments underlying the Monroe Crossroads study site, it was determined that the radar signal penetrated to an estimated depth of more than 20 ft below land surface when the 300-MHz antenna was used. The depth of penetration of the radar signal was sufficient to display anomalies in the GPR records, which could indicate the locations of possible archaeological or other features.

During the GPR survey, the antennas were pulled along the survey grid lines as much as possible. In some areas of the survey grid, numerous trees made it impossible to pull the antennas along grid lines; in these areas, the antennas were pulled as close to the grid lines as possible. Because of the uneven terrain and numerous trees at the study site, the placement of flags at anomaly locations was accurate to within an estimated 2 ft of the actual location of the anomalies. Several anomalies were located at the intersection of two GPR survey lines and were detected at the same location by both GPR survey traverses. Because of the high number of anomalous features detected in the northern area of the grid, this area was surveyed with additional GPR lines between the established grid lines to more clearly define anomaly locations.

The dual 100-MHz antenna with a range setting of 600 ns proved to be the most useful configuration in surveying along Blues Road for deeper features that could not be detected with the 300-MHz antenna. Within the survey grid, the dual 100-MHz antenna did not improve the quality of data in comparison to the data collected by using the 300-MHz antenna. A very large and apparently deep anomaly centered at AN101 (figs. 2 and 6) was detected in the GPR records when the 100-MHz antenna array was used. The top of this large anomaly is located approximately 15 to 20 ft below land surface. This anomaly was surveyed along a series of transects parallel and perpendicular to the centerline of Blues Road to clearly define the center and extent of the feature.

Anomalies in the GPR records were distinguished from surrounding subsurface material by the hyperbolic image and characteristic ringing pattern present in the GPR records. A total of 87 anomalies were located at the study site during the GPR survey; locations of all anomalies detected are shown in figure 2.

ELECTROMAGNETIC SURVEY RESULTS

EM31 apparent conductivity readings along the EM background line (E-E'; fig. 2) ranged from 0.35 to 0.90 mS/m (fig. 6). EM31 inphase readings along the background line ranged from -0.1 to 0.1 ppt. EM31 readings from traverses run along the survey grid lines are at or near background levels with the exception of readings at AN57, AN81, survey grid points 15, 18, and 19, and the area of survey grid points 197 through 199 (fig. 7). AN57 and AN81 were anomalies indicated by GPR. The anomalies indicated by the EM31 at survey grid points 15, 18, and 19 and between survey grid points 197 and 199 (fig. 7) did not appear in the GPR survey records. A comparison of the GPR record showing a large anomaly (AN101) along E-E' and the EM31 record along the same survey line indicates no discernible change in apparent conductivity or inphase readings (fig. 6). Most of the anomalies from the GPR survey were not detected by the EM31.

In some parts of the survey grid, the EM31 operator had to contend with numerous trees and low branches. These made the proper orientation of the instrument nearly impossible to maintain. Some anomalies indicated by the GPR survey between survey grid points 36 and 3 (fig. 7) were indicated by slight EM31 fluctuations that could have been a result of changes in the instrument orientation as it was carried through this area.

EXCAVATIONS AT GROUND-PENETRATING RADAR ANOMALY LOCATIONS

Excavations at 44 selected GPR anomaly locations were conducted by the NPS as part of its archaeological project at the Monroe Crossroads Battlefield site. Of 44 anomalies tested, 9 were attributed to the Monroe house and Blue farmstead, and 3 were attributed to military activity (D.D. Scott and W.J. Hunt, Jr., National Park Service, written commun., 1994). The excavations produced a bedspring at AN13, a fireplace hearth and chimney fall at AN23 (fig. 5), and a large cut spike at AN102 (D.D. Scott and W.J. Hunt, Jr., National Park Service, written commun., 1994). Excavations at AN21 and AN27 (fig. 5) contained meals, ready to eat (MRE), and excavation at AN53 indicated a military foxhole (D.D. Scott and W.J. Hunt, Jr., National Park Service, written commun., 1994). Two anomalies located at AN20 and AN26 (fig. 5) were interpreted as possible porch footers of the Monroe house, a possible pit was indicated at AN41 (fig. 5), and an abandoned well was located at AN57 (figs. 5 and 7) (D.D. Scott and W.J. Hunt, Jr., National Park Service, written commun., 1994).

Excavations by the NPS at other anomaly locations indicated a variety of materials including cut nails, ceramic fragments, glass fragments, and other debris. For example, AN42 (fig. 5) contained an M16 blank cartridge, cut nails, ceramic fragments, glass fragments, and quartz flakes (D.D. Scott and W.J. Hunt, Jr., National Park Service, written commun., 1994). The National Park Service also excavated the area of the large, deep anomaly at AN101 (fig. 6) to a depth of 8.2 ft and discovered a clay lens (D.D. Scott and W.J. Hunt, Jr., National Park Service, written commun., 1994). The top of this anomaly occurs at a location more than 8.2 ft below land surface and could be a natural feature. Other anomaly locations as indicated by the GPR and EM surveys could also be results of natural subsurface features.

SUMMARY

A GPR survey of the Monroe Crossroads Battlefield site produced clear records of subsurface features to a depth of at least 20 ft below land surface. The depth of the GPR signal penetration was sufficient for locating subsurface archaeological and other features. The GPR records displayed a total of 87 anomalies at the study site. The anomalies were flagged within an estimated 2-ft horizontal location accuracy by placing surveyor's pin flags at the locations as they appeared on the GPR video display and on the thermal plotter. These flagged anomaly locations were surveyed to produce a map.

A surface electromagnetic survey of the Monroe Crossroads study site confirmed two of the anomalies located using GPR. One of the locations confirmed by the EM31 data was the site of an abandoned well. The EM31 also produced several anomalous readings at locations not indicated in the GPR records.

The concentration of anomalies was highest in the northern one-third of the survey grid. This is the area where buildings previously associated with the Monroe farm were located. Within this area, the NPS was able to locate several features of historic significance. These features included two possible porch footers of the Monroe house, a possible pit, and an abandoned well.

REFERENCES CITED

Barrett, J.G., 1963, The Civil War in North Carolina: Chapel Hill, University of North Carolina Press, 484 p.

_____1975, North Carolina as a Civil War Battleground 1861-1865: Raleigh, North Carolina Department of Cultural Resources, Division of Archives and History, 99 p.

Benson, Richard, Glaccum, R.A., and Noel, M.R., [1982], Geophysical techniques for sensing buried wastes and waste migration: Dublin, Ohio, National Ground Water Association, 236 p.

The Finnish Geotechnical Society, 1992, Geophysical research methods, ground penetrating radar: The Finnish Building Centre Ltd. (Rakennustieto Oy), 64 p.

Ross, Malcolm, 1965, The Cape Fear: New York, Holt, Rinehart, and Winston, 317 p.

CONVERSION FACTORS, VERTICAL DATUM, ABBREVIATIONS, AND ACRONYMS

Multiply	by	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
	Area	
square foot (ft^2)	0.09290	square meter
	Time	
second (s)	1.0×10^{-9}	nanosecond
	Velocity	
foot per nanosecond (ft/ns)	0.3048	meter per nanosecond
	Conductivity	
millisiemens per foot (mS/ft)	3.2808	millisiemens per meter
	Depth	
nanosecond per foot (ns/ft)	3.2808	nanosecond per meter
	Frequency	
cycle per second (cycle/s)	1.0×10^{6}	megahertz

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

ABBREVIATIONS AND ACRONYMS

- AN - anomaly
- c - velocity of radar pulse in free space (0.98 ft/ns)
- DPWE - Department of Public Works and the Environment
- EM - electromagnetic
- Er - dielectric constant, dimensionless
- GPR - ground-penetrating radar
- m - meter
- MHz - megahertz
- mm - millimeter
- MRE - Meal, Ready to Eat
- mS - millisiemens
- NPS - National Park Service
- ns - nanosecond
- ppt - parts per thousand
- SIR - Subsurface Interface Radar System
- TTT - two-way travel time per unit of depth in nanoseconds per foot
- USGS - U.S. Geological Survey

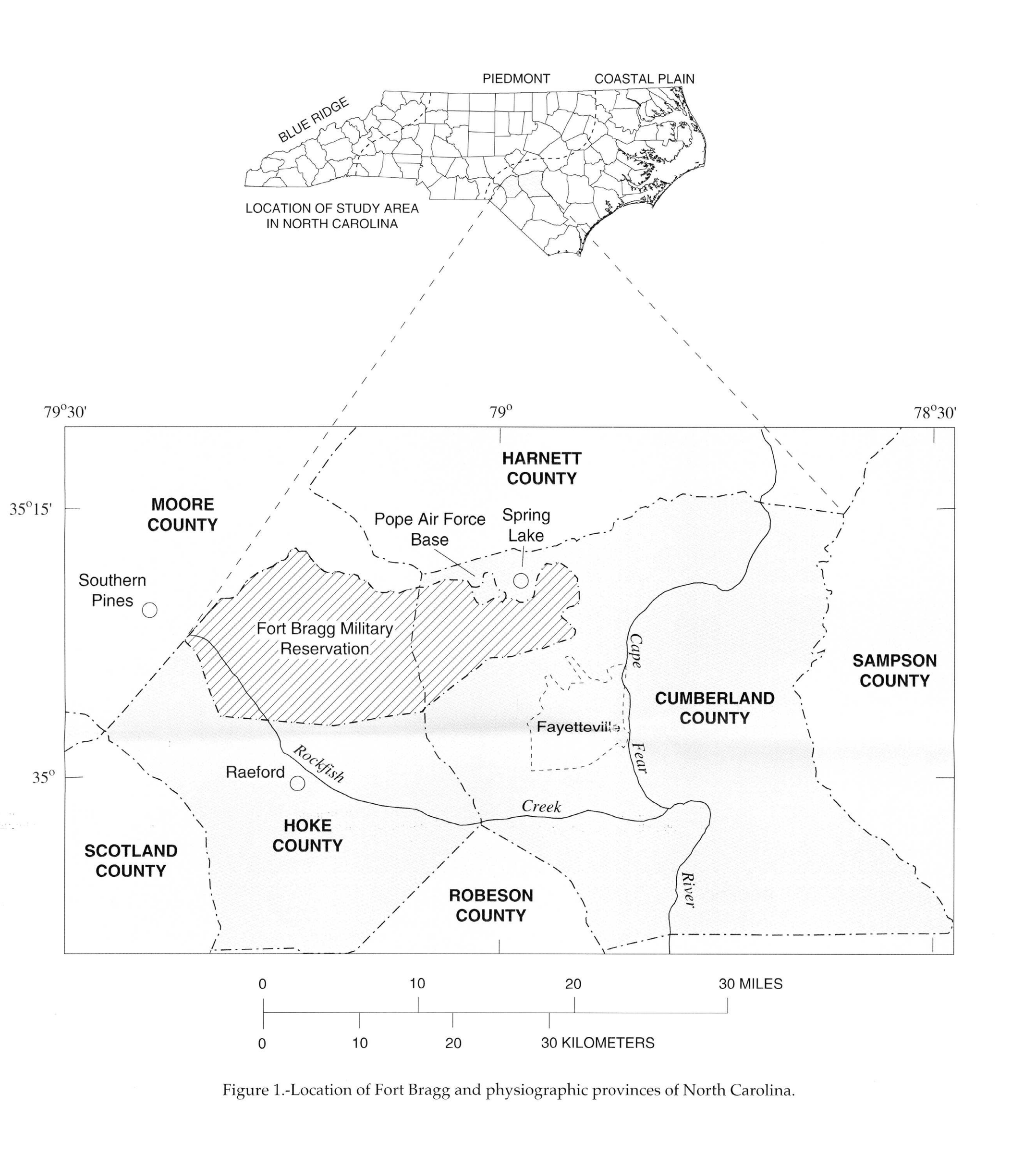


Figure 1.-Location of Fort Bragg and physiographic provinces of North Carolina.

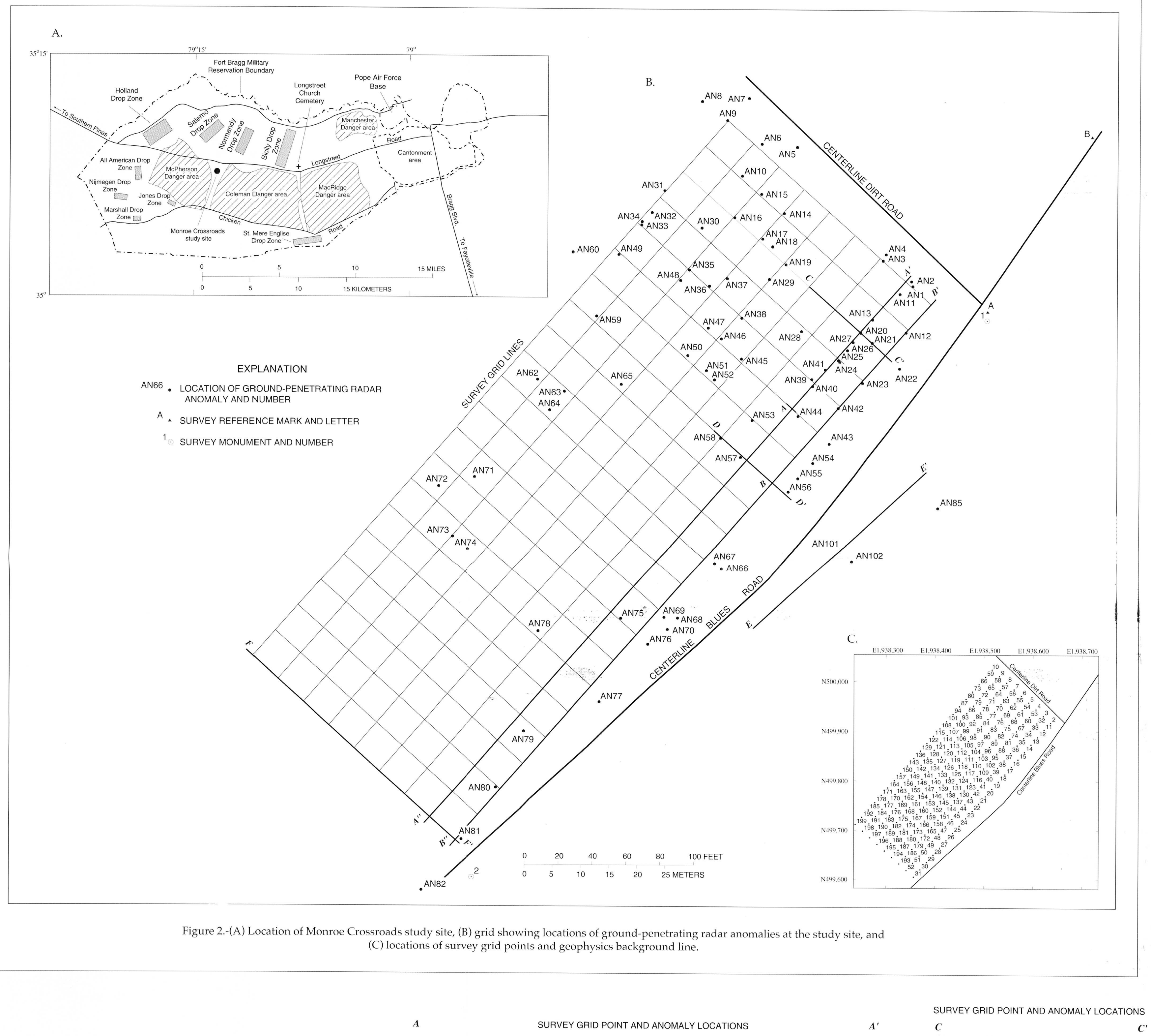


Figure 2.-(A) Location of Monroe Crossroads study site, (B) grid showing locations of ground-penetrating radar anomalies at the study site, and (C) locations of survey grid points and geophysics background line.

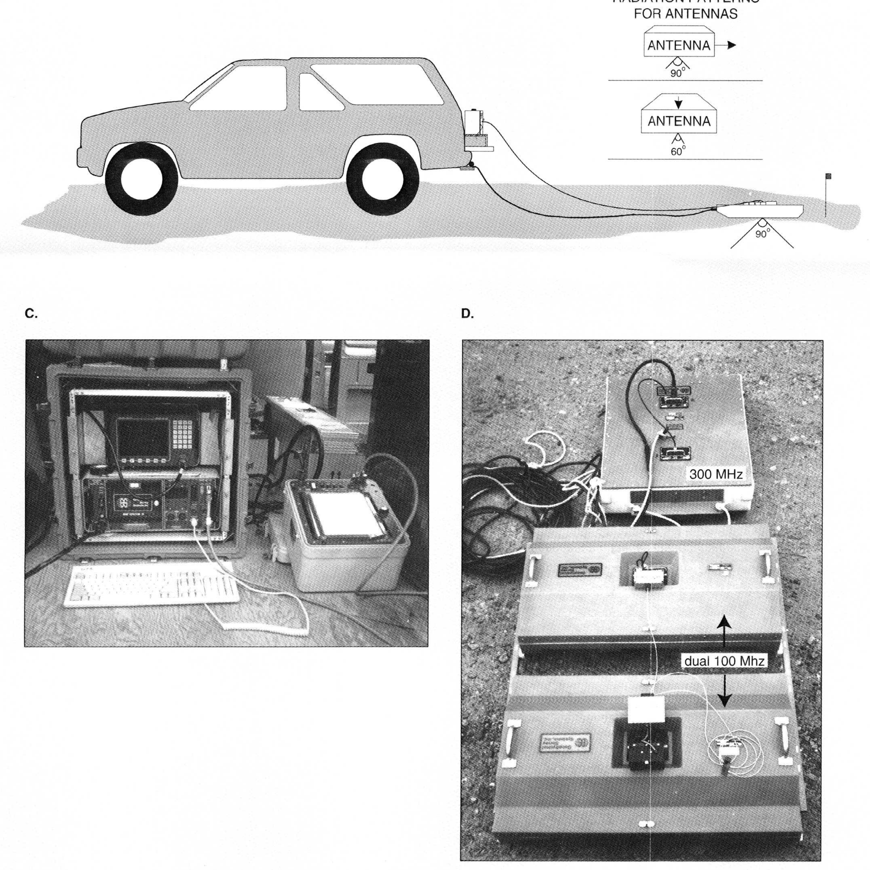


Figure 3.-Diagram and photographs of ground-penetrating radar data-collection equipment and procedure.

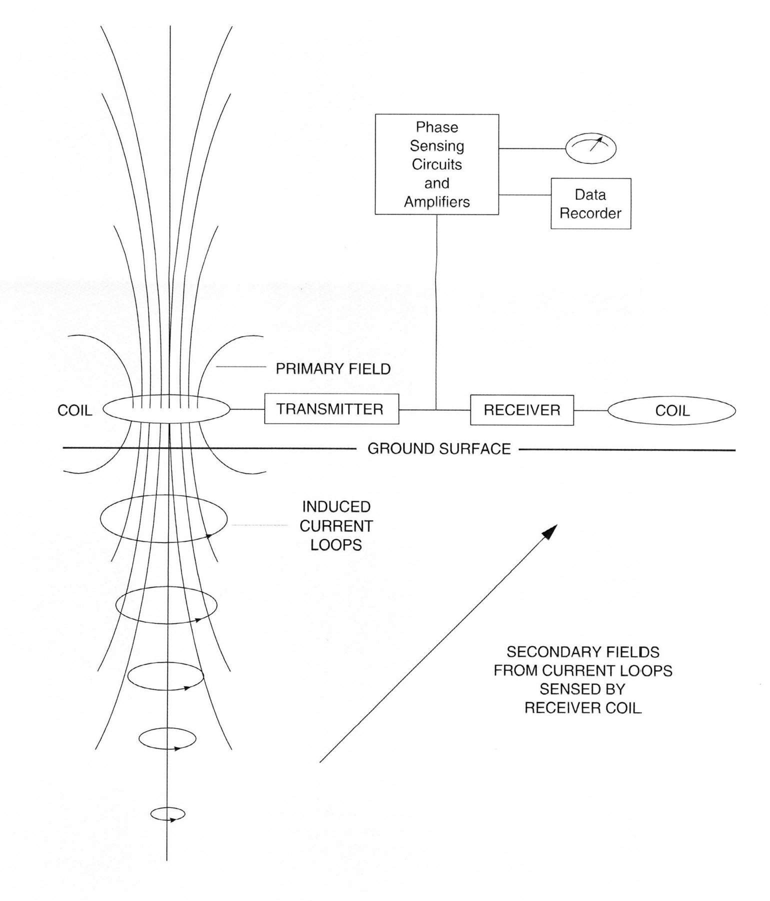


Figure 4.-Generalized diagram showing process by which electromagnetic data are collected (adapted from Benson, Glaccum, and Noel, 1982).

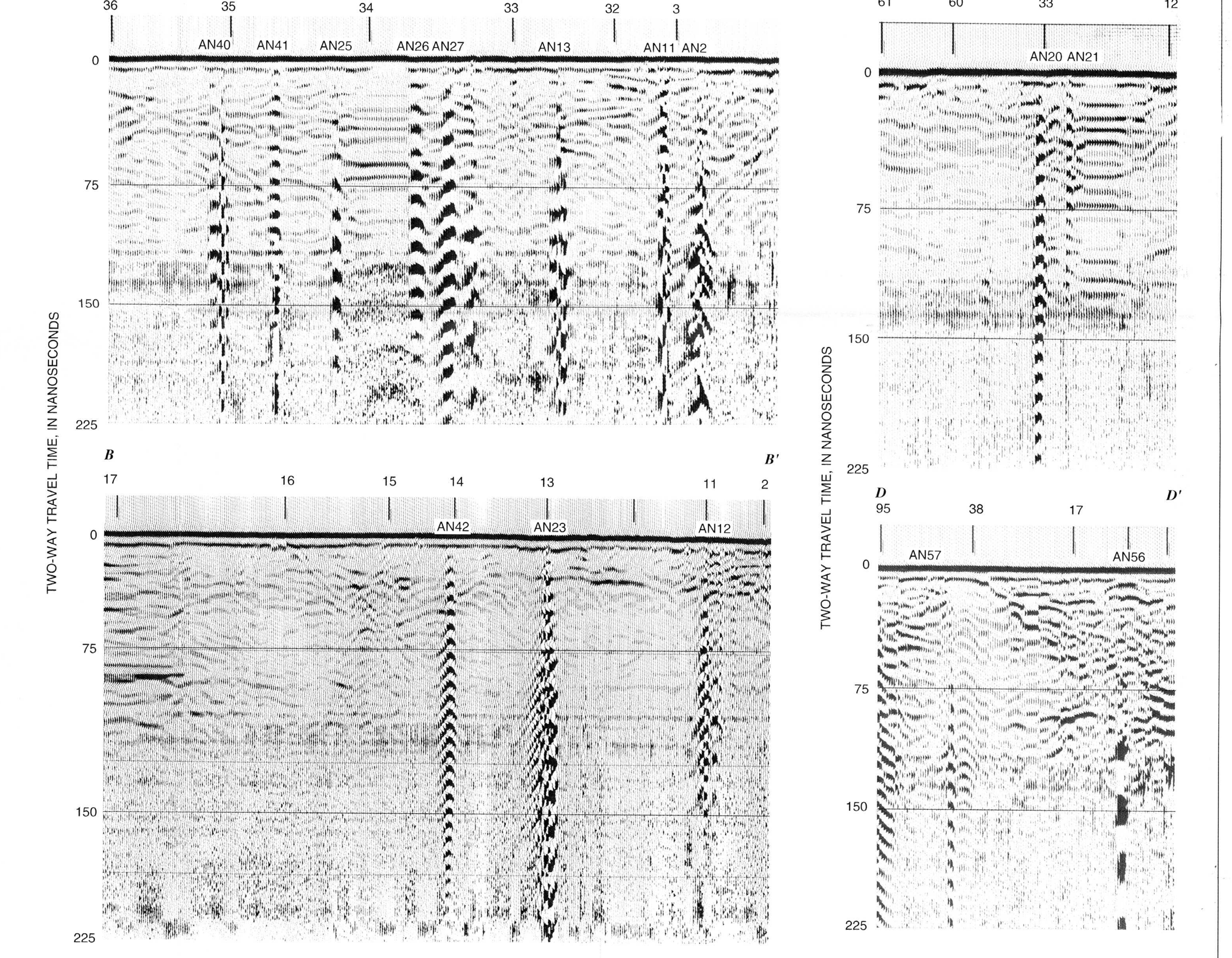
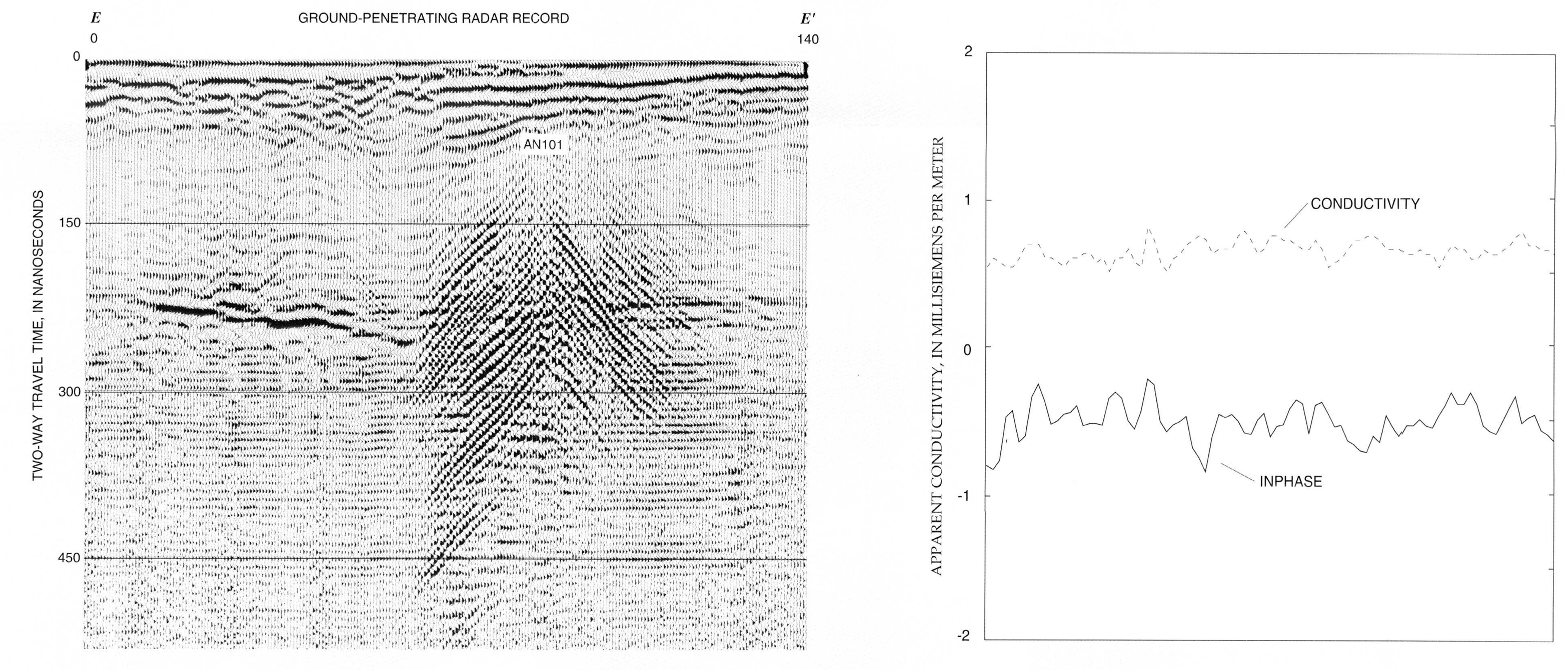


Figure 5.-Ground-penetrating radar records showing anomalies along selected survey lines.



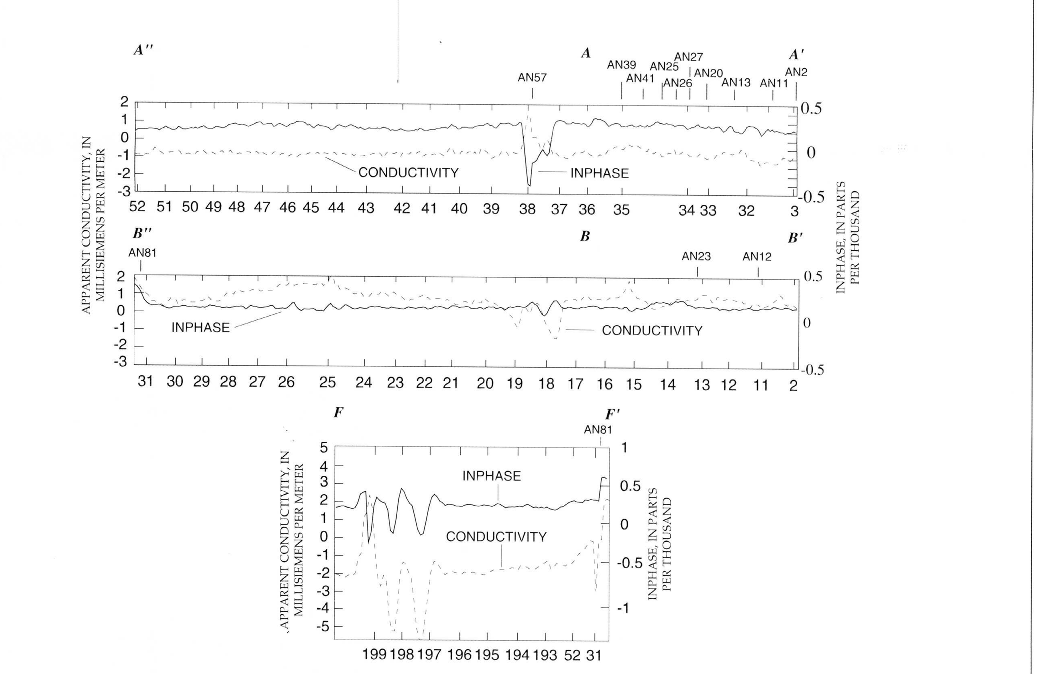
EXPLANATION

E——E' SURVEY LINE

AN101 ANOMALY IN RECORD

HORIZONTAL DISTANCES VARIABLE AND INDICATED BY GRID POINTS. SEE FIGURE 2 FOR LOCATION OF GRID POINTS, ANOMALIES, AND SURVEY LINES

Figure 6.-Ground-penetrating radar record displaying location of large anomaly along survey line ***E-E'***, and the EM31 record for this line.



EXPLANATION

A——A' SURVEY LINE

17 GRID POINT LOCATION

AN41 ANOMALY IN RECORD

HORIZONTAL DISTANCES VARIABLE AND INDICATED BY GRID POINTS. SEE FIGURE 2 FOR LOCATION OF GRID POINTS, ANOMALIES, AND SURVEY LINES

Figure 7.-Electromagnetic survey records showing anomalies along selected survey lines.

GROUND-PENETRATING RADAR AND ELECTROMAGNETIC SURVEYS AT THE MONROE CROSSROADS BATTLEFIELD SITE, FORT BRAGG, NORTH CAROLINA

By Richard Kessler, Raymond E. Strain, James I. Marlowe, II, and Kelly B. Currin