# Ground-penetrating Radar Analysis, Jicaro Beach, Guanacaste, Costa Rica

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**Javier Oviedo González**
San Jose, Costa Rica
javierog139@hotmail.com

Lawrence B. Conyers
Denver, Colorado
lconyers@gpr-archaeology.com

**Abstract**

The ephemeral remains of buildings in a Late Period Costa Rican village proved challenging for GPR mapping because little remained but foundation stones and compacted earth floors. Those features had been disturpted over the last 800-900 years by erosion, flood deposits, root action and slumping of the ground. Standard amplitude mapping proved to be beneficial in showing patterns of stones that were consistent with what is known about the shape of these ancient dwellings. Those patterns were confirmed in three locations by the identification of high amplitude planar reflections generated from compacted floor surfaces. Only with the integration of those two image types were the ancient buildings in the village understood and mapped.

**Introduction**

In 2018 and 2020, ground-penetrating radar (GPR) data were collected in a variety of grids just to the west of Jacaro Beach in the Guanacaste Provence of Costa Rica. This area on the Pacific coast (Figure 1) had previously been found to contain a variety of surface artifacts, including stone tools, pottery, small cooking ovens and abundant shell middens (Steinbrenner et al. 2021). The goal of the GPR surveys was to explore for and map possible buried features associated with habitation locations and associated use areas. The area of study was slated to become vacation townhomes with a tennis court, and the developer wanted to make sure not to destroy any important archaeological features that might be discovered with these surveys.


**Figure 1:** Location of the site on the Pacific Coast of northwestern Costa Rica.

The location of the GPR surveys is just inland from a beach, on a slope leading upward to an uplifted marine terrace (Figure 2). This raised terrace is composed of Holocene volcaniclastic rocks interbetted with marine turbidites. Today the upland areas are being developed into a golf course and an expansive tourist resort.

**Figure 2:** The upland terrace is covered in grass. The ground slopes down toward the bay, with the beach and slope where the GPR surveys were conducted just below where this picture was taken.

Both GPR surveys were conducted in April, at the end of the dry season when the tropical scrub forest area was very dry and access for the surveys was possible (Figure 3). During the rainy season, starting most years in June, this area is overgrown with tropical vegetation and inaccessible.

**Figure 3:** Collecting 400 MHz profiles in leaf-litter that covers the ground in this dry tropical forest in April.

A number of GPR grids were surveyed on what is mostly flat or gently sloping ground, just inland from the ocean (Figure 4). These grids were chosen based on a concentration of surface artifacts and shells, but also as they were flat areas where reasonably sized grids could be located. The ground was quite uneven, with many gullies that are active watercourses during the rainy season. Those gully areas were excluded from surveys.

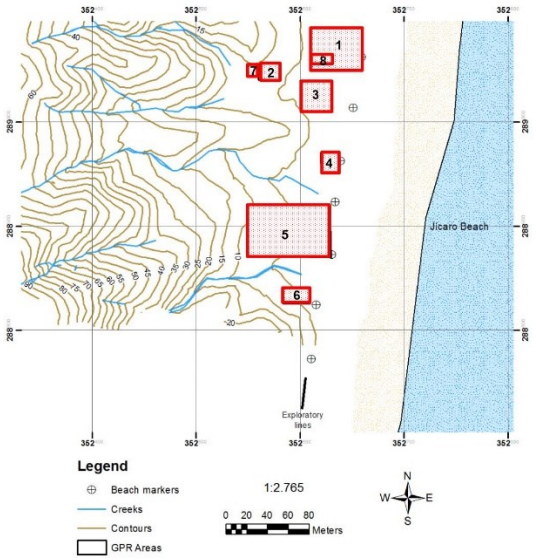



**Figure 4:** Locations of GPR grids between gullies and just inland from the beach.

The composition of the surface soils is important for GPR at this site. It is organic-rich with kaolinite clay and interbeds of silty sand. This is a very good medium for radar wave penetration (with low electrical conductivity when dry), and it was found that 400 MHz energy penetrated to about 2 meters or so with good subsurface feature resolution. The ground is complicated with the inclusion of many individual stones, which were likely deposited here during flood events as slope-wash events transported materials from the high areas to the west. Tree roots are also abundant in the surface soils, and they, and the individual stones, produce abundant point-source reflections that are common in all GPR reflection profiles.

Prehistoric dwellings, which were the targets of these surveys were dated as Late Period (AD 1000 to 1550), as defined by pottery styles. The buildings were likely simple thatched dwellings much like an artist representation (Figure 5). Some nearby archaeological work in this region indicates they were often circular, oval, and sometimes rectangular (Steinbrenner et al., 2021). They were usually constructed with stone foundations, and floors were raised and made of compacted earth.

**Figure 5:** Reconstruction of Late Period dwellings in the Guanacaste Region. From the Guayabo National Monument Museum display.

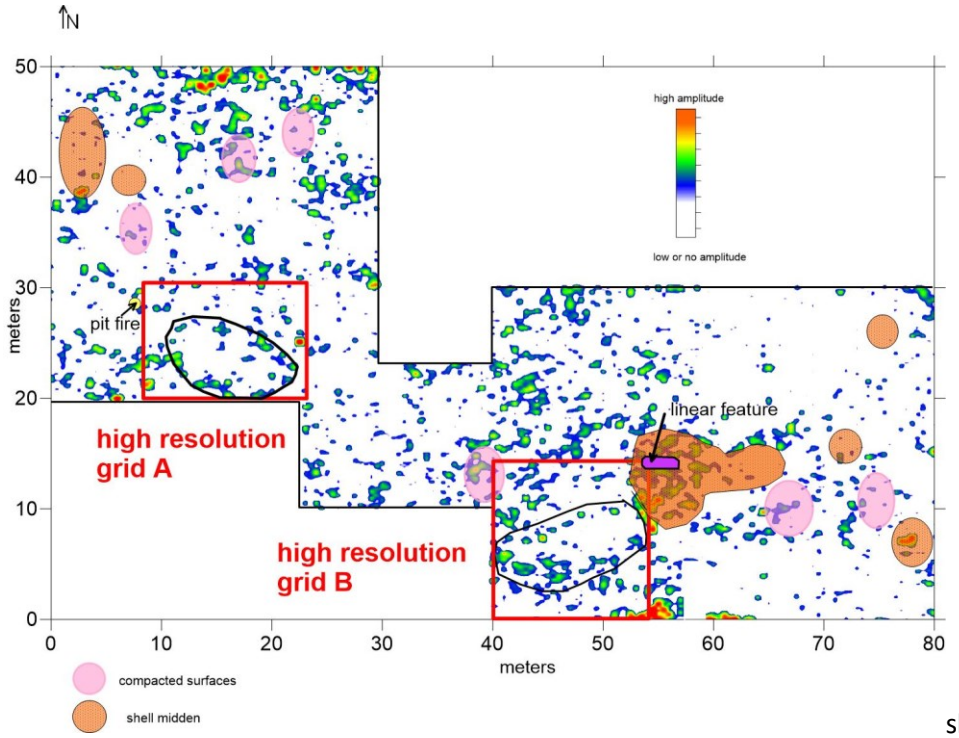
The ephemeral nature of the ancient dwellings, which left only stone outlines of dwellings and compacted floors, makes villages of this sort challenging for GPR mapping. Organic thatch and other easily decomposed artifacts produced from plant material quickly deteriorated in the tropical climate. To complicate the depositional and preservation history of this area individual stones that outlined work areas and dwelling foundations were often moved around during periodic prehistoric reconstruction efforts. To further complicate the preservation history miscellaneous random stones were washed into the area from the nearby highlands, which could be confused for construction stones in GPR images. All stones produce distinct point-source hyperbolas, so only patterns of stones (showing the outlines of structures) within amplitude maps could be used to delineate important buried architectural features. The abundant roots in this tropical forest are also easily confused for stones, as these also produce reflections that are similar to stones. Only by tracing the reflections in space to see if they resemble continuous roots, can the stones and roots be differentiated.

It was quickly discovered that pattern recognition of high amplitude point-source reflections (produced from both stones and roots) in amplitude maps was not enough to accurately define houses and other features (Conyers 2023). This is common with most GPR surveys, but not often conducted by many practitioners as it is labor intensive. Here it proved to be essential. Individual reflection profiles had to also be interpreted, and continuous planar reflections that were generated from compacted earthen floors within the stone foundation outlines was necessary for a complete analysis.

A few of the grids with the most distinct buried feature are discussed below. In both grids both amplitude maps and profile analysis in conjunction were necessary to define the buried architecture. There were many other features discovered with these surveys such as cooking ovens, shell middens and possible human burials, which are not discussed here.

**Grid 5**

This large grid is on the southern part of the study area in a mostly flat area between two gullies (Figure 4). The area shown on the base map is the overall grid, which actually contains four separate grid regions of varying dimensions, which were merged into one large grid (Figure 6). This area was chosen for surveying as it contains many shells visible on the ground surface.




shells

**Figure 6:** GPR amplitude map of Grid 5 showing the areas of shell and possible compacted surfaces and the higher resolution grids A and B, which are discussed below. Shell concentrations are shown in orange, with possible compacted clay surfaces in pink.

Two distinct oval patterns, which appeared to represent dwelling foundations, were discovered in Grid 5 and mapped individually as smaller Grids A and B (Figure 6). The high-resolution area within Grid 5,

called Grid A, displays a general oval outline of stones that were interpreted to be foundations of a dwelling. This high-resolution grid was produced by a re-sampling and interpreting of individual radar reflection amplitudes with a very small search radius for interpolation (Figure 7). In this way each individual stone was defined, but also tree roots, which can be seen as continuous meandering reflections. Each reflection profile was then interpreted individually, and the distinctive planar reflections interpreted as compacted ground were mapped. All were within this oval outline, which is consistent with a dwelling (Figure 7).

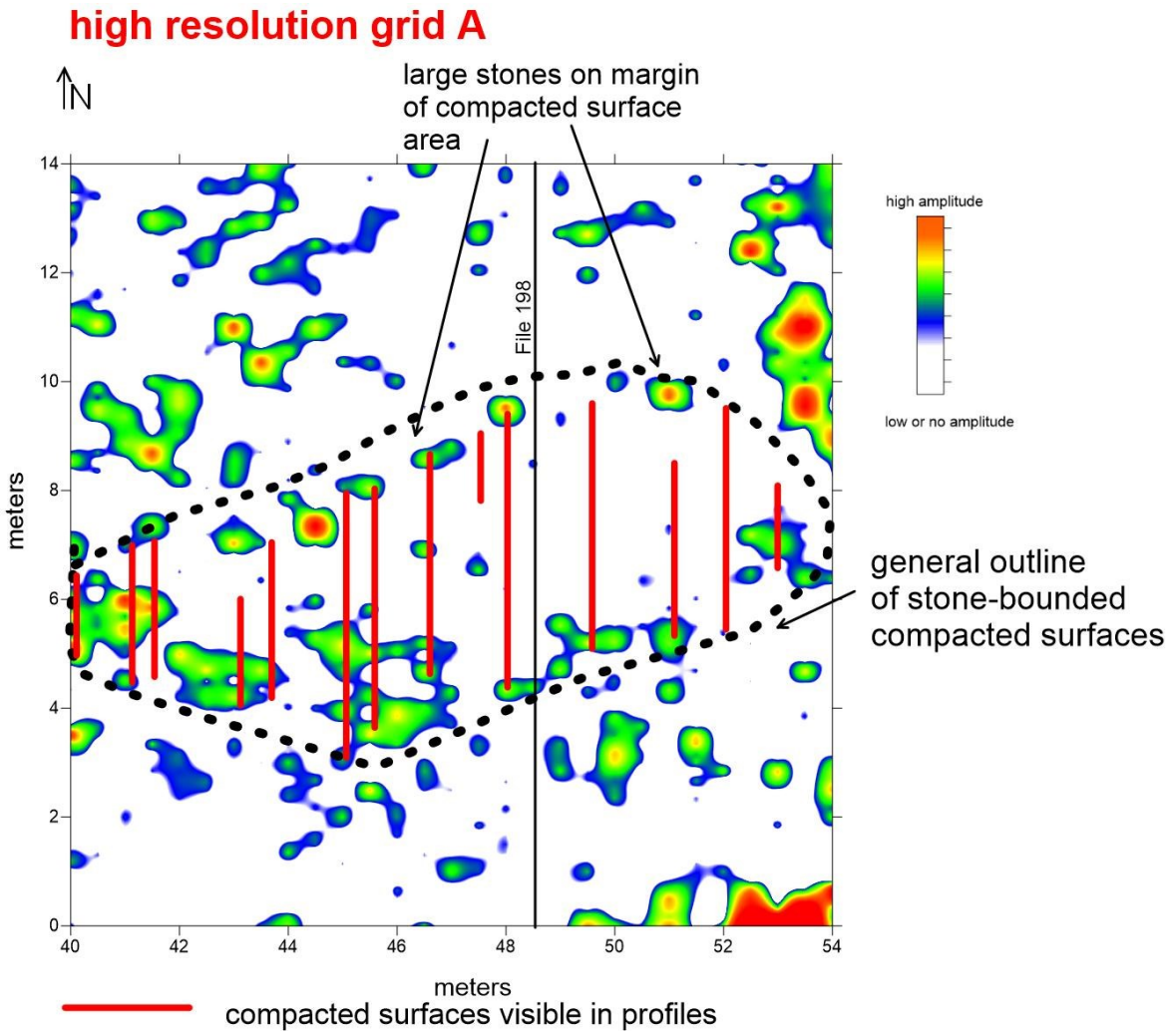



**Figure 7:** Amplitude map of high-resolution area A within Grid 5 showing the outline of stones that surround the compacted surfaces within.

These compacted surfaces of the floors and the stones that surround the house are illustrated in two-dimensions in Figure 8. There are un-annotated reflection features visible in profiles outside the stone outline, which could be compacted surfaces of some other extramural features. This is a poorly-supported working hypothesis as they were not excavated, but they could be an indication of foot traffic around this architectural feature from a great deal of human-use. Also visible are other reflections within the dwelling, which could be artifacts or objects buried under the floor.

All compacted floor reflections, visible as planar high amplitude reflections which were within the oval stone outline of the foundations, were drawn in red (Figure 7). Their prevalence within the oval is further support for the hypothesis that these are dwellings.

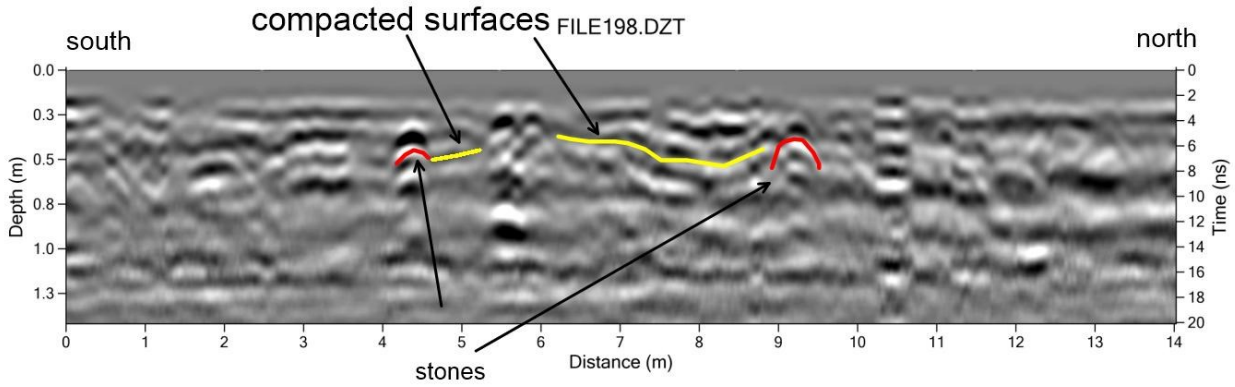



**Figure 8:** GPR reflection profile showing the compacted surfaces within the stone outline of detailed area A.

A very similar feature was defined in the high-resolution Grid B within Grid 5 (Figure 9). This oval feature is also visible by pattern recognition and shows exactly the same oval outline and size as that shown in high resolution Grid A.

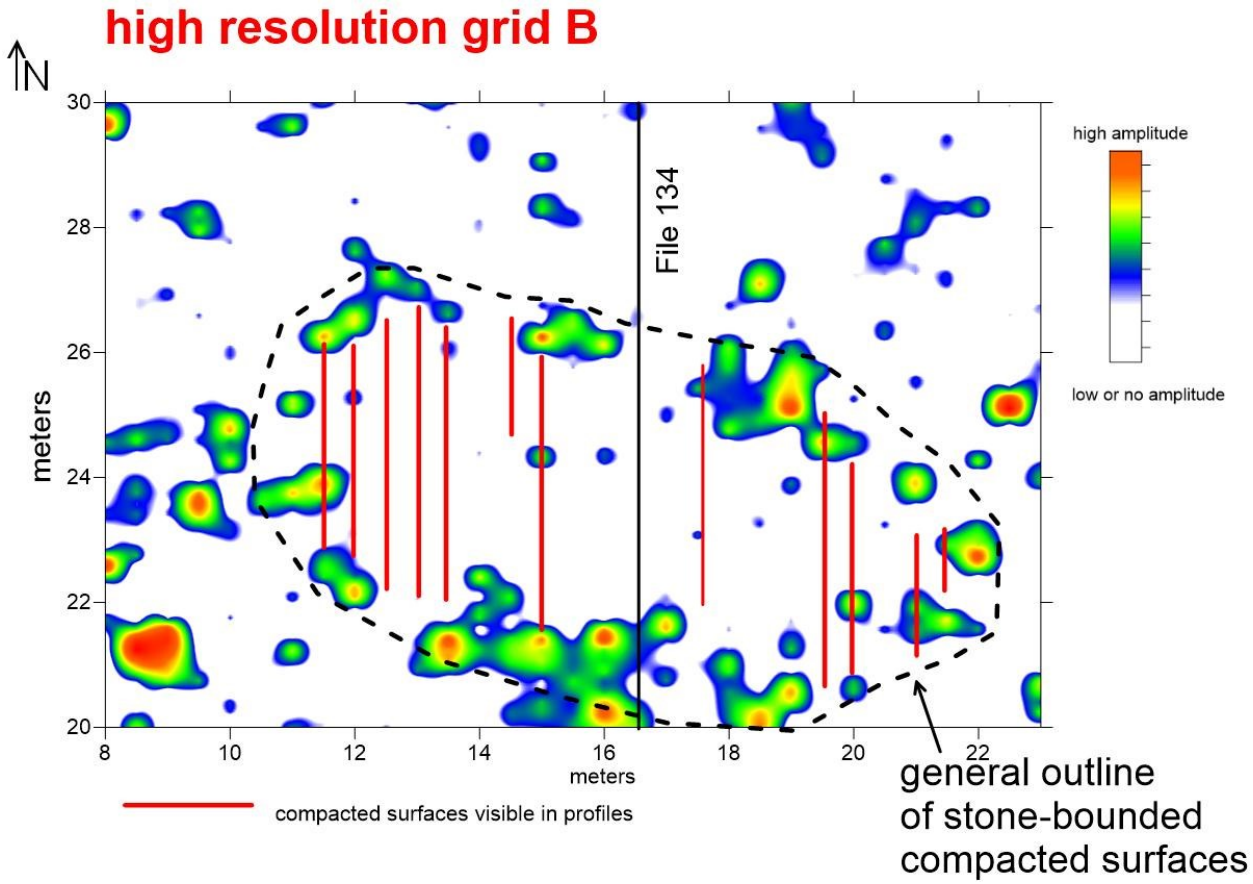



**Figure 9:** Amplitude map of high-resolution Grid B within Grid 5.

The same compacted surfaces are found within the oval stone outlines in high resolution Grid B (Figure 9). Here are found many objects, which appear as reflections or within or on top of the compacted surfaces (Figure 10). These are intriguing as they could be important artifacts. Their origin is unknown.

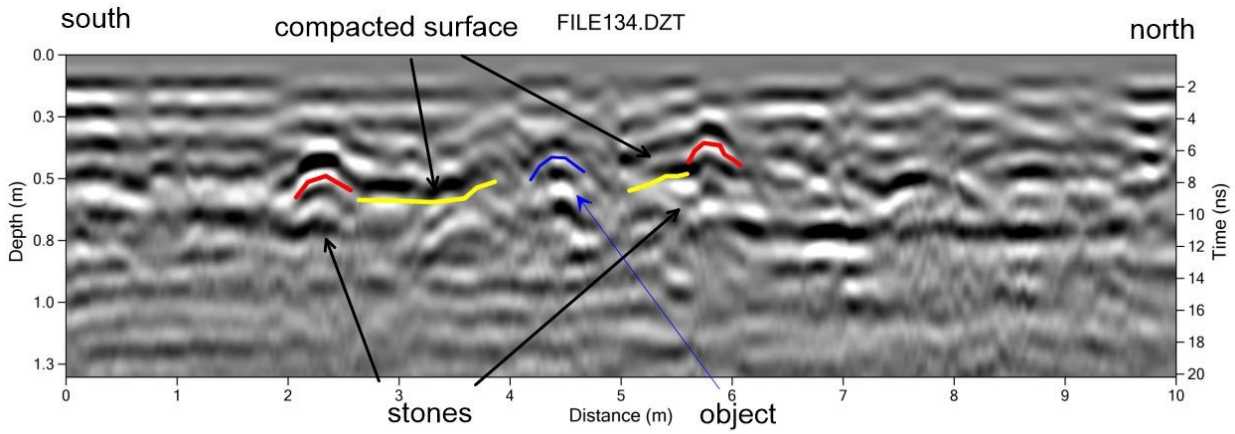



**Figure 10:** GPR reflection profile within high resolution grid B within Grid 5.

Grid 1 on the northern area of the study contained a very different geometric pattern than the ovals in Grid 5. Here the walls appear to be rectangular with distinct rooms that connect.

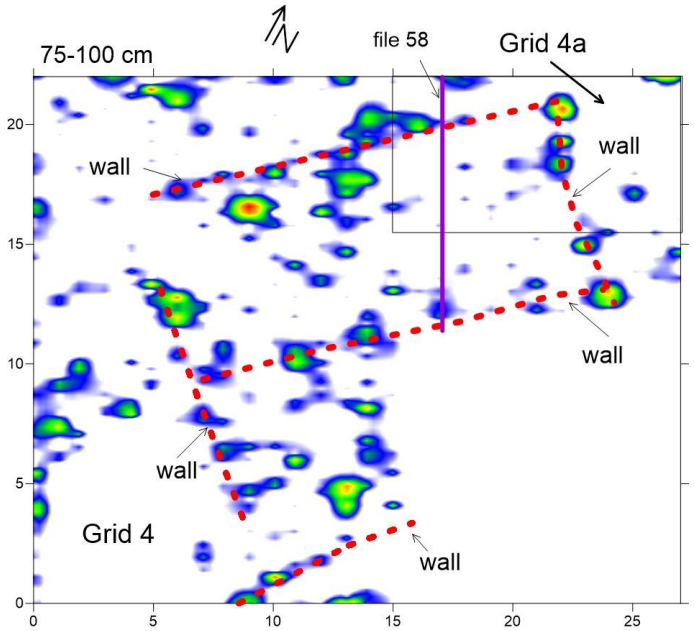



**Figure 11:** Grid 1 amplitude map that shows the highly reflective features from about 75-100 cm depth. Possible walls are annotated.

The floors are not visible in the amplitude maps, as they are much lower in amplitude than the stones that produce the high amplitude reflections. Floors are visible only in segments when viewed in reflection profiles as they have been disturbed over the centuries by root action, flood and landslide events. To determine where the floors are preserved in Grid 1, each of the reflection

profiles was analyzed in two-dimensions and the presence of planar reflections annotated on the amplitude map in the same fashion as Grid 5 (Figure 12).

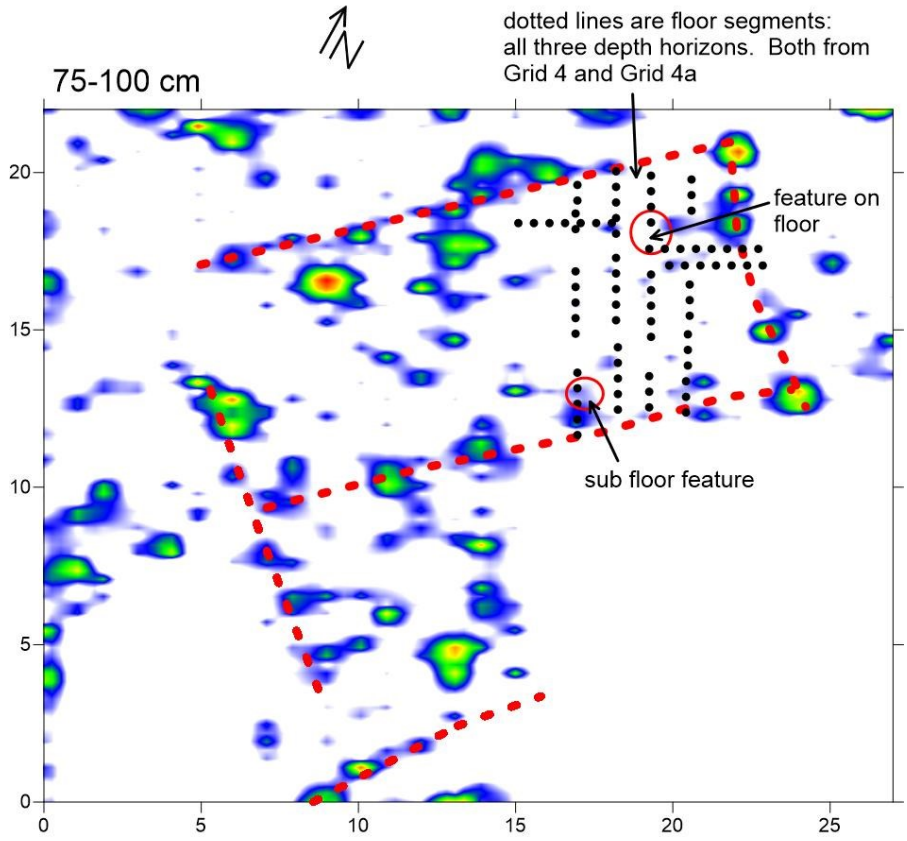



**Figure 12:** Location of all the notable features visible in Grid 4 with floors as dotted lines and other features annotated.

One feature was that appears to be a raised work surface or artifact such as a grinding stone is located on the floor, which shows up well in profile (Figure 13). It can be seen to rise about 20 cm above the floor. This house also contains a deeper floor, showing that there was structure renovation over time. The deeper floor was built directly on the sandstone bedrock layer.

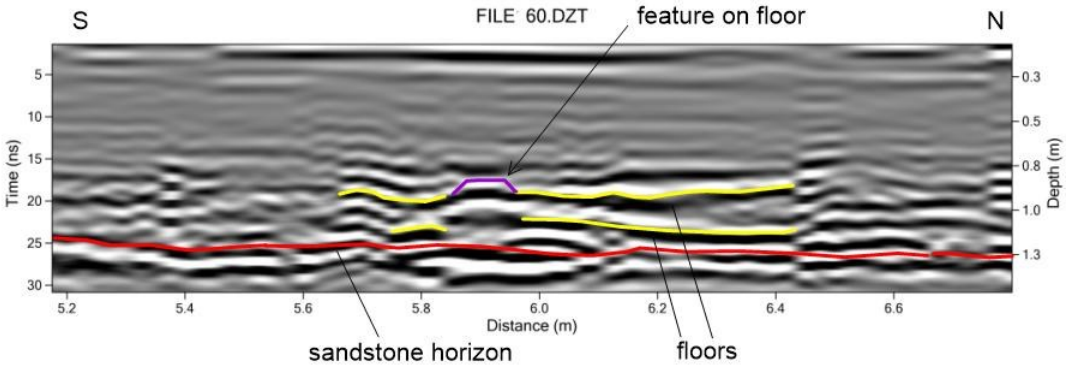



**Figure 13:** Reflection profile in Grid 1 showing a feature built on the middle occupation floor.

## Conclusions

Four dwellings were discovered at the study area, three of which were oval in shape, and one that is two rectangular rooms that shared a wall. These likely dwellings were first identified by pattern recognition in amplitude maps, where the stone foundations could be interpreted. Individual reflection profiles were then analyzed, and all high amplitude planar reflections were then identified and mapped. Those reflection features were found to mostly be within the foundation stones, lending support to them being compacted floors. Other planar reflections outside the dwelling perimeters were possible outdoor work areas.

In this complicated ground an integration of both amplitude maps and two-dimensional reflection profiles was necessary. The patterns that could be seen in the amplitude maps were a good first indication of the location of dwelling foundations, but only after the floors within them were identified could they be confirmed.

Excavations were conducted in some of these dwellings, which confirmed their origin and date. Those excavations showed that these architectural features were actually much more disturbed by tree root action and ground slumping than was originally interpreted using only GPR analysis. The resort developer has confirmed that these archaeological features will be preserved and has re-located roads, townhome footprints and the tennis court top avoid these cultural resources.

## References cited

Conyers, Lawrence B. *Ground-penetrating Radar for Archaeology*. Rowman & Littlefield, 2023.

Steinbrenner, Larry, Alexander Geurds, Geoffrey G. McCafferty, and Silvia Salgado, eds. *The Archaeology of Greater Nicoya: Two Decades of Research in Nicaragua and Costa Rica*. (2021).

## Acknowledgments

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