The Search for Ancient Helike: a GPR Case Study

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ABSTRACT

In 373 BC, the Classical city of Helike, on the Gulf of Corinth in Greece, was destroyed by a catastrophic earthquake and mass-movement of the deltaic sediments upon which it was built. Due to subsequent burial by sedimentation, and tectonic uplift of the northern Peloponnesos, the ruined site is now believed to be on land. Since 1988, the search for Helike has been conducted using sonar, bore hole drilling, geophysical survey (including magnetometry and GPR), and excavation.

In June 1996 we used GPR in seven areas near the presumed site of Helike. Data collected using GSSI's SIR-2 and monostatic 400 MHz antenna achieved a maximum penetration of 3 m using filters and a running weighted average stack. Despite limited resolution and penetration, we observed several hyperbolic targets. One of these was a tile floor dating from the Roman Era. GSSI's multi-low-frequency bistatic antenna, used in the 80 MHz configuration, achieved depths of approximately 5 to 6 meters in some areas.

INTRODUCTION

In 373 BC, the Classical city of Helike, on the southern shore of the Gulf of Corinth in Greece, was destroyed by a catastrophic earthquake and tsunami. From references in Pausanias, and other ancient writers, the site is believed to be a few kilometers southeast of Aigion, in the area of the coalesced deltas of the Selinous, Kerynites, and Vouraikos Rivers (Figure 1). This Gilbert-type fan delta constitutes the hanging wall of the Helike Fault, which is one of several subparallel faults bounding the southern margin of the Gulf of Corinth. The Helike Fault marks the sharp contact between the delta and the mountains. This is a high energy environment, subjected to violent flooding, shifting of the three rivers and their anastomosing distributaries, tectonic uplift, and the mass-movement of deltaic sediments. Stratigraphically, the delta is extremely heterogeneous, with an interfingering of terrestrial flood plain deposits, lacustrine-lagoonal silt and clay, and beach and delta front marine sediments. At least part of Helike was apparently submerged by the earthquake. However, due to subsequent sedimentation and tectonic uplift, the main site is now believed to be on land.

Since 1988, the Helike Project has been directed by Dora Katsonopoulou and Steven Soter, under the auspices of the American School of Classical Studies in Athens. They have employed sidescan and subbottom sonar, bore hole drilling, geophysical survey (including magnetometry and GPR), and excavation. Using bore hole drilling they have located ceramic bearing occupation horizons from near

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the surface down to about 12 m, dating from the Roman to Early Bronze Age periods. A magnetometry survey in this area, conducted by the Laboratory of Geophysics, University of Patras, revealed the contours of a large structure. Partial excavation of this site in 1995 brought to light a Roman building with standing walls over 2 m high.

FIELD SET-UP AND ACQUISITION

In June 1996 we used GPR in seven areas near the presumed site of Helike. These areas were selected based on the results of topographical studies carried out by the directors of the project, archeological evidence from the major Helike area, and reports of antiquities found by residents. Many of the areas were irrigated fields or orchards where farmers have added over a meter of clay-rich topsoil and fertilizers, resulting in less than optimal radar conditions.

A Geophysical Survey Systems, Inc. (GSSI) SIR System 2 radar instrument was used to collect the data. We used a monostatic 400 MHz and a bistatic multi-low frequency (MLF) antennas for the survey. We conducted calibrations on a large cut-stone block, typical of those used in the area in antiquity. We determined the average velocity through the known thickness of the block, and hence the dielectric constant (i.e. the real dielectric permittivity), which was about 5.9.

CMP calibrations were also performed at two different sites using GSSI's MLF bistatic antenna set at 80 MHz. Transmitting and receiving antennas were connected using a fiberoptic cable to eliminate ringing from the data. The dielectric constant is about 7.5 at the Koutroumanis Site, and about 8.0 at the Partes site. From this we assume that any reflections from building blocks used in antiquity will produce low- to moderate-amplitude hyperbolic reflections (i.e. "diffractions") on the radar record.

RESULTS

Many of the irrigated clay-rich fields resulted in less-than-optimal survey conditions. Based on calibrations at two different sites, we estimate that GPR penetrated approximately 1 to 2.5 meters below grade using the 400 MHz antenna, depending upon the thickness of the clay topsoil and how recently it had been irrigated. Figures 2 through 4 summarize GPR results at three of the most important sites.

At the Koutroumanis Site (Figure 2), GPR signal penetration was significantly better than other areas as the upper 1 meter of topsoil had been removed by the farmer for development of his plot. We observed numerous small, low- or moderate-amplitude hyperbolic reflectors at depths ranging from 0.7 to 3.5 meters. These may be attributed to large cobbles or possibly blocks. Many of these hyperbolic reflectors are aligned, suggesting the presence of an ancient wall. Using both the 400 MHz and MLF 80 MHz antennas, we also observed numerous large hyperbolic and dipping reflectors at depths ranging from about 2 to 5 meters. Although some of these dipping reflectors may be attributed to catastrophic flood events and are "natural horizons", other reflectors could be produced by buried man-made structures.

The second site (Romanos Field) was investigated because Roman finds were reported from the area. An 80 MHz antenna frequency was chosen for this site because of the anticipated target depth.

Because of a moderately high clay content, the maximum range at this site was about 3.5 to 4 meters. Also, the overall resolution was reduced because of clay and conduction loss effects.

Several large hyperbolic reflectors were observed at depths of 1.3 to 3.5 meters. These could be caused by blocks, walls, and other structures. Other large, but flat-lying anomalies were also observed. These may be attributed to a localized clay lens, or possibly a floor slab. Figure 3 summarizes our GPR interpretation from the Romanos Site.

At the third site (Partes), we were able to use both 400 and 80 MHz antenna frequencies, although the proximity of a high-voltage tower and power lines, and metal gates created significant sources of noise when using the unshielded 80 MHz antenna. Fortunately, the clay content was less at this site, and as a result, targets as deep as 2 meters were observed in the unfiltered 400 MHz antenna data. After performing a running-weighted averaged stack and filtering of the data, targets as deep as 2.5 meters were observed.

Figures 4 and 5 summarize our GPR interpretation at the Partes Site. Numerous small hyperbolic reflectors were observed at depths of about 0.8 to 1.5 meters. These reflectors appear clustered in a small area, and were not typically observed along the road. Because they appear below the fill, they might be attributed to building blocks and other small structures from antiquity.

Several large, high-amplitude hyperbolic reflectors were also observed. The relative size and shape of these buried targets may be inferred by their continuity along several GPR traverses. One such large anomaly, located along Line 0+60E, from about 0+10S to 0+12S is shown on Figure 6. This anomaly was later determined to be a tile floor of Roman Age. Consequently, other large GPR reflectors observed in the area may be associated with the same Roman horizon.

CONCLUSION

Numerous anomalies were detected using GPR at the three sites presented here. We expect to observe more areas of interest as data from the other sites are interpreted. Currently, we are in the process of trying to image GPR anomalies, such as the one created by the tile floor, in three dimensions to obtain a more complete picture of the structure before excavation begins.

ACKNOWLEDGMENTS

We wish to thank Joan Friedman, Maria Argyropoulou, and Maria Stefanopoulou for their assistance with the data collection. We also wish to thank Jie Zhang of the Massachusetts Institute of Technology, Earth Resources Lab, for his GPR data processing advice.

We also wish to thank Geophysical Survey System, Inc. for the use of their multi-low frequency antenna.

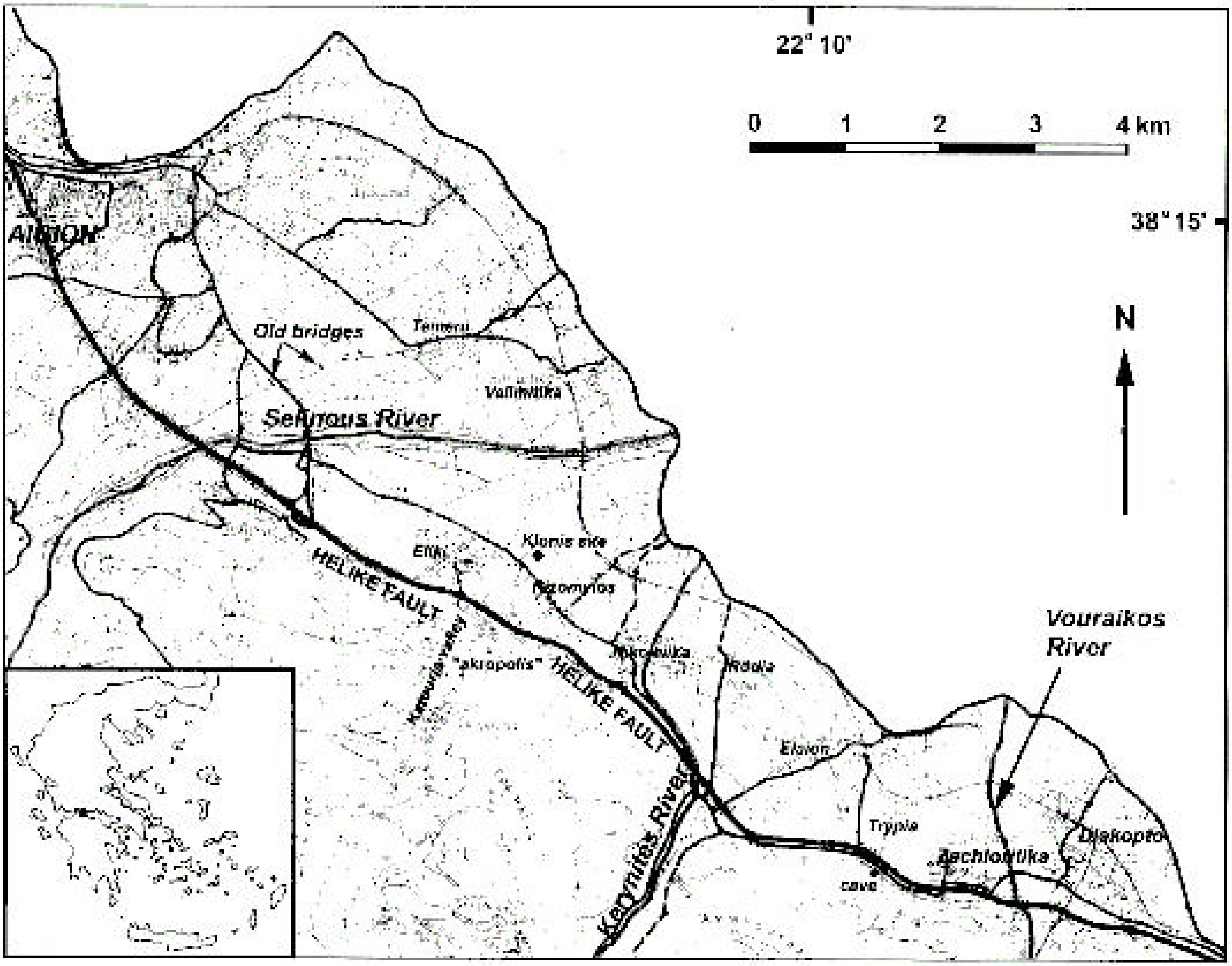

FIGURE 1: General Area of Investigation.

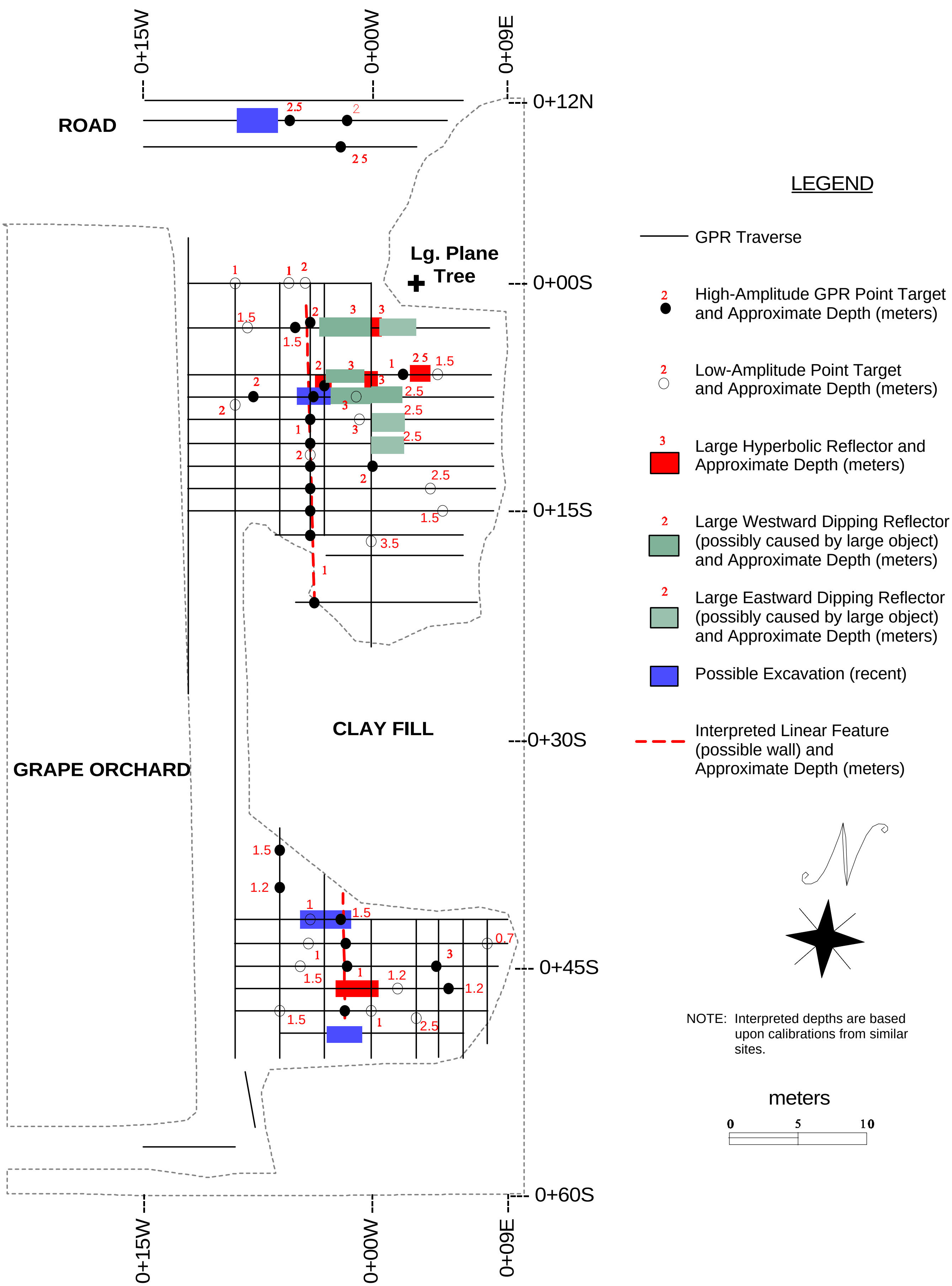

FIGURE 2: Summary of interpreted GPR data from Koutroumanis Site.
Data were acquired using 400 and 80 MHz antennas.

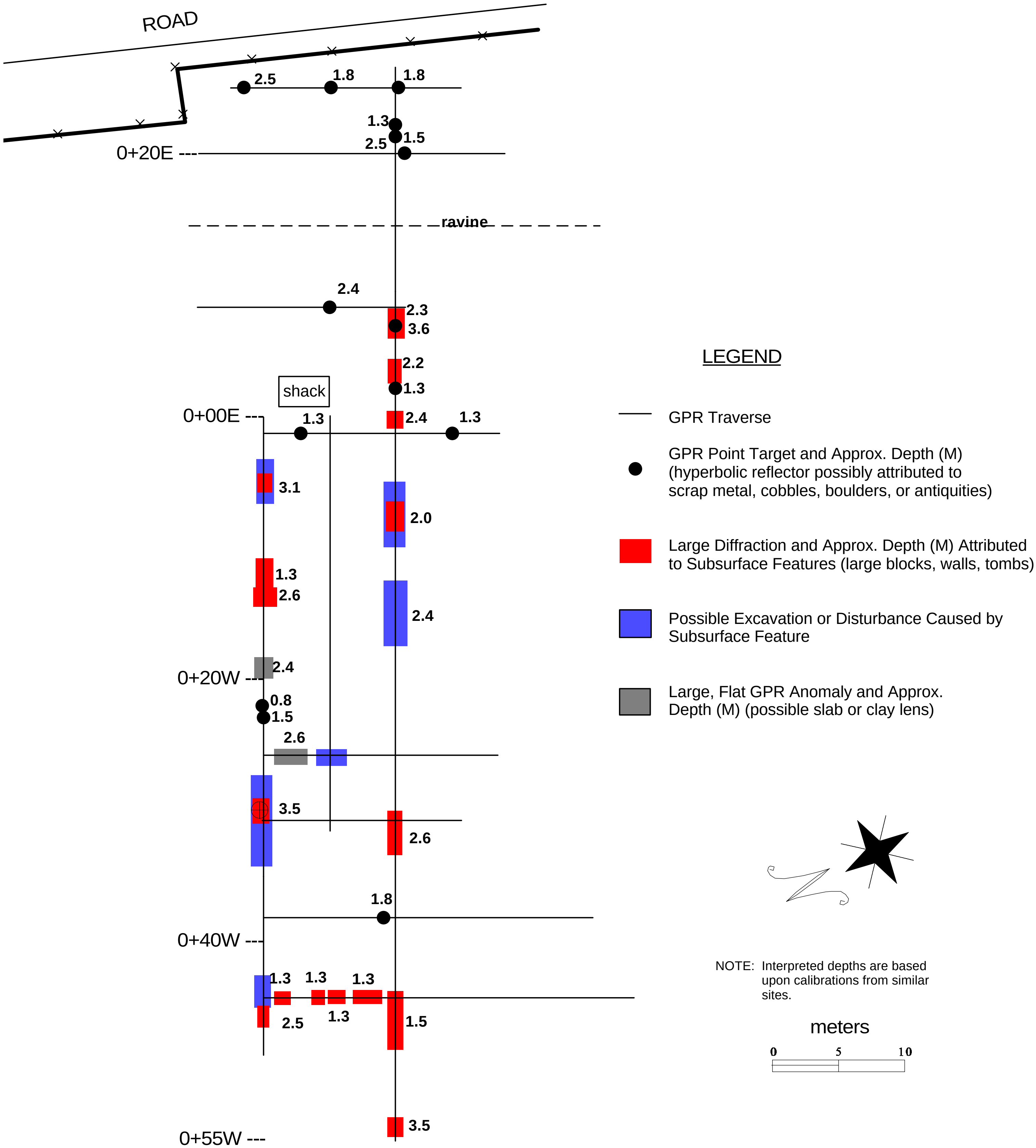

Figure 3: Interpreted GPR results from the Romanos Field. Data were acquired using the 80 MHz antenna.

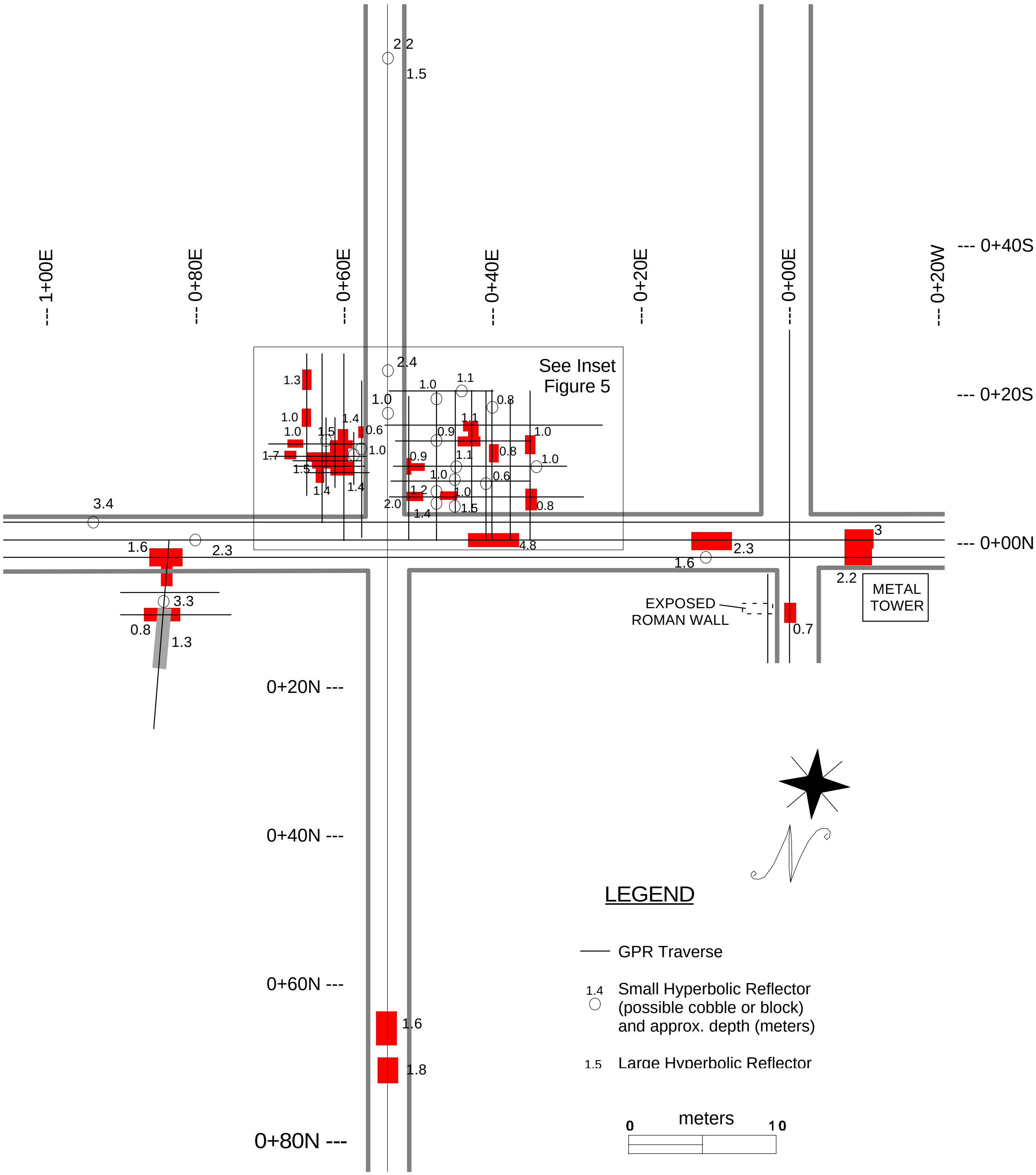

FIGURE 4: Interpreted GPR results from the Partes Site.

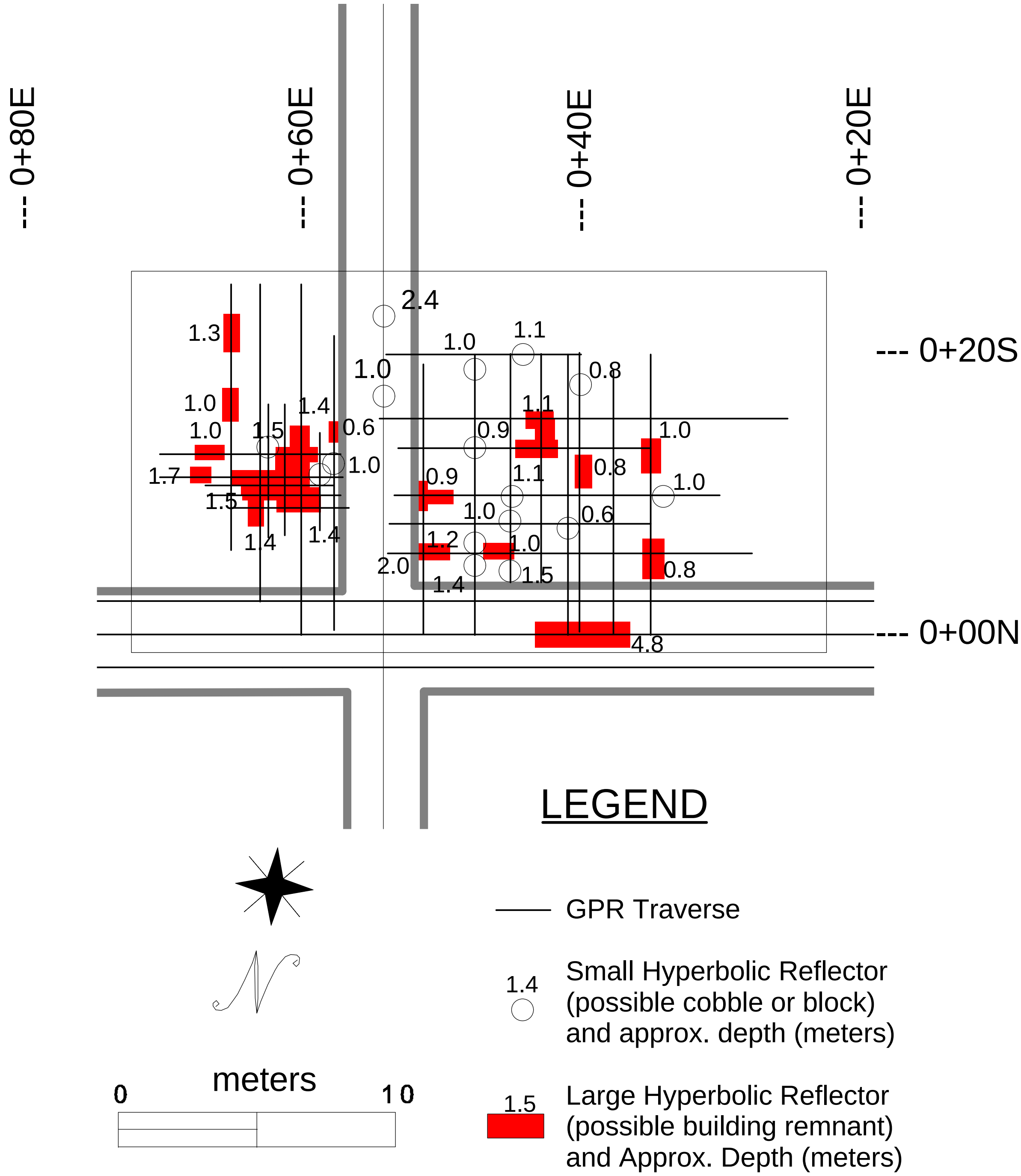

FIGURE 5: Enlarged inset area from Figure 4, Partes Site.

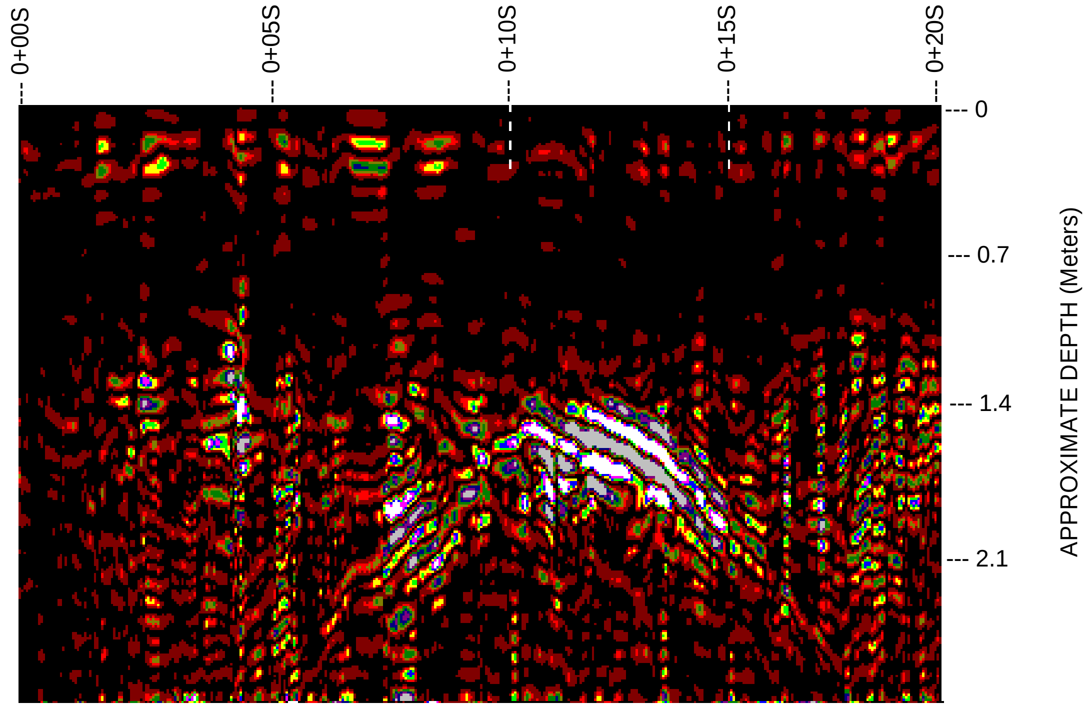

Figure 6: A GPR Record from the Partes Site showing a large hyperbolic reflector, subsequently found to be a tile floor of Roman Age. Data were collected using GSSI's 400 MHz Antenna.