Finding bedrock in uncontrolled clayey fill – success with GPR profiling

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SUMMARY

GPR in clay rich environments is often assumed to yield poor results due to signal attenuation, however it can still be possible to penetrate deep enough to reflect off targets of interest. Finding the bedrock level in an old quarry filled with clay and building rubble was successful using GPR reflection image profiling primarily due to the fact the fill material had previously been dewatered. Distinctive layers were observed in the fill material which when drilled corresponded to specific dominant material types. It appears the compaction level of the clay and the moisture content of the fill were important factors in the success of the GPR profile.

Key words: GPR imaging, clay, bedrock depth, fill

INTRODUCTION

Ground Penetrating Radar (GPR) is a popular non-destructive technique for imaging and interpreting structures in environmental and geotechnical applications, ranging from detecting re-enforcement in concrete to finding buried pipes (e.g. Reynolds, 1997). The use of GPR in sediments is expanding rapidly as it provides high resolution images of the shallow subsurface that cannot be derived by any other non-destructive technique (Jol and Bristow, 2003). GPR has evolved from just characterising environments from reflective patterns to a more qualitative assessment of geometry and architecture, especially when correlated with other often destructive techniques (e.g. boreholes). However it is often assumed that in grounds with an abundance of clays, GPR produces poor results due to the attenuation of the signal produced by clays generally high electrical conductivity. But there are instances where GPR has had success in clay rich environments where radar energy has penetrated deep enough to be reflected from targets of interest and still be received back at the ground surface (e.g. Conyers, 2004). In many cases the type of clay and the moisture content is likely to be an important factor in the success of GPR.

In NSW, large parts of western and north-western Sydney are characterised by several meters of clay overlying the shale bedrock. In some areas quarrying of the shale has occurred for making bricks and supplying road base materials. These quarries are often infilled in a geotechnically controlled manner to be built on (e.g. Norbrik Quarry, Bella Vista NSW). The site of this study is an old quarry that has been infilled in a non-controlled manner and as such the type of material and depth of fill is unknown. The area of investigation was recently covered with a HDPE plastic liner and 3m of compacted clay.

The old quarry was infilled with materials between 1990 and mid 2004 but it is unclear how deep is the fill material in the quarry and what kind of material was in the fill. During a partial excavation it was found to contain clay, crushed shale and sandstone, crushed rocks and bricks, building material, concrete with re-enforcing bars and other waste materials / objects (e.g. cars). The excavated portion found the depth to the base was generally 6m below the surface but a deep portion, 12m below the surface, was discovered near the edge of the excavation. A GPR survey was undertaken of the non-excavated portion as it was unclear the extent of this deep portion and the overall depth of the fill material.

The aim of the GPR survey was firstly to assess the depth of the fill material and basement profile, then assess if there was any perched water within the fill material. The fill material was assumed to be fully saturated prior to dewatering which was carried out before the partial excavation. GPR reflection profiling was able to suitably resolve the basal bedrock reflector of the quarry as well as identify several distinctive layer reflectors within the fill material which were further investigated via drilling.

METHOD AND RESULTS

The GPR survey was undertaken using a MALA in continuous profiling mode (reflection mode) with at 25MHz unshielded streamer antenna with a 6m spacing. The antenna was pulled along the ground profile and survey followed to record the ground surface elevation. The ground surface profile was highly compacted clayey material with some sections uneven due to compaction with a sheeps foot roller (i.e. steel drum with teeth). The uneven ground caused the antenna to jump and or stick which introduced some noise to the data. Several passes of the profile were undertaken to tune the collection parameters for the best image. The targeting depth and sampling frequency were adjusted each pass of the profile until an acceptable image of the bedrock was achieved. The final parameters were a targeting depth 17.38m and a sampling frequency of 2308.61 hz. Two profiles were collected (Figure 1) and the processed radargrams are shown in Figure 2 with the interpreted radargram for Profile 1 shown in Figure 3.

The profiles were processed in REFLEXW where there was the application of uniform spatial increments, time zero adjustment, disguarding of late arrival times and data enhancing and filtering. The bedrock reflector is inferred to represent either the top of the weathered rock or the top of rock and ranges in depth from 2m to 14m below the surface. GPR is sensitive to water / moisture content (e.g. Conyers, 2004), which can make it a useful technique for assessing and mapping perched water tables. In each profile there is high amplitude signal from 0m to 2m depth which is likely associated with wet material from dust suppression. This is particularly apparent in Profile 2 which runs along the compacted road which is regularly watered to minimise dust generation. Neither profile shows any distinctive saturation of material below this depth. This is due to dewatering of the material associated with the partial excavation works. Without the dewatering activities the GPR may have attenuated at the top of the water table.

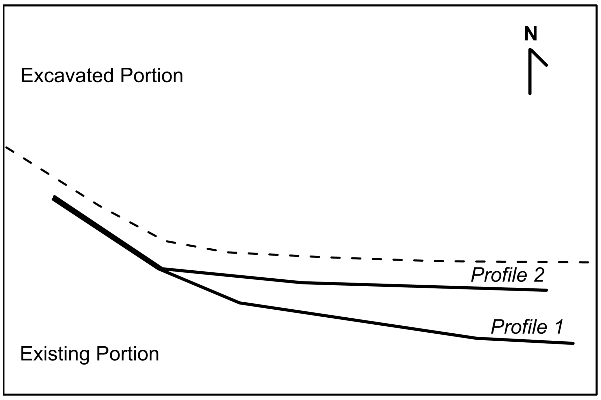

Figure 1: Location of GPR profiles within quarry site with boundary (dashed line) between excavated and existing portions

The profiles show five distinctive layers / intervals within the interpreted fill material which appear continuous across the site. In order to characterise these layers a borehole was drilled for Profile 1, offset approximately 5m south of the GPR line. The location of the borehole was determined relative to site access constraints and was unable to be directly on the GPR profile. The borehole was drilled to 12m using the sonic drilling technique, preserving the sample and making it possible to drill safely through unknown subsurface conditions. The results of the borehole log are annotated on Figure 3. Drilling observed low levels of compaction of the fill material producing numerous void spaces. These void spaces would have been full of water had the fill material not been dewatered.

There was a good correlation between the depth to rock inferred by the GPR profile and the depth encountered by drilling. Bedrock was encountered at 10.5m below ground, however the ground surface had increased since the GPR profile by 1.2m, making the depth below ground on the profile approximately 9.3m. The GPR profile indicated bedrock at around 8.5m. The discrepancy most likely due to the borehole being offset from the line. The different layers within the fill material appear to correspond to distinctive material dominance with the fill. What was originally interpreted to be reworked shale was found to crushed basalt and concrete, forming quite an undulating contact surface over some residual clay with minor gravel which is likely to represent reworked weathered bedrock. There is great similarity in GPR signal between Profile 1 and Profile 2 for the layers within the fill material. It is therefore highly likely that composition of those layers laterally extensive across the site and would be representative of the material should it be excavated.

CONCLUSIONS

The GPR streamer was able to successfully delineate the base of the quarry through the compacted clay surface and clayey fill material. The success of the GPR imaging may be in part to the fact the fill material was not fully saturated. There was good correlation of the bore depth to bedrock with the interpreted depth to bedrock and the borehole provided insight into the composition of the distinctive layers in the fill material. The two profiles show relatively uniform signal and interpreted layers and it is likely that the material is consistent laterally between the profiles. The drilling showed the fill material was not as compacted as predicted and this may also have aided in the success of the GPR.

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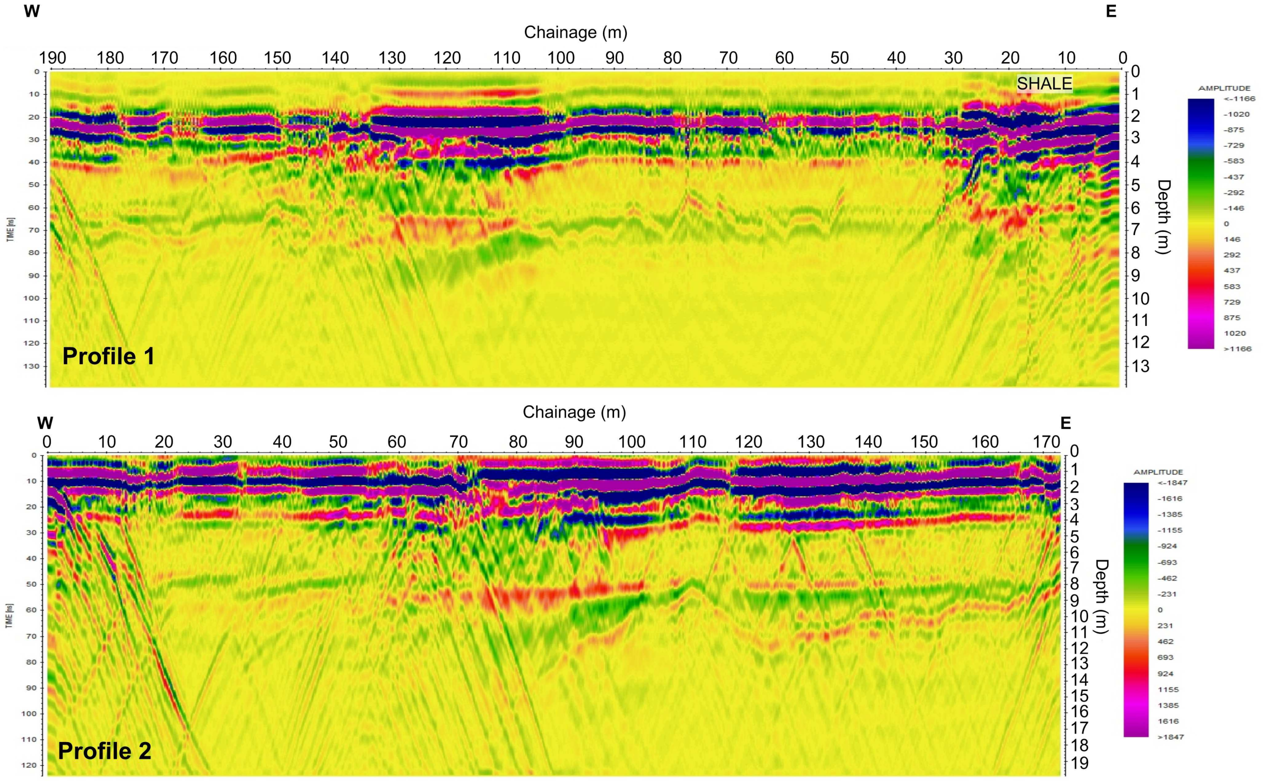

Figure 2: GPR Profile 1 and GPR Profile 2, un-interpreted. Refer to Figure 1 for location.

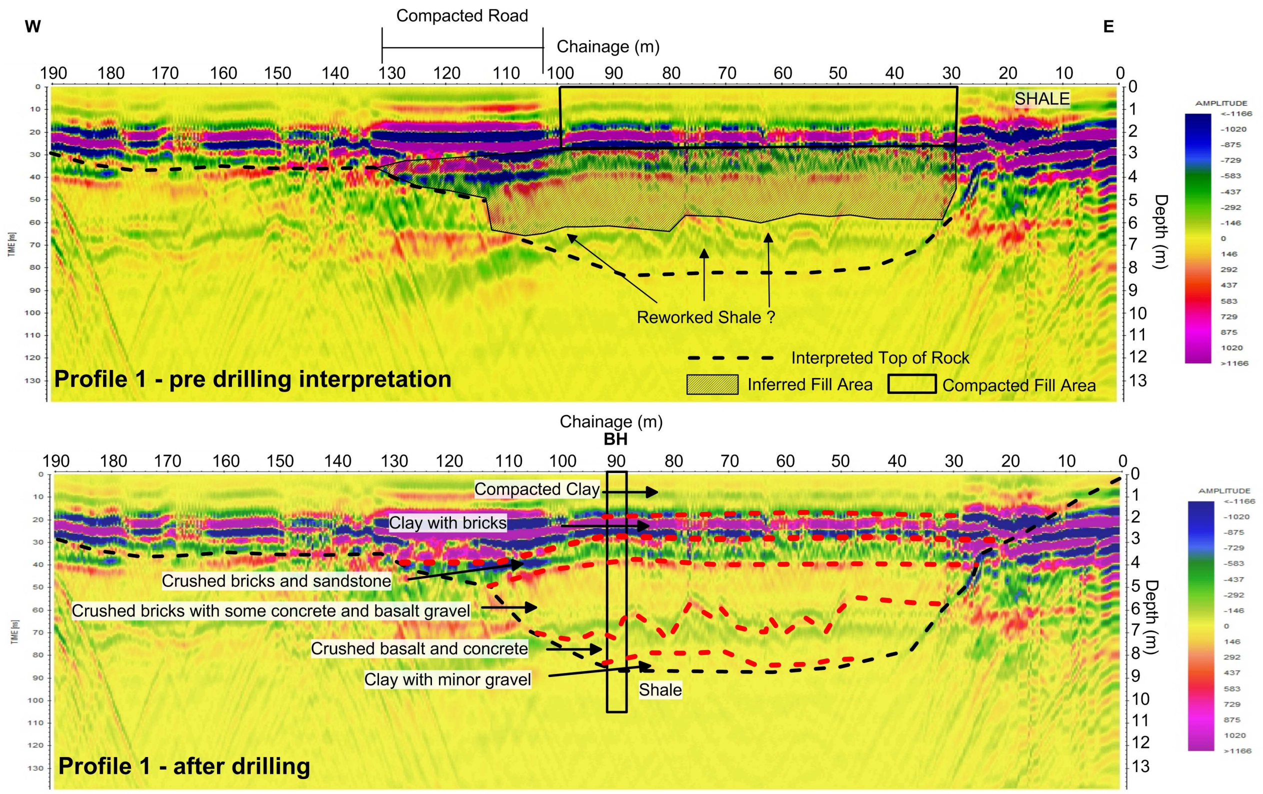

Figure 3: Interpreted GPR Profile 1 pre drilling and after drilling.