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Ground-penetrating Radar Mapping in Clay: Success from South Carolina, USA

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ABSTRACT A ground-penetrating radar (GPR) survey conducted in a clay-rich floodplain of the Savannah River, South Carolina, produced what were very difficult to interpret reflection profiles caused by energy coupling changes. These changes were caused by deep hardened plow furrows at the ground surface that caused antenna movement to be irregular, and energy to be transmitted into the ground at various angles, and with different properties. A dense clay layer also attenuated much of the radar energy at about 50 cm, further obscuring the profiles. Despite these ambiguous data, amplitude mapping at slices below the clay layer yielded images of distinct circular and linear features, which proved to be palisade walls dating from about the late Mississippian to Early Contact period (AD1400-1740). This survey illustrates that it is possible to obtain good GPR results even when energy passes through dense clay and when reflection profiles are obscured by attenuation and coupling changes. Copyright © 2006 John Wiley & Sons, Ltd.

Key words: ground-penetrating radar; clay; attenuation; amplitude analysis

Introduction

It has long been assumed that ground with an abundance of clay yields poor ground-penetrating radar (GPR) results, as most radar energy is attenuated very close to the surface due to clay's high electrical conductivity (Jol and Bristow, 2003; Leckebusch, 2003). There have, however, been some interesting GPR successes in clay, where radar energy has penetrated deep enough to be reflected from targets of interest, and still received back at the ground surface (Conyers, 2004a). Preliminary work suggests that the mineralogy of the clay in these areas produces a somewhat electrically resistive media. These clays appear to be either rock clasts of clay size, or mineral clays, such as kaolonite, which have a low cation exchange capacity (Conyers, 2004b).

A successful GPR survey in very clayey ground was conducted at Riverfront Village, South Carolina, which contains late Mississippian to Early Contact Period (AD 1400–1740) remains preserved under floodplain sediments. Previous test excavations indicated the presence of possible structures and palisade walls as well as a dense trash midden, and possible refuse and storage pits.

The survey

A 100×94 m grid covering the prospective area was surveyed using a GSSI SIR-3000 system and 400 MHz antennae. Reflection data were collected in transects 1 m apart over a grassy field that retained furrows from recent ploughing. The residual plough furrows made movement of the antennae along the ground quite difficult as they produced ridges about 10–15 cm tall, spaced about 30–40 cm apart.

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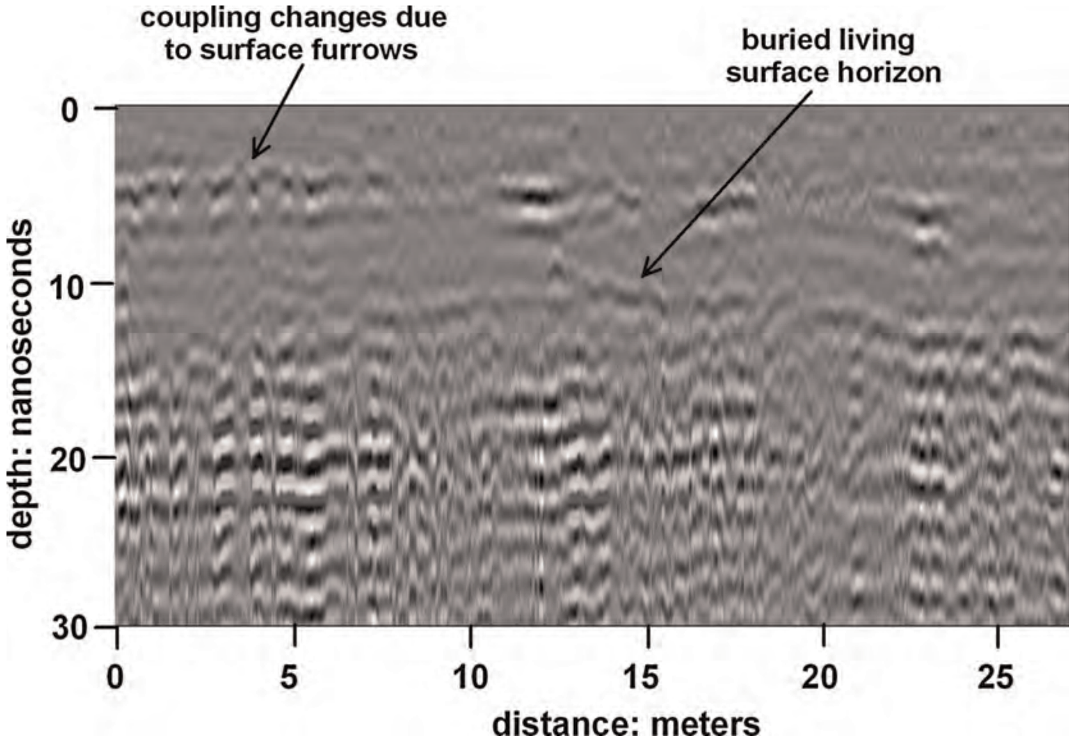

Figure 1. Reflection profile showing coupling changes due to surface furrows and indistinct reflections at about 20 ns.

Preliminary stratigraphical investigations in the survey area exposed a clay layer about 40–50 cm below the present ground surface that varied in thickness from 5 to 20 cm. This stratigraphical layer was observed overlying a historic plough zone in a buried soil horizon containing nineteenth century artefacts. The clay layer is thought to represent deposits from the flood of 1888 that inundated this floodplain area. Beneath the buried historic plough zone prehistoric features and

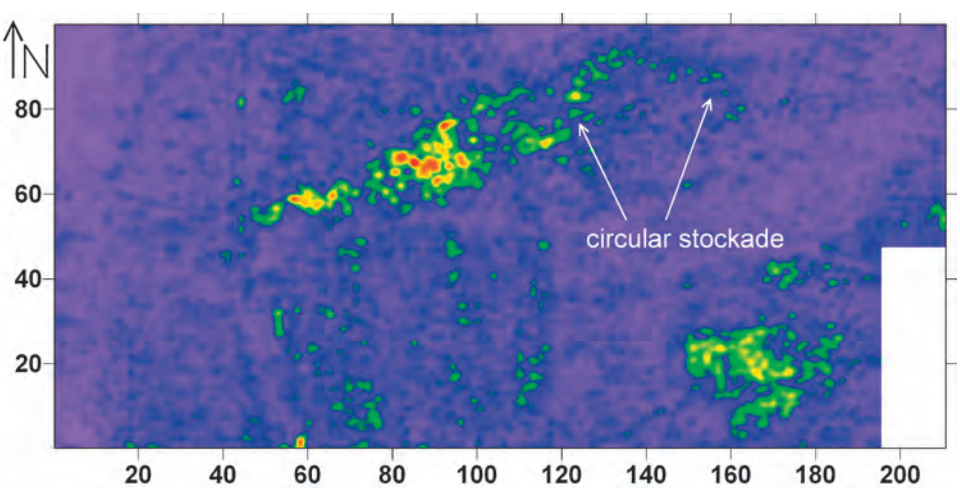

Figure 2. Amplitude slice-map from 21 to 24 ns showing linear and circular features, corresponding to palisade walls and other historic features built on the pre-1888 flood living surface.

Figure 3. Linear post moulds of a prehistoric palisade wall that were imaged on the GPR slice maps in Figure 2.

artefacts were also found from the late Mississippian occupation of the area. Little was known about this prehistoric component of the site.

Reflection profiles showed a plethora of very erratic reflections caused by many near-surface energy coupling changes as the antennae passed over the hardened furrows (Figure 1). In addition the dense clay layer appeared to have attenuated much of the radar energy around 20 ns, which velocity tests showed to be about 40–50 cm in the ground. All profiles in the grids were sliced in 3-ns slices and reflection amplitudes interpolated between profiles using a 1 m search radius. The slice from 21 to 24 ns (about 40–45 cm in the ground) yielded an amplitude map that showed distinct linear and circular features at a depth just below the buried nineteenth century soil horizon (Figure 2). Most important, the features that might have caused these distinct patterns were not visually discernable in any of the individual reflection profiles (Figure 1). The patterns in the southern part of the survey were hypothesized to be the remains of post moulds from vertical wooden logs that made up a palisade wall (Figure 2).

A large open excavation cleared all the overburden to within the nineteenth century soil horizon at about 45–50 cm depth (Figure 3). A linear palisade wall composed of very large post moulds was uncovered within that layer about 10 cm beneath the clay horizon deposited during the flood of 1888. These visually distinct features in the excavations were not visible in the reflection profiles, probably because they are composed of material that is not distinct chemically or physically from the surrounding matrix and therefore do not produce readily visible radar reflections. There are still subtle differences that can be measured in the digital reflection data, however, which become apparent in the amplitude slice-maps (Figure 2).

Conclusion

Reflection profiles in this area were so ambiguous that no usable interpretations could be made from them. Surface furrows created many coupling changes in the reflection profiles, and energy attenuation below about 20 ns accentuated mostly background noise and not the very weak reflections generated from the features of interest. Even with the seemingly ambiguous reflection data the amplitude maps constructed from all reflection profiles yielded useful maps that showed distinct linear and circular patterns. These features proved to be palisade post foundations of a pre-contact Mississippian age village. In this difficult area for GPR data mapping, amplitude analysis of all reflections with a 1 m search radius proved that usable reflection information still exists within profiles that exhibited no readily interpretable reflections to the human eye. Although the composition of the overlying clay is not known, it appears to be less electrically conductive than many clay units found elsewhere, and still allowed the penetration and reflection of radar energy to at least 1 m in the ground. This survey shows that if targets are not too deeply buried, good results can be obtained even in the densest of clay environments with a good deal of ground surface disturbance.

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