Investigating the Whittington and Ailhaud St. Anne Sites with Ground Penetrating Radar, A Summary of Results from the 2006 and 2007 Field Seasons

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INTRODUCTION

As part of the National Center for Preservation Technology and Training (NCPTT) Prospection in Depth Workshop, the University of Mississippi Center for Archaeological Research conducted a geophysical survey of the Whittington (16NA241) and Ailhaud St. Anne Site (16NA529) sites in Natchitoches Parish, Louisiana using ground penetrating radar (GPR). GPR survey was conducted in conjunction with magnetic gradiometer, electrical resistance, and electromagnetic induction survey conducted by Steve De Vore of the National Park Service's Midwest Archeological Center. Resulting data were used to guide excavation at the sites during and after the workshop.

METHODS

Ground penetrating radar (GPR) operates by sending out an electromagnetic wave pulse into the ground that reflects off materials with contrasting electrical properties (Figure 1) (Weymouth 1986:371; Conyers and Goodman 1997:23). This is related primarily to the electrical conductivity and magnetic permeability of the materials (Conyers and Goodman 1997:32). Relative dielectric permittivity (RDP), the ability of a material to store and pass a magnetic field, is the accepted property used to describe the materials. RDP (K) ranges from 1 for air to 81 for water and is expressed by $K = c^2 / V^2$, where c is the velocity of light and V is the velocity of the wave (Conyers and Goodman 1997:33; Reynolds 1997:689). For soils, the RDP ranges from 3 from the driest sand to 40 for saturated clay. The strength of the reflection is proportional to the difference in RDP of the two materials and relies on an abrupt change between the materials (Conyers and Goodman 1997:34; Geophysical Survey Systems Inc. 1999:36). A contrast in RDP as small as 1 can cause a reflection in some cases (Geophysical Survey Systems Inc. 1999:31).

Furthermore, the travel time of the interaction is recorded as a matter of course in GPR surveys and this can be related to the depth of the target. When a radar wave is bounced off a subsurface reflector, the total travel time is recorded in nanoseconds (ns). This time is directly proportional to the depth of that target. Therefore, if the RDP is known for the medium, the depth can be found. RDP is difficult to determine accurately in the field, but can be estimated by several methods (Conyers and Goodman 1997:32; Geophysical Survey Systems Inc. 1999:79). One commonly used technique is geometric scaling in which a curve is fit to the properties of hyperbolic reflections in the data generated by strong reflectors. Because of the geometry of reflectance as the antenna passes over a target, the reflection will be expressed as a hyperbola and the width of that hyperbola is determined by the dielectric permittivity of the soil (Geophysical Survey Systems Inc. 199:83).

An interface is visible if the electrical properties of two substances contrast enough to produce a reflection. The magnitude of the reflection depends on the amount of contrast in the dielectric properties of the materials at an interface. This characteristic of GPR can contribute substantially to the study of stratigraphy. For example, a sand layer overlying a packed clay floor, a buried stone wall, or an air filled cavity will be likely produce a measurable reflection.

GPR antennas are available in various center frequencies, usually between 100 MHz and 1500 Mhz, which are related to the optimum depth of propagation and the resolution of the signal (Geophysical Survey Systems Inc. 1999:51). In general, lower frequency antennas propagate energy to greater depths. However, the vertical resolution also decreases (Geophysical Survey Systems Inc. 1999:56). For example, low frequency antennas can penetrate as far as 50 meters in ideal circumstances. In contrast, a 1000 Mhz antenna may only penetrate to about .5 meters, but can resolve features to a thickness of a centimeter (Geophysical Survey Systems Inc. 1999:52). A 400 MHz antenna is often used in archaeological applications because of the intermediate depth abilities. For all frequencies of antenna, a cone of energy is sent out that is roughly 90 degrees from front to back and 60 degrees from side to side (Geophysical Survey Systems Inc. 1999:45).

Limitations in GPR are related to the mechanics of sending electromagnetic energy through materials with high dielectric values, such as clayey soil (Reynolds 1997:688). Such soils cause the electromagnetic energy to attenuate at shallower depths as a result of the dispersion of the energy (Conyers and Goodman 1997:55). Attenuation causes the resultant data to be blurry when viewed and returns from even strong reflectors can be obscured. Wetter soils, often including clays, and high salinity materials are not ideal conditions for GPR survey. Dry sand, however, can often produce exceptional results.

GPR has been demonstrated to be good at detecting a number of archaeological features including pits, trenches, hearths, stone foundations, kilns, buried living surfaces, metal objects, voids, burials, tombs, tunnels, and caches (Conyers and Goodman 1997:23, 197-200). In some cases, construction stages in prehistoric mounds can be detected. Archaeological features that are unlikely to be detected using GPR include very thin stratigraphic layers, features within a rock lined burial, small clay or stone artifacts, and any feature below a wet clay layer (Conyers and Goodman 1997:197-200).

The data processing that is necessary in order that GPR data be used to its maximum potential by archaeologists is more involved than any of the other geophysical methods. Analysis begins by locating targets in the radar profiles, estimating the average RDP, and estimating the depth to targets. In the radar profiles, the amplitude of a reflection is positive if a high dielectric medium is encountered below a lower dielectric medium and negative when the reverse occurs. A strong narrow reflector will often produce an anomaly alternating between signs in a hyperbolic shape. Further processing is somewhat complex and includes creating plan view amplitude slice maps and three dimensional data cubes. Usually, the amplitudes are squared so that strong positive or negative anomalies appear the same.

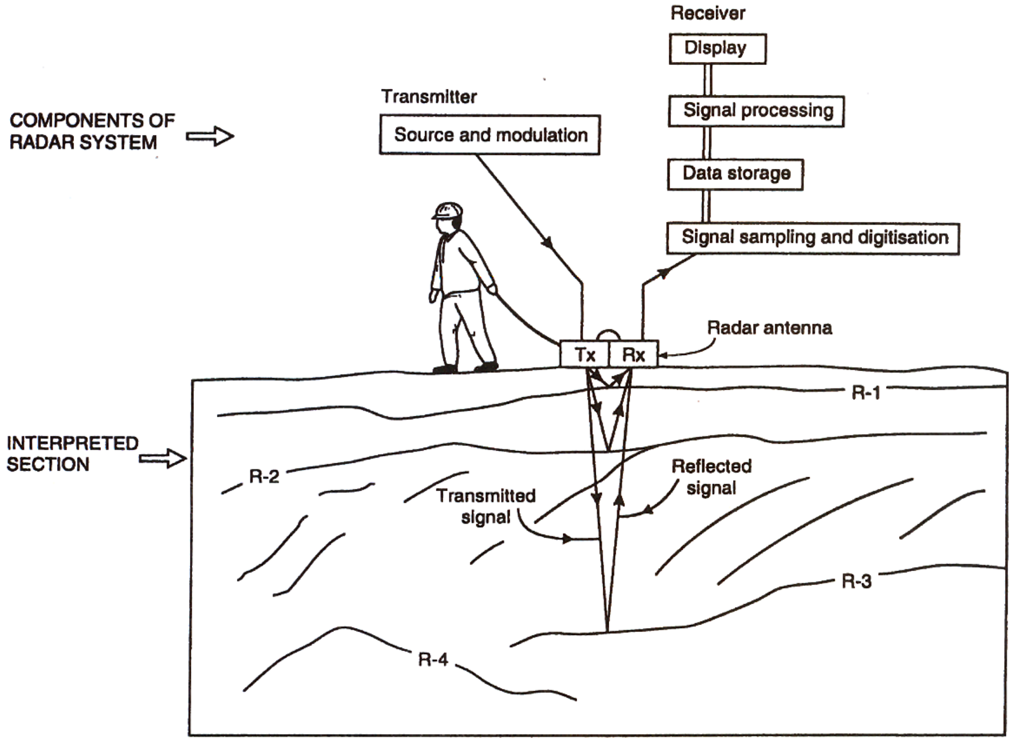

Figure 1. Operation of a GPR system (from Reynolds 1997).

Figure 2. The GSSI SIR2000 GPR with the 400 MHz antenna.

DATA SPECIFICATIONS

The University of Mississippi operates a Geophysical Survey Systems Incorporated SIR2000 system with 300 MHz bistatic and 400 MHz (used for this project) antennas (Figure 2). GSSI radar systems are regularly used in archaeological research in North America. The SIR2000 system includes a control unit built from a laptop computer with 2.1 GB of storage and a battery (Geophysical Survey Systems Inc. 1999:5). The components can be worn on a harness, mounted on a cart, or separated using a long cord. Vertical profiles are displayed in real time on the screen. An integrated survey wheel, which is used to determine the distance along the transect line, attaches to the antenna sled.

Data were collected using N-S oriented transects spaced either .5 meter (portions of Whittington) or 1 meter apart (portions of Whittington and all of Ailhaud St. Anne). Samples were collected at a 512 per scan and 32 scans were collected per meter. A standard time window of 60 ns was used. A radiometric resolution of 8 bits was used.

For a portion of the Ailhaud St. Anne survey (north of the N40 line), a Geophysical Survey Systems Incorporated SIR3000 with a 400 MHz bistatic antenna and a cart was used. Setup parameters were used to mimic the SIR2000 data so that it could be compared and ultimately composited to form one data set.

RESULTS

The GPR data were downloaded to a laptop computer and processed using GPR Slice software, produced by the Geophysical Archaeometry Laboratory. For each data set, twelve amplitude slice maps were created to a depth of approximately 110 cm. Because of the highly conductive soil, data below this depth were degraded and excluded from analysis. A hyperbola fit was performed on the data to allow the depth to be estimated. An overlay was constructed of all twelve slices to locate strong anomalies throughout the data. The raster data set was exported from GPR Slice to be included in a GIS, where anomalies were identified for three depth ranges: 0 – 30cm, 40 – 70cm, and 80 – 110cm. For the Whittington Site, amplitude slice maps are shown in Figure 3, the overlay shown in Figure 4, and anomalies are identified in Figure 5. For Ailhaud St. Anne, amplitude maps are shown in Figure 6, the overlay shown in Figure 7, and anomalies identified in Figure 8.

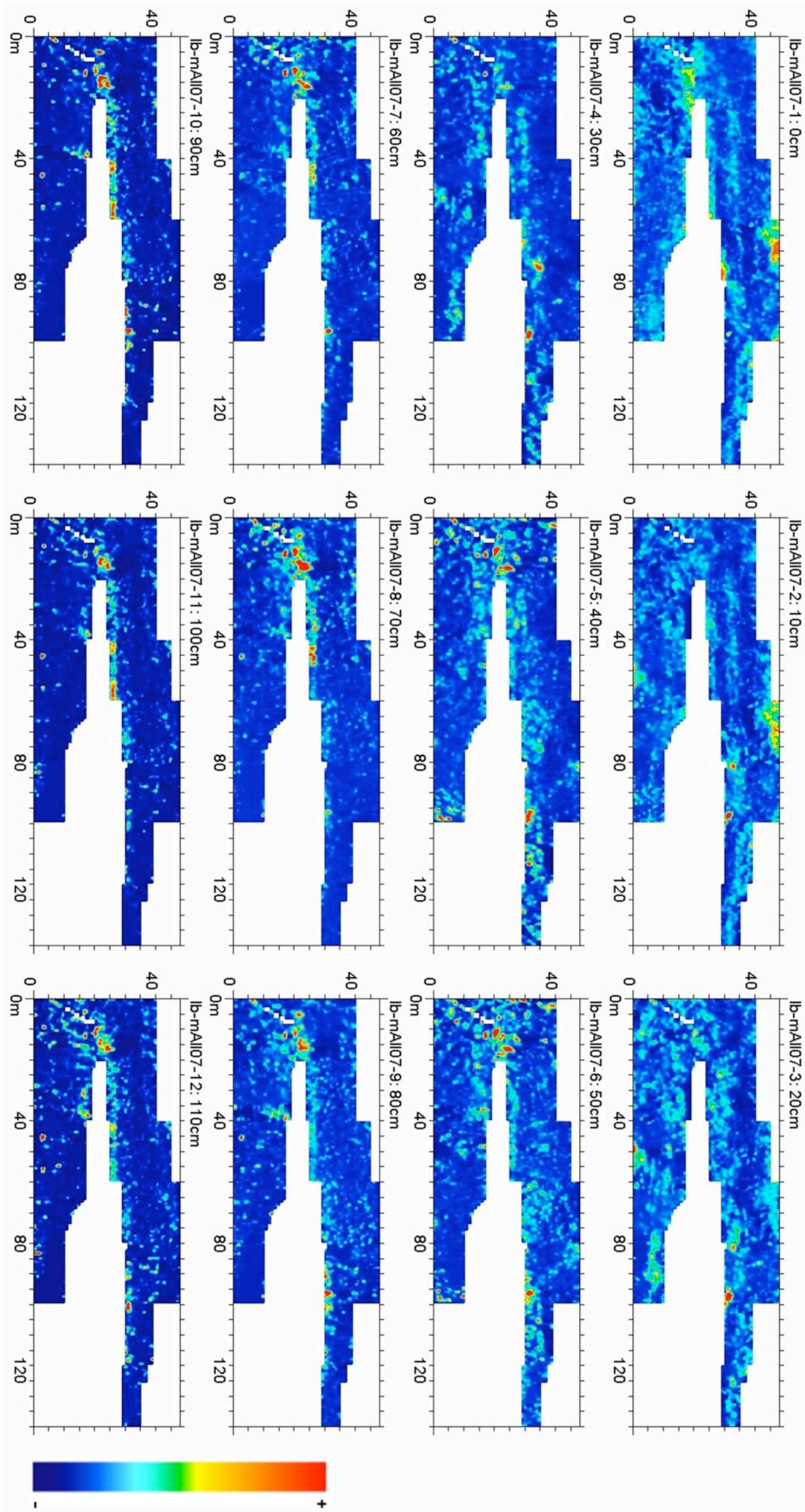

Figure 3. GPR survey results with approximate depths for Whittington.

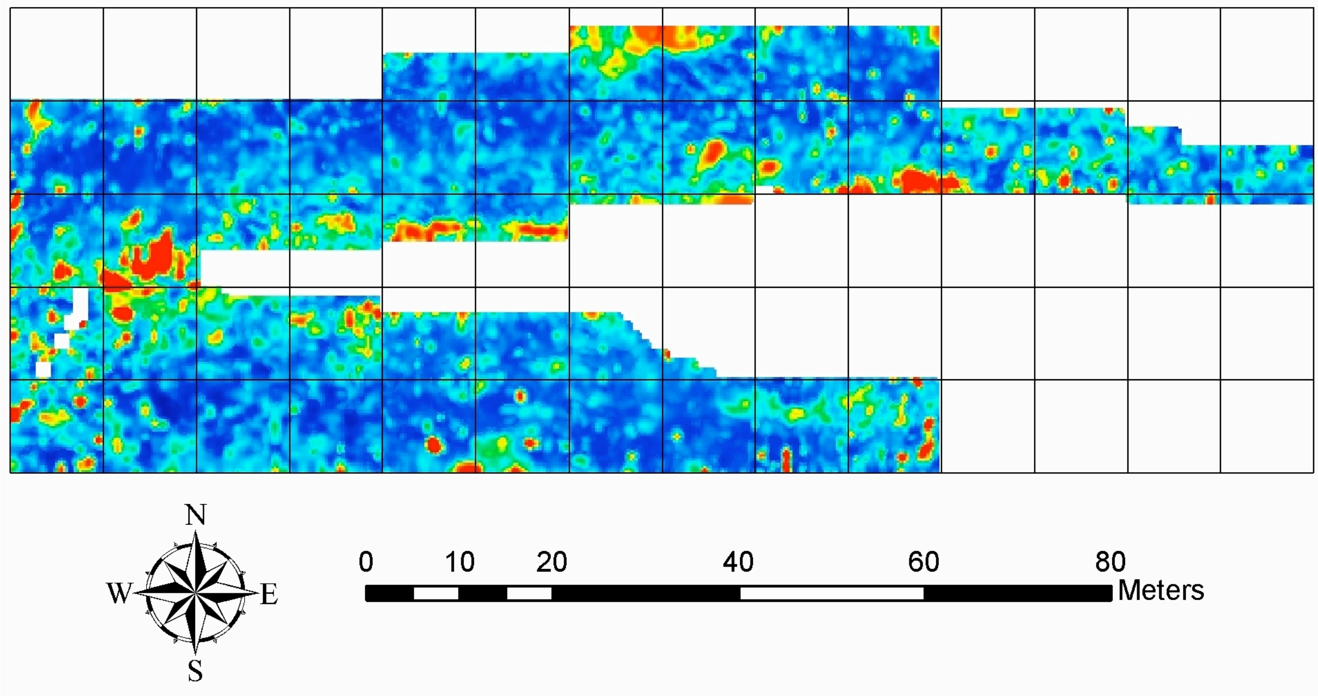

Figure 4. An overlay of GPR amplitudes from all twelve depths for Whittington.

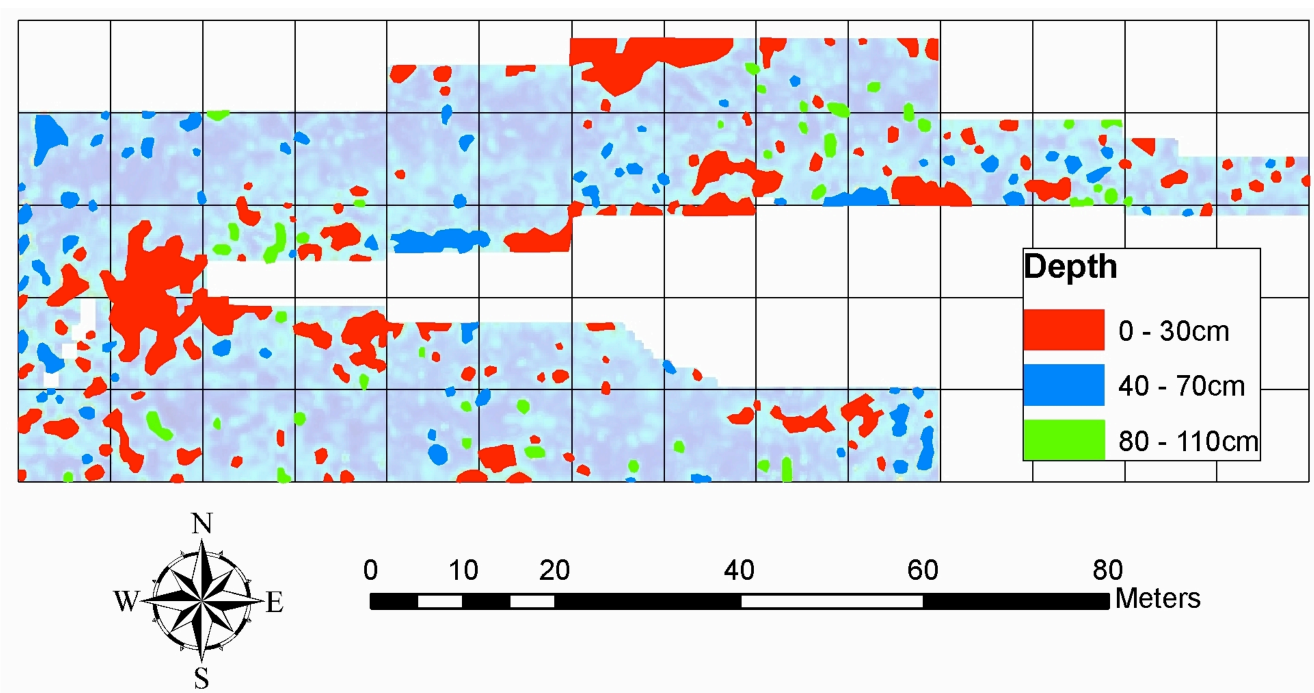

Figure 5. GPR anomalies identified at Whittington.

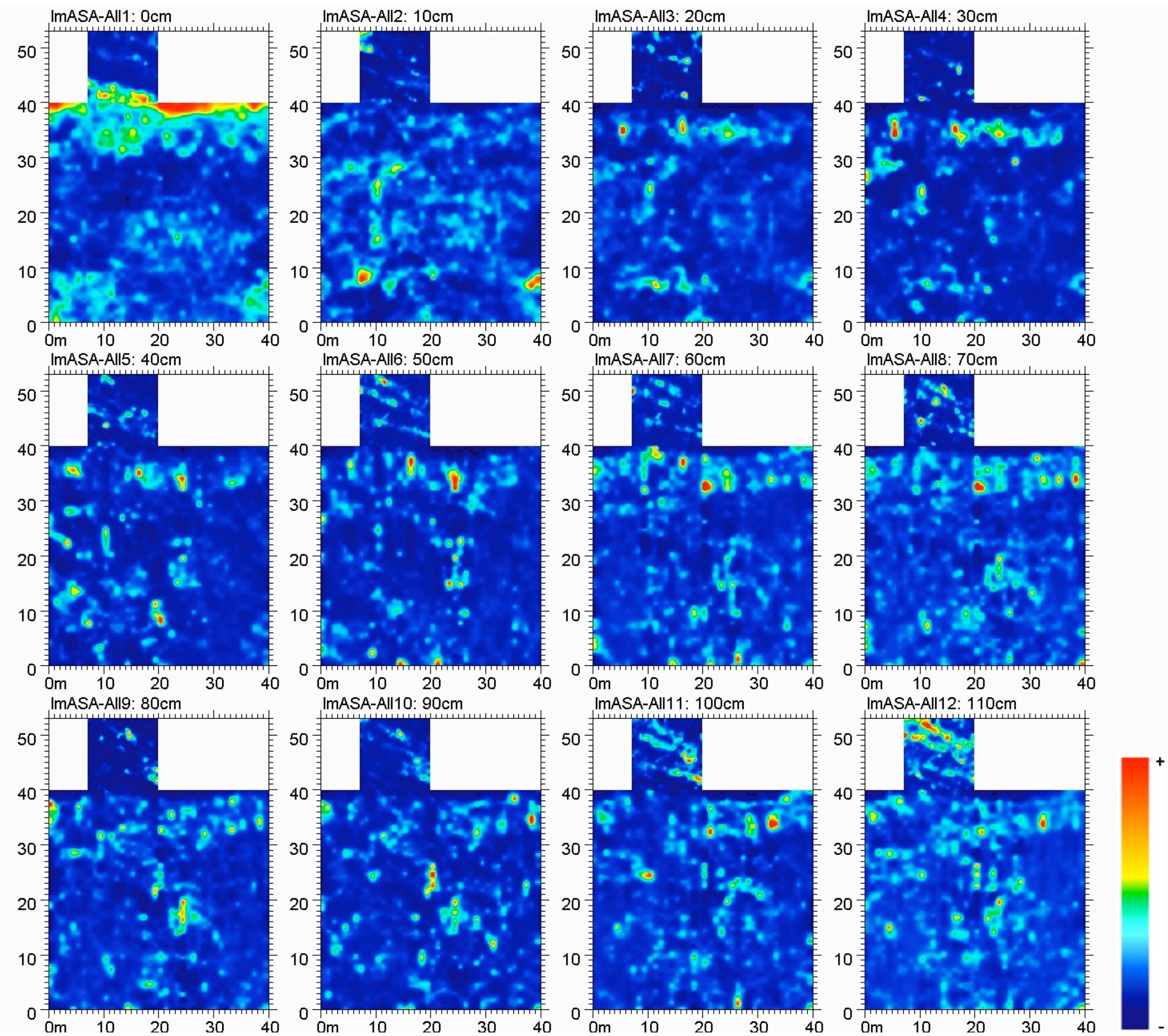

Figure 6. GPR results with approximate depths for Ailhaud St. Anne.

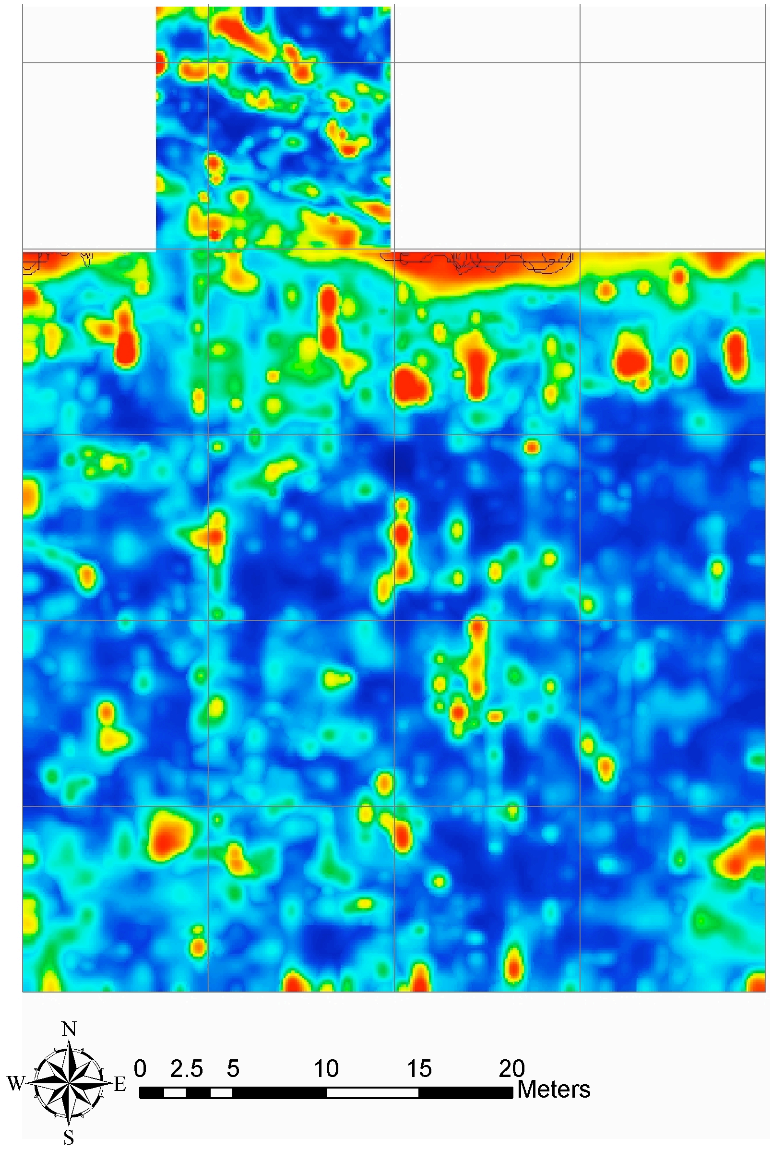

Figure 7. GPR overlay of all depths for Ailhaud St. Anne.

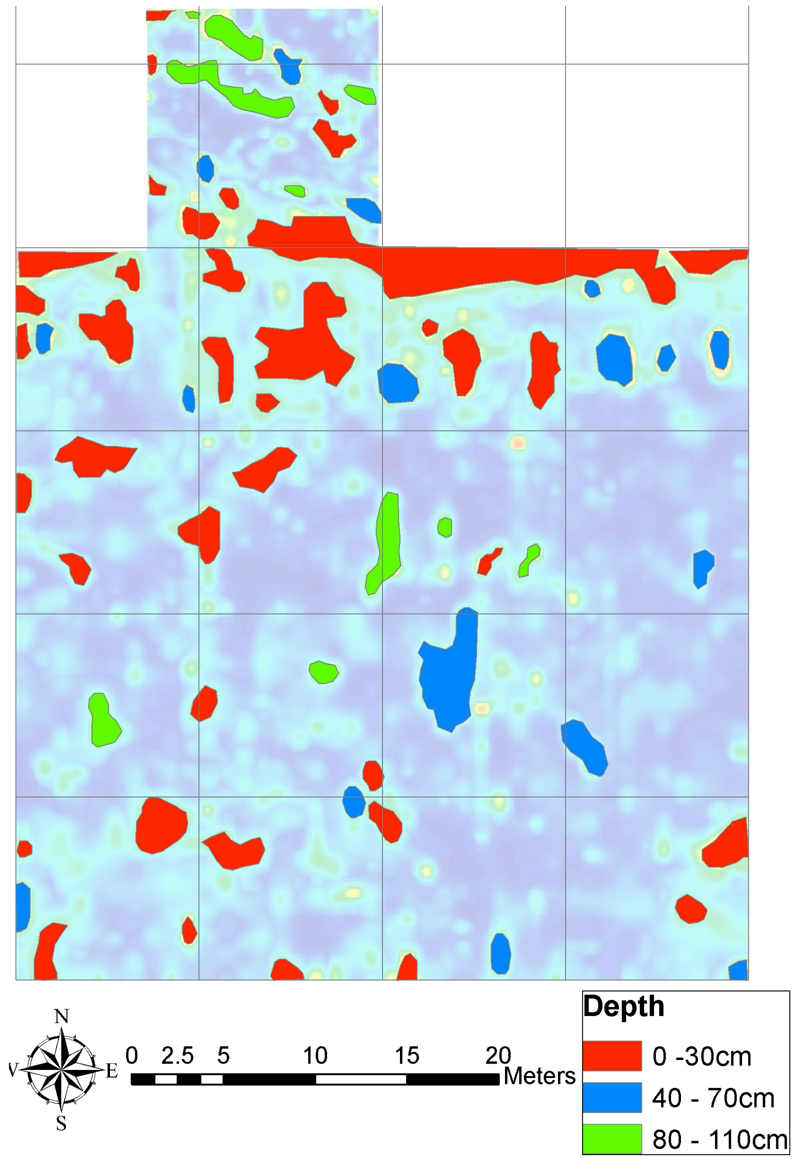

Figure 8. GPR anomalies for Ailhaud St. Anne.

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