United States Department of Agriculture	**Natural Resources Conservation Service**	**5 Radnor Corporate Center, Suite 200 Radnor, PA 19087-4585**

Subject: Archaeology -- Geophysical Assistance **Date:** 5 January 1998

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Purpose:
The purpose of this investigation was to provide geophysical field assistance to the Charleston Museum, South Carolina Institute of Anthropology and Archaeology, South Carolina Department of Natural Resources and the Nature Conservancy. Ground-penetrating radar (GPR) was used to conduct archaeological surveys at the Fort Santa Elena (Paris Island), James Island Archaeological Site, Fort Johnson (Charleston), and Peach Tree Rock (Gaston). At each site, surveys were designed to map major subsurface anomalies. Studies attempted to demonstrate the value of integrating contemporary geophysical and computer technologies with traditional archaeological techniques. The successful integration of these techniques provides more comprehensive site coverage, reduces the number of unsuccessful exploratory pits, and decreases field time and costs.

Participating Agencies:
Charleston Museum
College of Charleston
South Carolina Department of Natural Resources, Heritage Trust Program
South Carolina Institute of Archaeology and Anthropology (SCIAA)
USDA-Natural Resources Conservation Service
University of South Carolina

Principal Participants:
Ron Anthony, Assistant Curator of Historical Archaeology, Charleston Museum, Charleston, SC
Larry Cadigan, Volunteer, Charleston Museum, Charleston, SC
Chester DePratter, Research Associate Professor, SCIAA, Columbia, SC
Jim Doolittle, Research Soil Scientist, USDA-NRCS, Radnor, PA
Jim Errante, Archaeologist, USDA-NRCS, Columbia, SC
Tariq Ghaffar, Field Director, University of South Carolina, Columbia, SC
Chris Judge, Archaeologist, South Carolina DNR, Heritage Trust Program, Charleston, SC
Stanley South, Research Associate Professor, SCIAA, Columbia, SC
Carl Steen, Archaeologist, Diachronic Research Foundation, Columbia, SC
Sean Taylor, Field Technician, University of South Carolina, Columbia, SC

Activities:
All field activities were completed during the period of 16 to 19 December 1997.

Equipment:
The radar unit used in this study was the Subsurface Interface Radar (SIR) System-2, manufactured by Geophysical Survey Systems, Inc. This unit is backpack portable and requires two people to operate. The use and operation of GPR have been discussed by Morey (1974), Doolittle (1987), and Daniels and others (1988). The SIR System-2 consists of a digital control unit (DC-2) with keypad, VGA video screen, and connector panel. The model 3102 (500 mHz) and 3110 (120 mHz) antennas were used in this investigation. The lower frequency, 120 mHz antenna has greater powers of radiation, longer pulse widths, and emits signals that are less rapidly attenuated by earthen materials than signals emitted from the higher frequency, 500 mHz antenna. The 500 mHz antenna is smaller, provides better depth and lateral resolution of subsurface features, but is more depth restricted than the 120 mHz antenna. The system was powered by a 12-VDC battery.

To help summarize the results of this study, the SURFER for Windows program, developed by Golden Software, Inc.,* was used to construct two-dimensional simulations. Grids were created using kriging methods with an octant search. All grids were smoothed using a cubic spline interpolation.

Ground Penetrating Radar:
The GPR is a time scaled system. This system measures the time that it takes electromagnetic energy to travel from the antenna to an interface (i.e., soil horizon, stratigraphic layer, bedrock surface) and back. To convert the travel time into a depth scale, either the velocity of pulse propagation or the depth to a reflector must be known. The relationships among depth (d), two-way, pulse travel time (t), and velocity of propagation (v) are described in the following equation (Morey, 1974):

$$v = 2d/t$$

The velocity of propagation is principally affected by the dielectric permittivity (e) of the profiled material(s) according to the equation:

$$e = (c/v)^2$$

where c is the velocity of propagation in a vacuum (0.98 ft/nanosecond). The velocity is expressed in feet per nanosecond (ns). The amount and physical state of water (temperature dependent) have the greatest effect on the dielectric permittivity of a material. Tabled values are available that approximate the dielectric permittivity of some materials (Morey, 1974; Petroy, 1994). However, as discussed by Daniels and others (1988), these values are simply approximations.

Calibration trials were conducted at each site. The purposes of the calibration trials were to determine the velocity of propagation of electromagnetic energy through the soil materials, establish a crude depth scale, verify interpretations, and optimize control and recording settings.

Discussion:

Fort Santa Elena, Paris Island

Introduction:

Historic Fort Santa Elena was occupied by the French in 1562 and by Spanish from 1566 to 1587. A goal of the ground-penetrating radar survey was to locate former wells associated with the Spanish occupation.

Study Area:

The survey area was located on the driving range of the Base Golf Course, Paris Island.

Calibration:

The suitability of GPR was assessed during calibration trials conducted on the site. The purpose of these trials was to evaluate the observation depth and resolution of the 500 mHz antenna.

A shovel blade was buried at a depth of 1.58 ft (19 inches). The depth to this buried feature was used to estimate the velocity of propagation through the soil. Based on the round-trip travel time to the buried shovel blade, the averaged velocity of propagation through the upper part of the soil was estimated to be 0.333 ft/ns with the 500 mHz antenna. The dielectric permittivity was estimated to be 8.6. With an average velocity of propagation of 0.333 ft/ns, a scanning time of 40 ns provided a maximum observation depth of about 6.6 ft.

Field Procedures:

An irregular-shaped rectangular grid was established across the site (1.83 hectares). The grid interval was 3 meters. The maximum dimensions of the grid were 135 m by 252 m. The radar survey was completed by pulling the 500 mHz antenna along 46 north-south trending grid lines. Grid lines varied in length from 102 to 201 m. This procedure provided about 6555 m of continuous radar imagery. Each radar profile was reviewed for anomalies.

Results:

Numerous point reflectors were recorded on the radar profiles. Many of the detected point reflectors represent buried artifacts. The artifacts detected with the radar are undoubtedly from different historical periods.

The number of point reflectors detected with the radar was large. It was considered impractical to plot these reflectors individually. Figure 1 shows the survey site and areas having high concentrations of buried point reflectors. In areas having a high concentration of detected subsurface point reflectors, exploratory test pits are more likely to unearth greater accumulations of artifacts.

A goal of the survey was to locate former wells associated with the Spanish occupation. Two areas within the survey site contained unique, high-amplitude, and repetitive signals that suggested potential wells or privies. These two areas are shown in Figure 1. Exploratory test pits in these areas will unearth a structural feature. While GPR located these features, their identities can only be confirmed by traditional archaeological methods.

James Island Archaeological Site - Catherine Parker Site

Study Area:

The Catherine Parker Site represents a colonial period plantation on James Island that is being studied by the Charleston Museum. A goal of the ground-penetrating radar survey was to locate buried structural remains of the former plantation. The Charleston Museum has provided cultural resource training and is a preservation partner with NRCS.

Calibration:
The suitability of GPR was assessed during calibration trials conducted on the site. The purpose of these trials was to evaluate the observation depth and resolution of the various antennas.

A shovel blade was buried at a depth of 1.42 ft (17 inches). The depth to this buried feature was used to estimate the velocity of propagation through the soil. Based on the round-trip travel time to the buried shovel blade, the averaged velocity of propagation through the upper part of the soil was estimated to be 0.302 ft/ns with the 500 mHz antenna. The dielectric permittivity was estimated to be 10.5. With an average velocity of propagation of 0.302 ft/ns, a scanning time of 40 ns provided a maximum observation depth of about 6.0 ft.

Field Procedures:
Three rectangular grids were established across the site. The area enclosed by these grids ranged in size from about 0.06 to 0.10 acre. The grid interval was 5 feet. The radar survey was completed by pulling the 500 mHz antenna along 84 grid lines. Grid lines varied in length from 25 to 45 feet. This procedure provided about 3655 feet of continuous radar imagery. Each radar profile was reviewed for anomalies. Relative distances were recorded and conspicuous anomalies were marked on the radar profiles.

Results:
A cursory review of the radar profiles revealed 141 identifiable point reflectors. No major plane reflector, potentially indicating the presence of a major structural feature or cultural layer, was evident on the radar profiles. Based on knowledge and earlier work at this site, the absence of a major structural feature was surprising. Based on this information, archaeologist will shift their search efforts for structural remains of the former plantation to the surrounding wooded areas.

The approximate locations of the 141 point anomalies have been plotted in Figure 2. Based on exploratory observations and the number of artifacts recovered, the number of detected anomalies is considered low. While no area can be considered virtually free of subsurface features, some areas contain higher or lower concentrations of anomalies than other areas. No major structural feature was detected.

Historic Fort Johnson - Charleston

Study Area:
The fort is being studied by the South Carolina Department of Natural Resources, Marine Resources Division. A goal of the ground-penetrating radar survey was to locate structural remnants of a former tabby fortification.

Field Procedures:
A grid and traverse lines were established across selected portions of Historic Fort Johnson. Radar survey was completed by pulling the 500 mHz and 120 mHz antenna along grid and traverse lines. Each radar profile was reviewed for anomalies in the field. Relative distances were recorded and conspicuous anomalies were marked on the radar profiles. All records of grid and traverse line locations were maintained and kept by Tariq Ghaffar (Field Director, University of South Carolina, Columbia, SC).

Results:

The radar surveys revealed the location of many buried point and plane reflectors. Many of these buried reflectors are believed to represent twentieth century features (mostly buried utility lines and pipe lines). A unique planar reflector was recorded on a portion of a traverse line that was conducted in the middle of a street. This reflector could represent the remains of a tabby fortification. All radar profiles were turned over to Carl Steen (Archaeologist, Diachronic Research Foundation, Columbia, SC) before my leaving the site.

Peach Tree Rock - Gaston

Study Area:

Peach Tree Rock is a prehistoric rock shelter site located near Gaston, South Carolina. Goals of the ground-penetrating radar survey were to provide information on the extent of fallen rock debris and to map buried "cultural" layers within the shelter.

Calibration:

The suitability of GPR was assessed during calibration trials conducted on the site. The purpose of these trials was to evaluate the observation depth and resolution of the 500 mHz antenna.

A shovel blade was buried at a depth of 1.67 ft (20 inches). The depth to this buried feature was used to estimate the velocity of propagation through the soil. Based on the round-trip travel time to the buried shovel blade, the averaged velocity of propagation through the upper part of the soil was estimated to be 0.444 ft/ns with the 500 mHz antenna. The dielectric permittivity was estimated to be 4.86. With an average velocity of propagation of 0.444 ft/ns, scanning times of 50 and 35 ns provided maximum observation depths of about 11.1 and 7.8 ft, respectively.

Field Procedures:

Five lines were established in front of Peach Tree Rock. Four parallel lines, spaced about 5 m apart, were extended outward from the Rock. One additional line was established orthogonal to the others and immediately in front of the overhanging rock ledge. Survey flags were inserted in the ground at a one meter interval along each line. Lines varied in length from about 30 to 44 meters. A radar survey was completed by pulling the 500 mHz antenna along each of the five lines. The scanning time was 50 ns. Each radar profile was reviewed for anomalies.

An irregularly shaped, rectangular grid was also established across a portion of the site. The grid interval was 1 m. Grid lines varied in length from 14 to 11 m. The radar survey was completed by pulling the 500 mHz antenna along 11 parallel grid lines. The scanning time was 35 ns. This procedure provided about 144 m continuous radar imagery. Each radar profile was reviewed for anomalies.

Results:

Radar profiles collected at Peach Tree Rock were comprehensible and contained an abundance of subsurface information. Distinct bands of lamellae within the soil, and strata within the underlying bedrock were discernible. Radar profiles contained numerous point (tree roots, rock fragments, artifacts) and planar (soil layers and horizons, and noise) reflectors. Unique planar reflections occurred within and near the rock ledge. However, without ground-truth auger or pit observations, their identity is uncertain. Conclusions as to their composition is presently speculative. Unwanted background noise was produced by high gained settings (parallel bands appearing at fixed time intervals or apparent depths) and reflections from the overhanging rock ledge (bands which uniformly plunge from relatively shallow to deeper depths with increased distances from the ledge).

A cursory review of the radar profiles from the detailed grid revealed 61 identifiable point reflectors. Many of these point reflectors are believed to represent tree roots or rock fragments. Some may represent artifacts. The approximate locations of these point reflectors are plotted in Figure 3. In this figure, the area located below an overhanging rock ledge has been approximated with a dashed line. Several buried point reflectors are located beneath or near the overhanging rock ledge. These reflectors may represent buried artifacts.

Conclusions:

1. Ground-penetrating radar provided high resolution and continuous measurements of subsurface conditions at each site. Continuous measurements of subsurface conditions provide greater spatial coverage and increase the potential of detecting buried cultural features. At each site, GPR provided archaeologists with a rapid, cost-effective, and non-destructive method to locate buried artifacts.

2. Ground-penetrating radar interpretations are considered preliminary estimates of site conditions. The results of GPR investigations do not substitute for direct observations, but rather reduce their number, direct their placement, and supplement their interpretations. Radar interpretations should be verified by ground-truth observations.

3. A large number of buried point reflectors were identified at each site. Some of these reflectors represent buried cultural features. Location maps have been prepared for three sites. These maps may help archaeologists develop search strategies. Major structural features were identified at the Paris Island and Historic Fort Johnson sites.

4. Copies of all radar profiles from Fort Santa Elena (Paris Island), Catherine Parker Site (James Island), and Peach Tree Rock (Gaston) have been turned over to Jim Errante for disposition.

It was my pleasure to work in South Carolina and with members of your fine staff.

With kind regards,

James A. Doolittle

James A. Doolittle
Research Soil Scientist

cc:

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References

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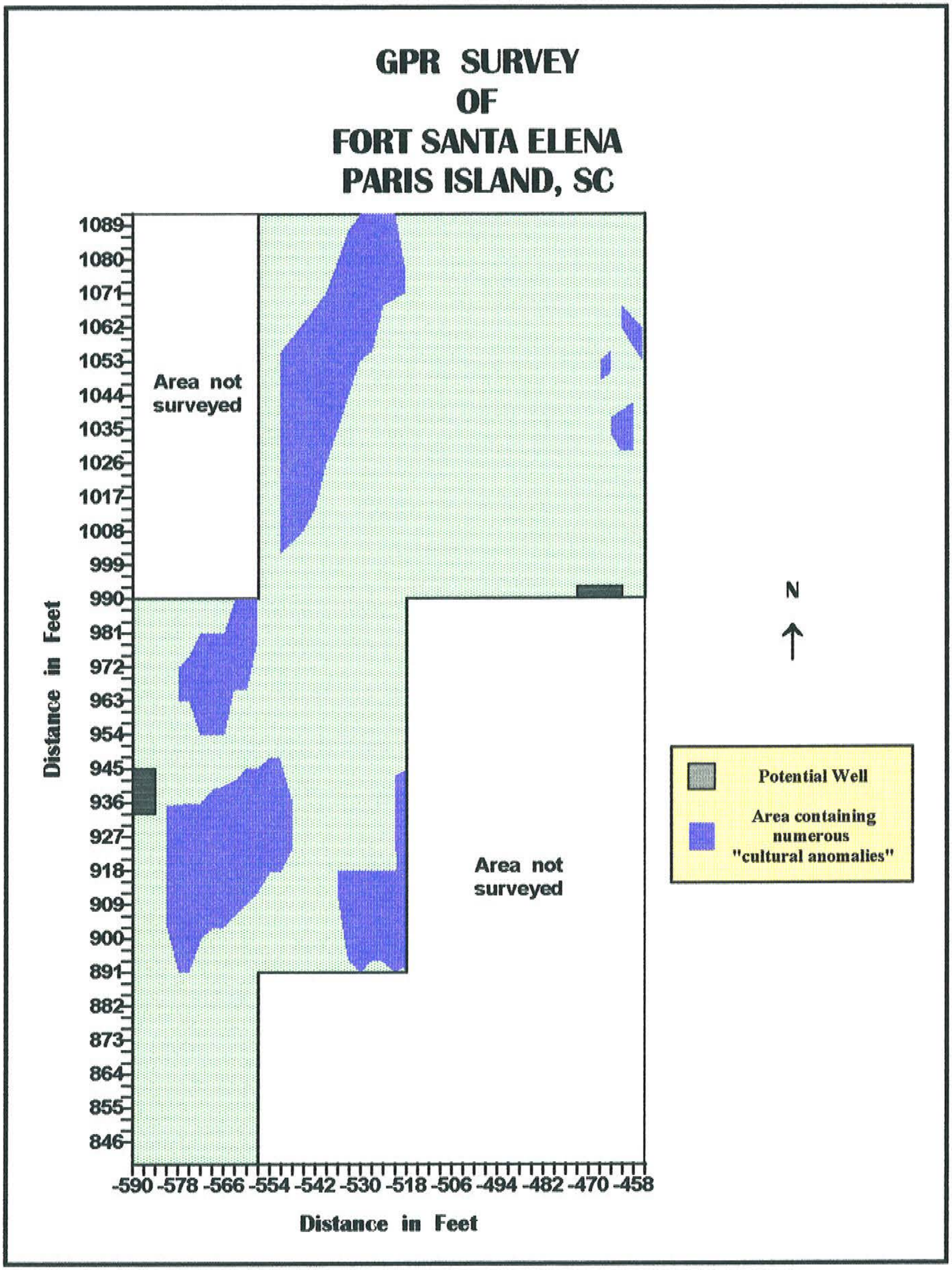
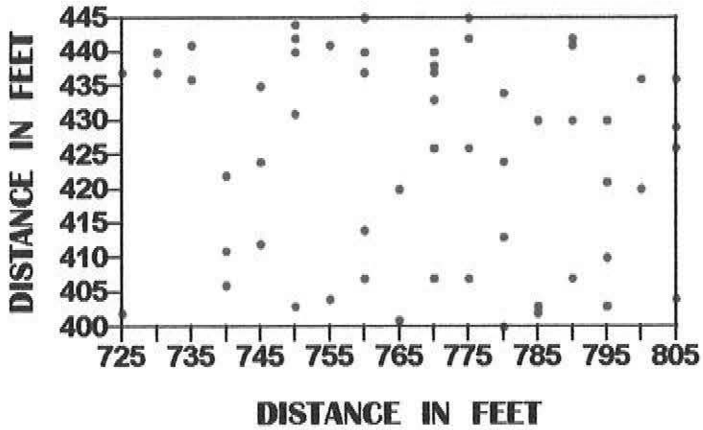


GPR SURVEY
OF
FORT SANTA ELENA
PARIS ISLAND, SC
Area not surveyed
Area not surveyed
Distance in Feet
1089
1080
1071
1062
1053
1044
1035
1026
1017
1008
999
990
981
972
963
954
945
936
927
918
909
900
891
882
873
864
855
846
-590 -578 -566 -554 -542 -530 -518 -506 -494 -482 -470 -458
Distance in Feet
N
Potential Well
Area containing numerous "cultural anomalies"

CATHERINE PARKER SITE
(38CH857)
LOCATIONS OF SUBSURFACE ANOMALIES

GRID #1



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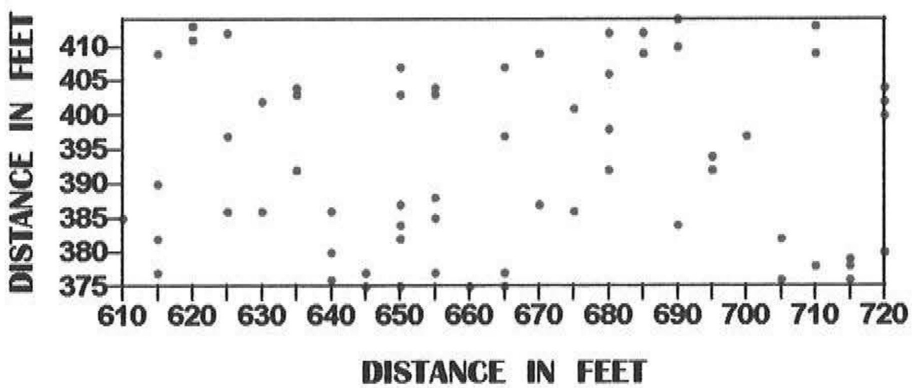

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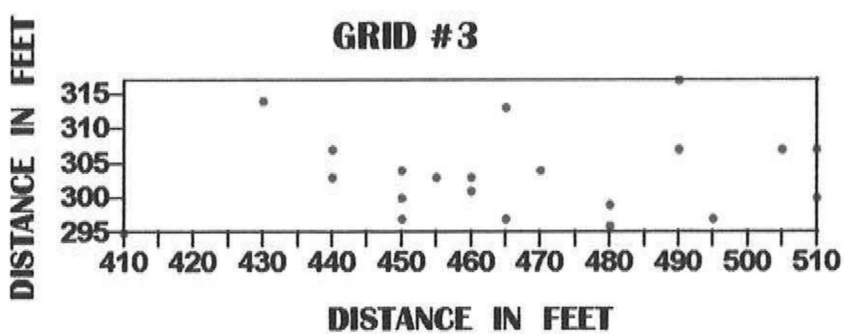

PEACH TREE ROCK
GASTON, SOUTH CAROLINA

LOCATIONS OF POINT ANOMALIES DETECTED WITH GPR