INTERKONSULT

REPORT

Presented by

INTERKONSULT Limited

to

THE HERITAGE TRUST LINCOLNSHIRE LTD

For

A Ground Radar Survey of the West Face of Welton-le-Wold Gravel Quarry, Lincolnshire

July 2003

Registered Member

GROUND PROBING RADAR SURVEY
GRAVEL QUARRY AT WELTON-LE-WOLD

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GROUND PROBING RADAR SURVEY
GRAVEL QUARRY AT WELTON-LE-WOLD

1. INTRODUCTION

This report is presented by INTERKONSULT LTD (IKL) to the Heritage Trust of Lincolnshire Ltd (HTLL) for a Ground Probing Radar (GPR) survey carried out near the North West face of the old gravel quarry at Welton-le-Wold, Lincolnshire.

The objective of this survey is to explore a pre-delimited section of the quarry floor where it is believed a previously documented bench of archaeological interest remains intact under a layer of clay in-fill material.

The survey was carried out on 27 June 2003 under dry conditions.

2. BACKGROUND

The village of Welton-le-Wold is located approximately 6 km west of Louth in the district of East Lindsey, Lincolnshire. The area is rural and the landscape is rolling chalk downland – designated an Area of Outstanding Natural Beauty (AONB) in 1973.

In the late 19th century, sand and gravel extraction was started in a former river valley on the northeastern limit of the village. Extraction intensified during the 1st and 2nd World Wars to provide materials to build runways. The quarry ceased to operate in the mid 1970s, after nearly a century of excavations, leaving an area of extraction of approximately 50Ha, much of which has been partially back-filled and reinstated to pasture or planted with trees. Prior to restoration, the exposed quarry benches were logged and several archaeological artifacts recovered which proved to be of historical importance. As a result, the quarry is a designated geological Site of Special Scientific Interest (SSSI) and a Regional Important Geological Site (RIGS) due to its important sequence of ice age deposits.

The aim of this GPR survey is to locate the original 1970's gravel section, or the existing buried gravel face in the western quarry exposure and forms part of the scope of work of the Project entitled "Towards An Understanding Of The Ice Age At Welton-Le-Wold Lincolnshire" under an ALSF funding application to English Nature and English Heritage.

The original publication of the western quarry face at Welton-le-Wold included an 8 figure National Grid Reference. It is not known how much more gravel was excavated after the section was recorded. It is likely to be minimal, however as the quarrying operations ceased soon afterwards. By locating the original section on the ground, the most likely area for investigation will be targeted from the outset. A rectangular 60m x 40m grid has been set out by HTLL over the last known bench position and forms the target for the GPR mapping which is the subject of this report.

A preliminary machine hole excavated in 2001 located the gravels beneath an overburden of 4m of clay. After location of the gravel bench a series of five boreholes will be sunk 3-5 metres behind the gravel bench face at 10 metre intervals parallel to the known section recorded. A view of the study area is presented in Figure 1.

Figure 1 – GPR Mapping area

GPR is relatively simple system in which electromagnetic (EM) waves are transmitted from an antenna into the medium under investigation, through which they radiate until they reach an electromagnetic contrast (e.g. soil – bedrock) where some waves are reflected back to surface to be detected by a second antenna. Here, radar is the electromagnetic analogue of seismic reflection. By moving the antennae across the ground, an "image" of the subsurface is developed.

The effectiveness of radar to “see” into the ground is determined by many factors which are mainly dictated by the depth and physical characteristics of the material to be investigated and the associated rate of attenuation.

Lowering frequency improves depth of exploration because attenuation primarily increases with frequency. As frequency decreases, however, two other fundamental aspects of the GPR measurement come into play.

First, reducing frequency results in a loss of resolution. Second, if frequency is too low, electromagnetic fields no longer travel as waves but diffuse which is the realm of inductive EM or eddy current measurements.

Attenuation is primarily determined by the ability of the material to conduct electrical currents. In simple uniform materials this is usually the dominant factor; thus a measurement of electrical conductivity (or permitivity) determines attenuation.

In most materials energy is also lost to scattering from material variability and to water being present. Water has two effects; first, water contains ions which contribute to bulk conductivity. Second, the water molecule absorbs electromagnetic energy at high frequencies. The effects of water can be significant when attempting to define the interface between different materials with similar dielectric properties.

3. METHODOLOGY

For the purpose of this survey, a standard RAMAC control unit manufactured by Mala Geoscience of Sweden and associated electronics of the type shown in Figure 2 was used, coupled to a shielded 250 MHz antenna which is pulled by an operator on known geographic lines. This configuration was considered to be a good compromise in terms of sufficient penetration to define the top of the quarry bench and resolution to identify different material compositions.

Figure 2 – GPR Equipment

Seven parallel profiles were taken in a Southeast to Northwest orientation along the grid set out by HTLL as shown on Plan WLW001. The profiles were taken in the same direction in each case at a spacing of 10m. In addition, three additional profiles were taken at the Client's request to correlate with other survey work. The extent of the profiles was limited towards the North by the steep inclination of the surface and a ditch.

The profiles are processed and filtered for erroneous noise and key anomalies identified. For the purposes of this study, processing was limited to the addition of a Time-Gain filter to samples from below the 3m horizon. Use was also made of an intelligent pattern recognition system developed by IKL. The system is developed in the MATLAB software environment and uses both artificial intelligence in the form of a neural network and a Java applet to match digital and graphical data in the profiles to characteristics of known anomalies. In this way subtle differences between two images that appear identical can be highlighted. To assist in this part of the processing a "calibration" profile was run at the outset of the study over an area where the gravel bed had already been located by drilling. The characteristics of this image were to be used to identify gravel areas in other images. A composite view of the survey area has been generated using three-dimensional modelling software that combines the final images into a block as shown in Figure 3. Horizontal time-slices through the block provide maps at different depths which can be overlain onto the topography. The final images are presented in Appendix A and referred to in the analysis below.

Figure 3 – Block Model Composite of Profiles

4. SURVEY RESULTS

In general terms, good rates of GPR penetration have been achieved over the site, indicating that the prevalent host material is of a course matrix associated with sandy conditions or course clay. The dielectric properties of such an overlying material would be very similar to that of underlying gravel beds and, as a result, distinguishing between the two materials is difficult.

Although good rates of penetration have been achieved, no marked horizons that can immediately be attributed to the bench geometry were detected as would be possible, for example, in the case of a clay/limestone interface.

However, a number of characteristics were observed in the majority of the profiles that indirectly point to a major transition in material properties. These properties are probably more related to the permeability and porosity of the material (and therefore water content) than conductivity. The tendency for water to drain through the gravel beds more efficiently than the overlying clay fill will make the transition from one material to another apparent on the GPR images. A comparison of a test profile taken a week before the main survey (following a period of rainfall) and the same profile within the survey showed that water plays an important part in this analysis.

On profiles 2, 4, 5 and R a clear transition can be seen from a material with low permitivity to a material of higher permitivity. This generally coincides with the position of the bench section marked on the topographic plan (Figure 4). The effects shown by the GPR profiles are probably the influence of the bench on the overlying material in contrast with the undisturbed material where no extraction has taken place. In the area of the transition, (about 1.5m length) the ground appears to be more disturbed which could be representative of the interface/joint of one type of material with another. On the remaining profiles the transition effect is not so noticeable as the traces are generally weaker. This is confirmed by comparison of the intensity plots from an image where the transition is clearly visible and where the gravel bed is known to exist (Profile 1) and a profile where the effect is not visible (Profile 3). However comparison of the image patterns generates the same pattern histogram (See Figure 5) confirming that the underlying ground characteristics are present although they may be masked by local saturation.

The three-dimensional composite of the profiles also confirms a more permitive area to the Northwest of the survey grid. A horizontal section through the block at 2.5m depth is overlain on the topographic Plan WLW001 and Figure 4. The dark anomaly which coincides with the marked bench line extends towards the north-western part of the grid where the gravel beds are already known to be intact. When the GPR overlay image is compared to an aerial photograph both in its natural and filtered formats (Figure 6), the same "shadow" depicted on the GPR image is visible on the photograph and probably coincides with either differential vegetation growth or a slight difference in surface levels. Such an effect would be consistent with different ground materials or states of compaction associated with a back-filled quarry bench.

5. CONCLUSIONS

Good rates of penetration up to 8m were achieved during the GPR survey indicating that the host material is generally of a course matrix with good permitive characteristics.

No definitive structural boundaries were encountered; if these are present then they are masked by similar dielectric properties. This is possible if the gravel beds and fill are of similar material and were intermixed at closure.

However, a marked change in permitivity was detected in most of the profiles occurring beyond a depth of approximately 2.5m. When plotted on the topographic grid, an area of ground with different characteristics is evident and coincides with the edge of the 1970s bench position although it is not intact for the entire length. This feature also seems to be evident on enhanced aerial images of the area.

As a result, IKL believes that there is sufficient evidence to suggest that the 1970s bench may be intact and represent the final position of the quarry.

It is recommended that the feature highlighted by the GPR be investigated during the subsequent drilling programme to confirm that this does represent the limit of the gravel beds.

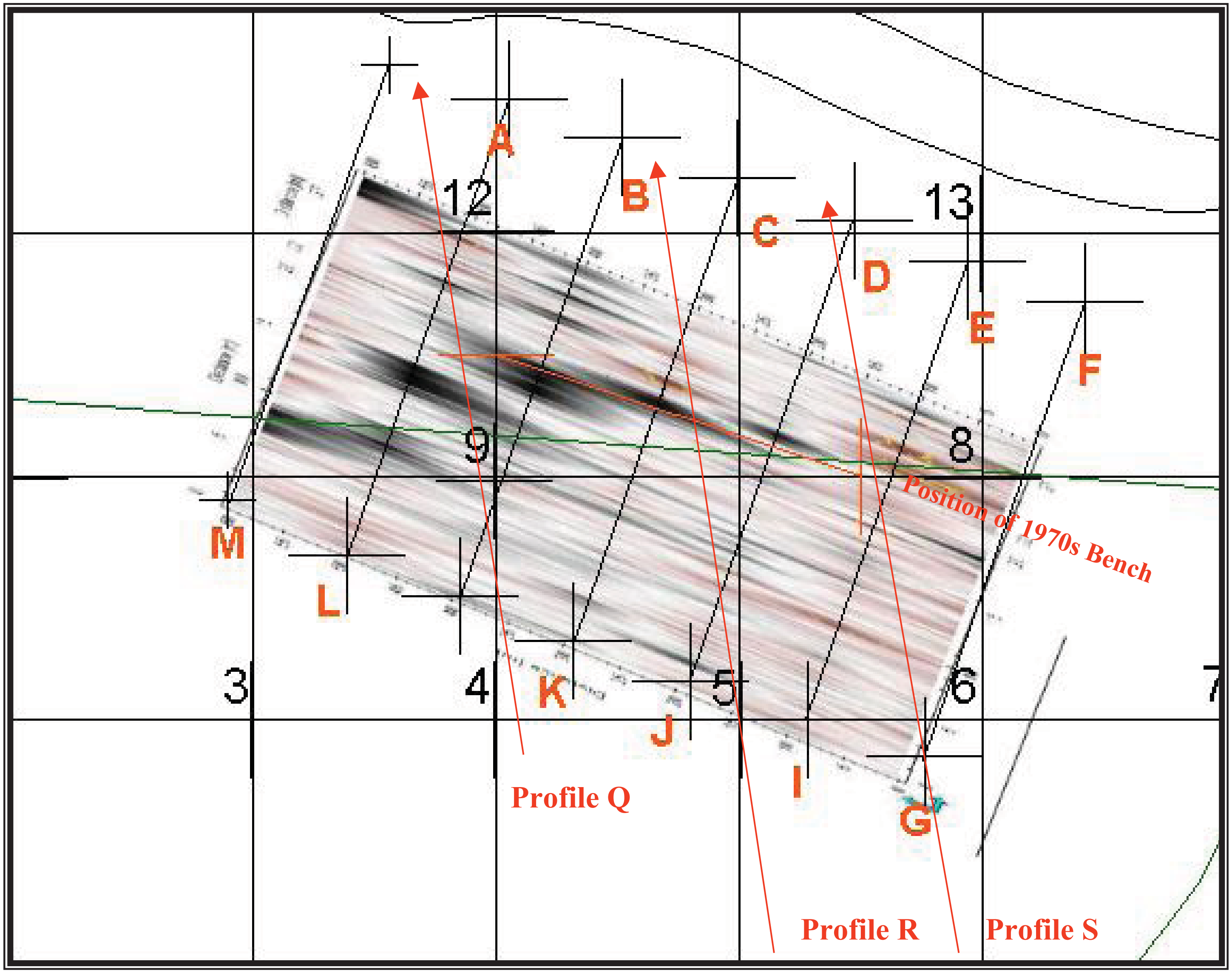
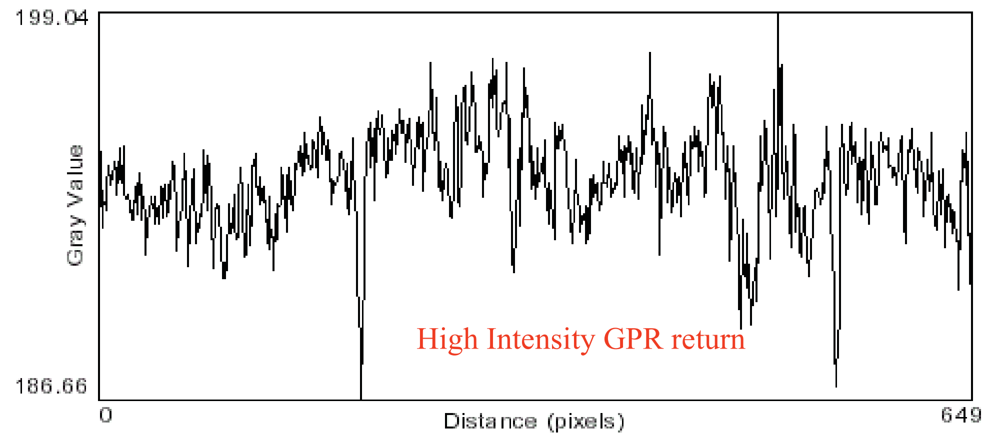
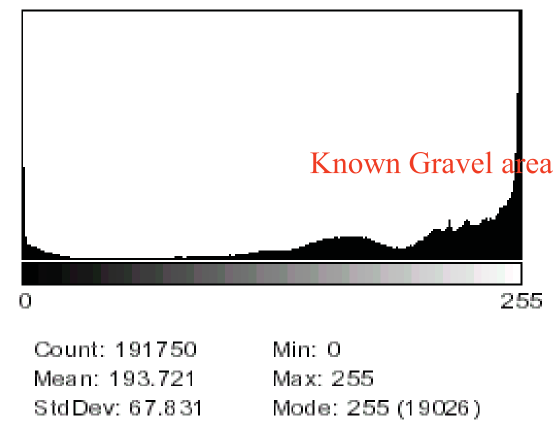
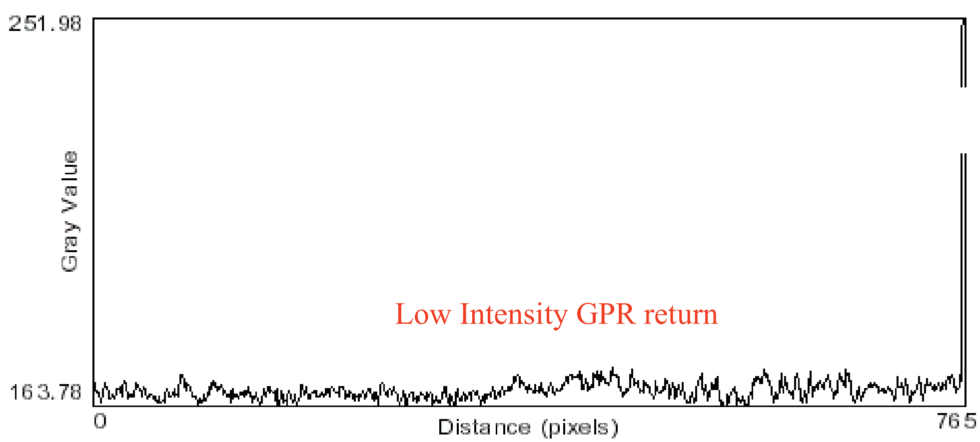


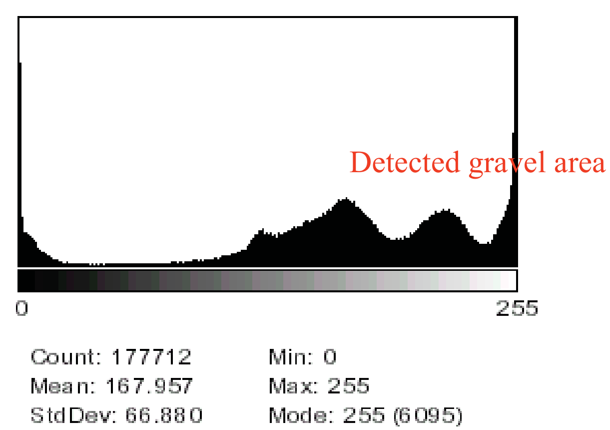
Figure 4 - Profile Overlay





Profile 1





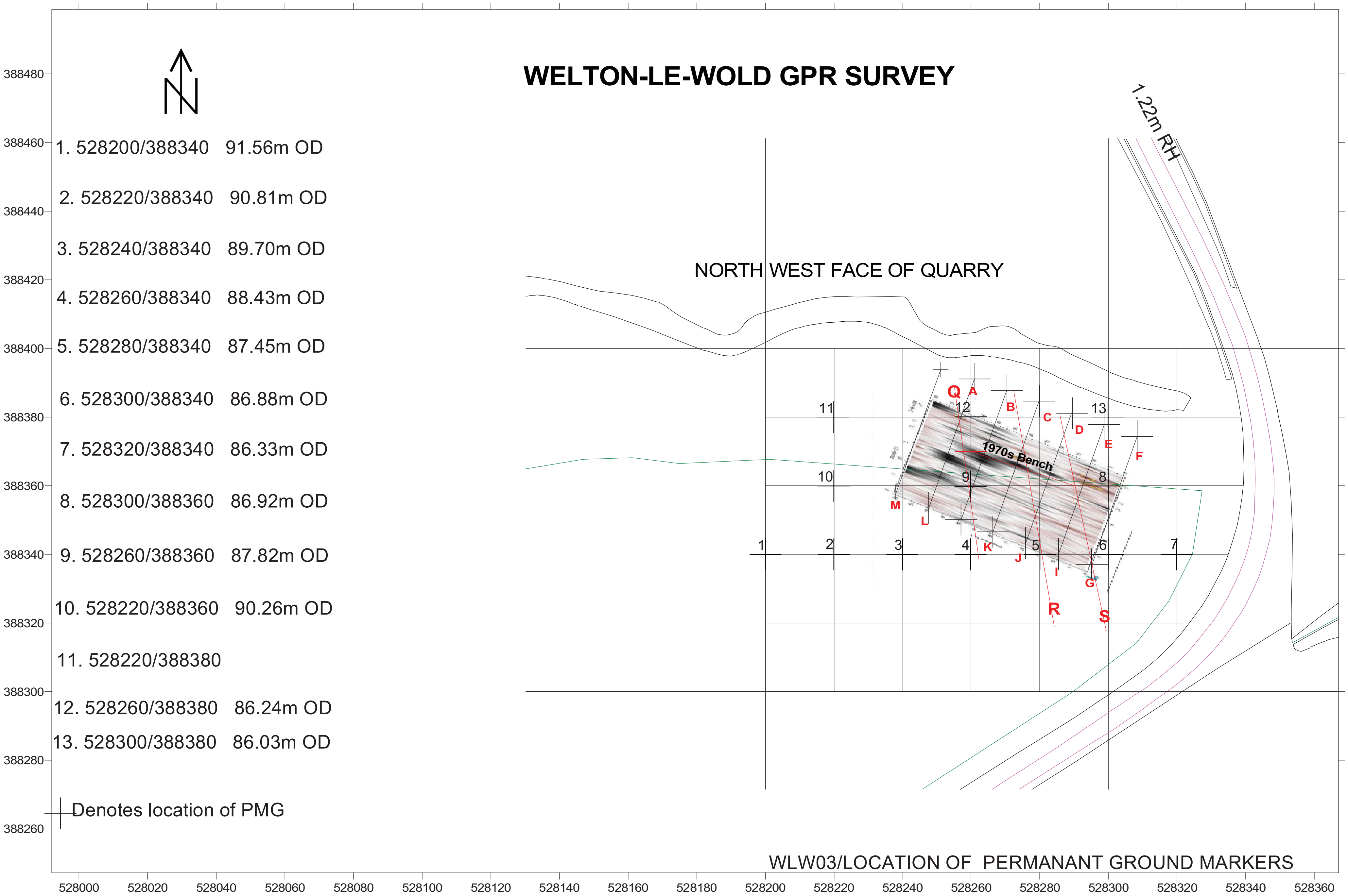
Profile 3

Figure 5 - Comparison of surface trace (left) and image histograms (right)

Unprocessed
aerial photograph

Aerial photograph
enhanced with emboss
filter

Figure 6 - Aerial photograph showing possible limit of bench



PLAN No. WLW001
Location of GPR Survey Lines &
Overlay of time-slice at 2.5m depth
Scale 1:10,000

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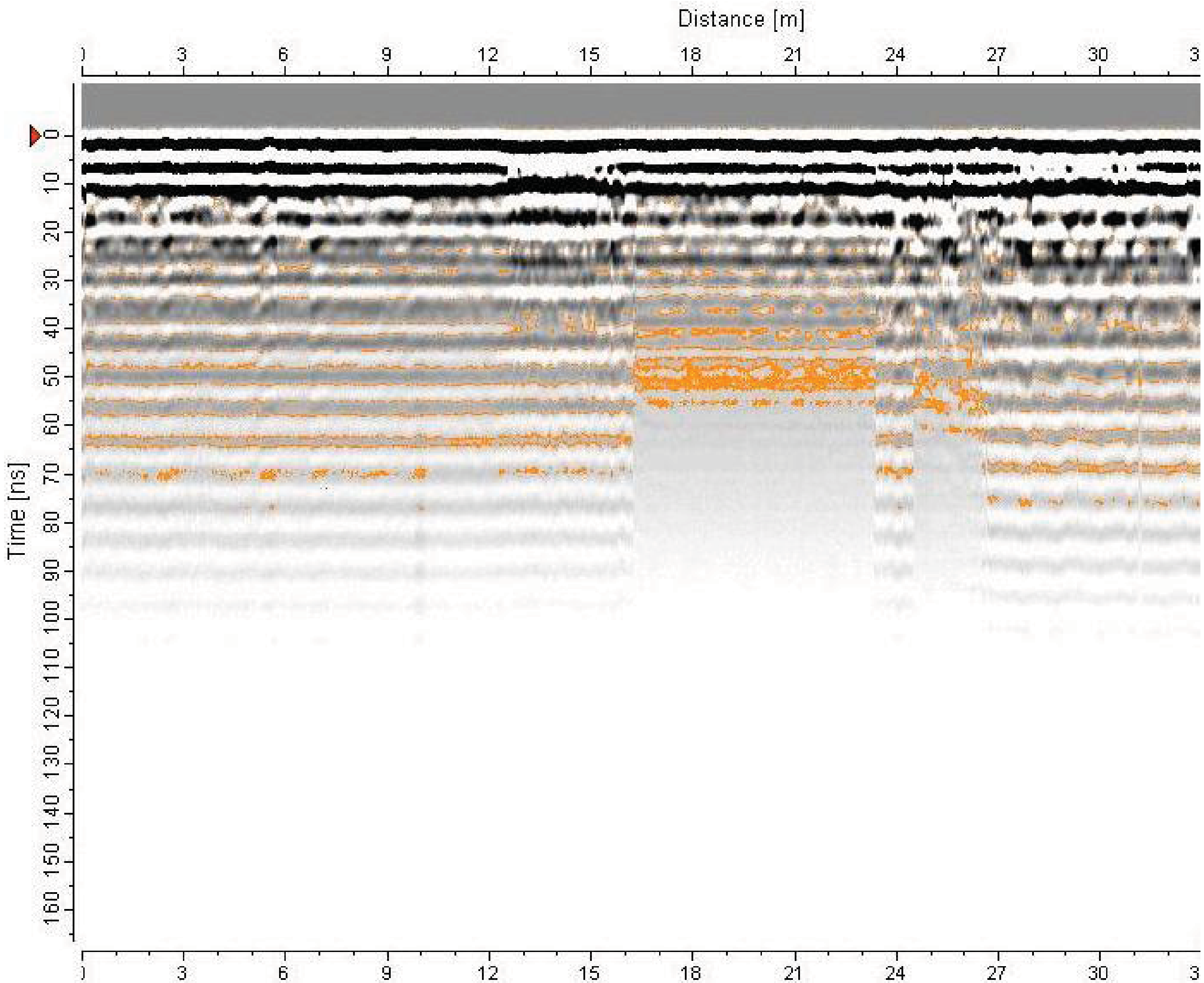
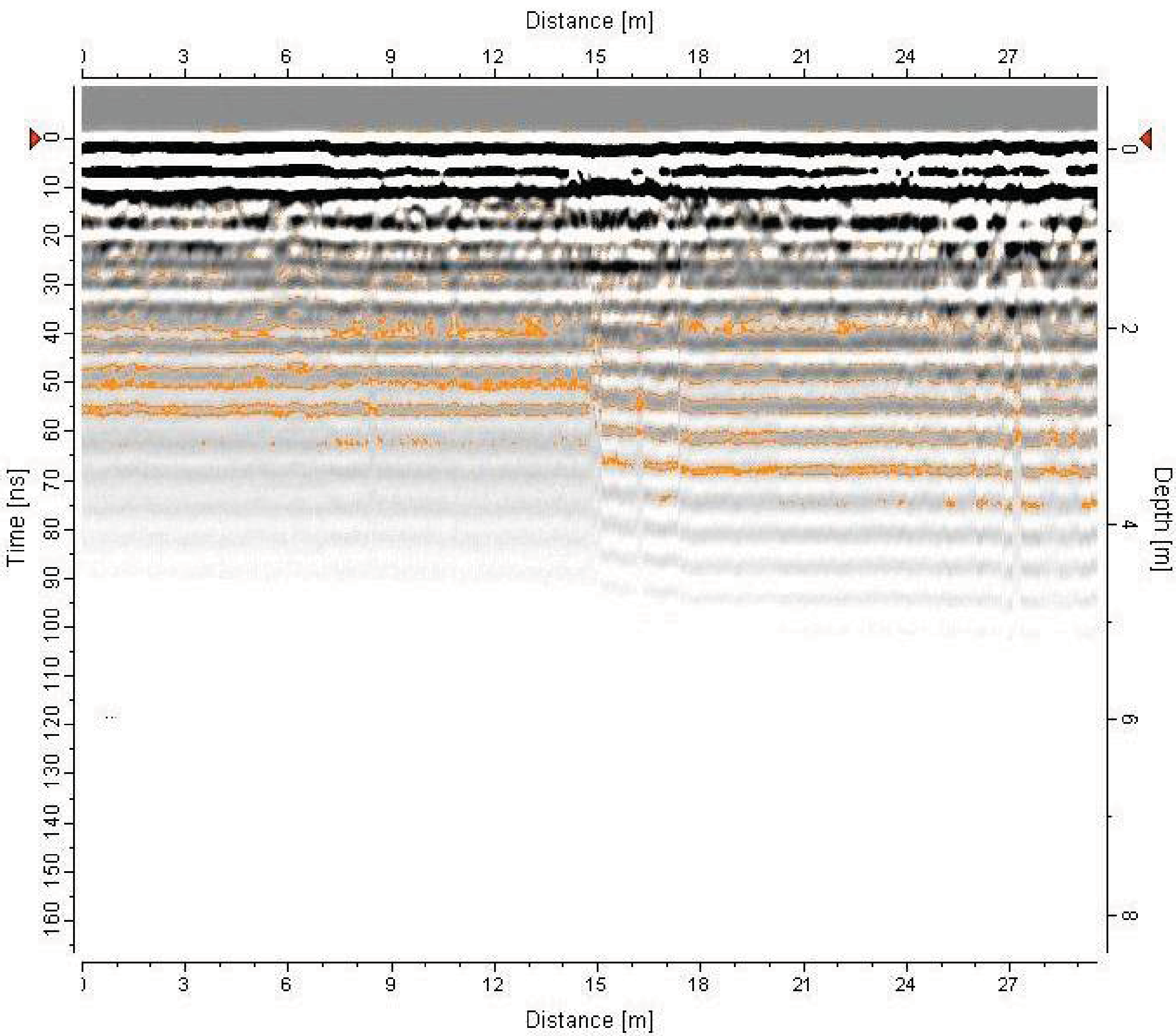
APPENDIX A

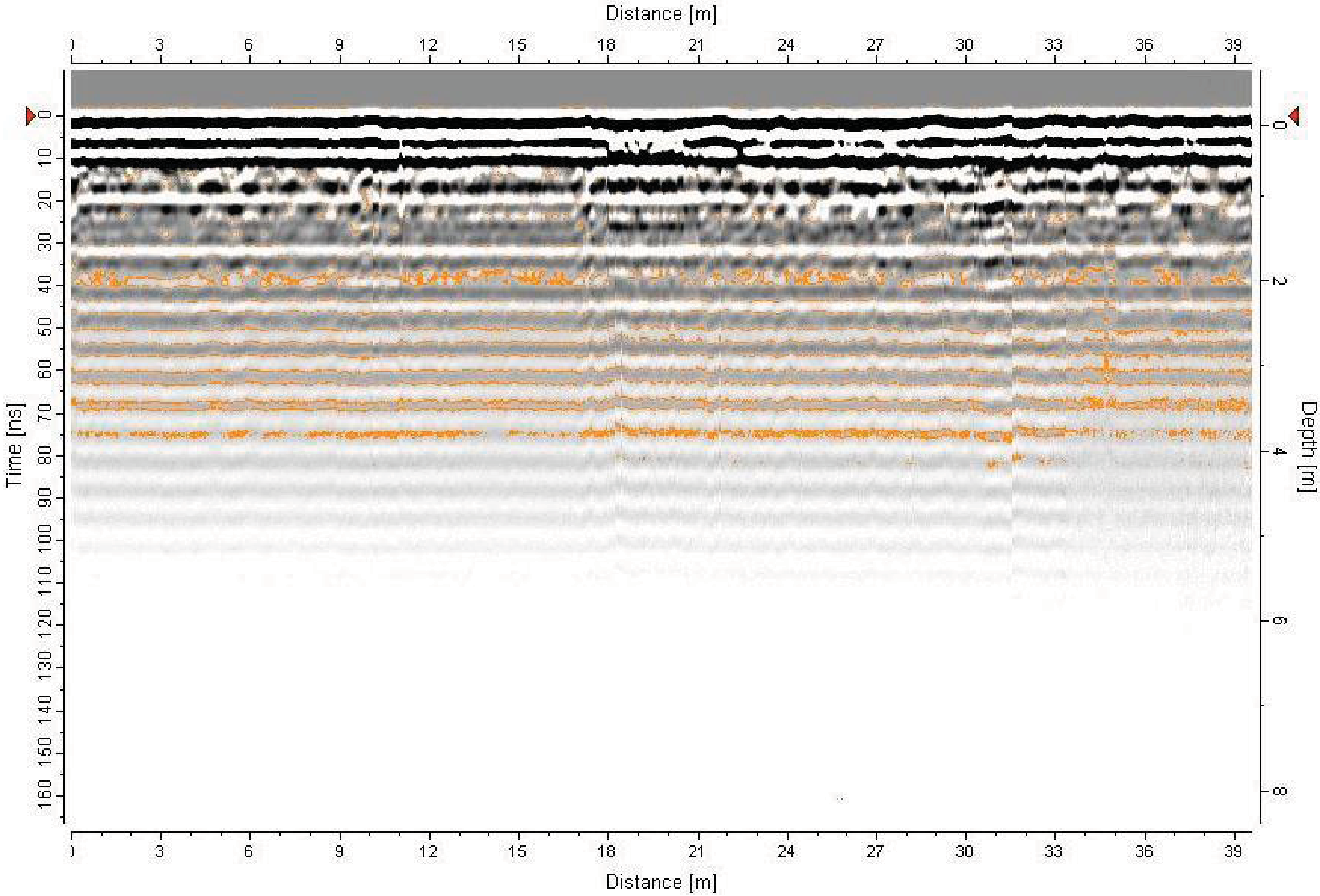
GPR PROFILES



Profile 1 - Transect M to Unmarked



Profile 2 - Transect L to A



Profile 3 - Transect No label to B

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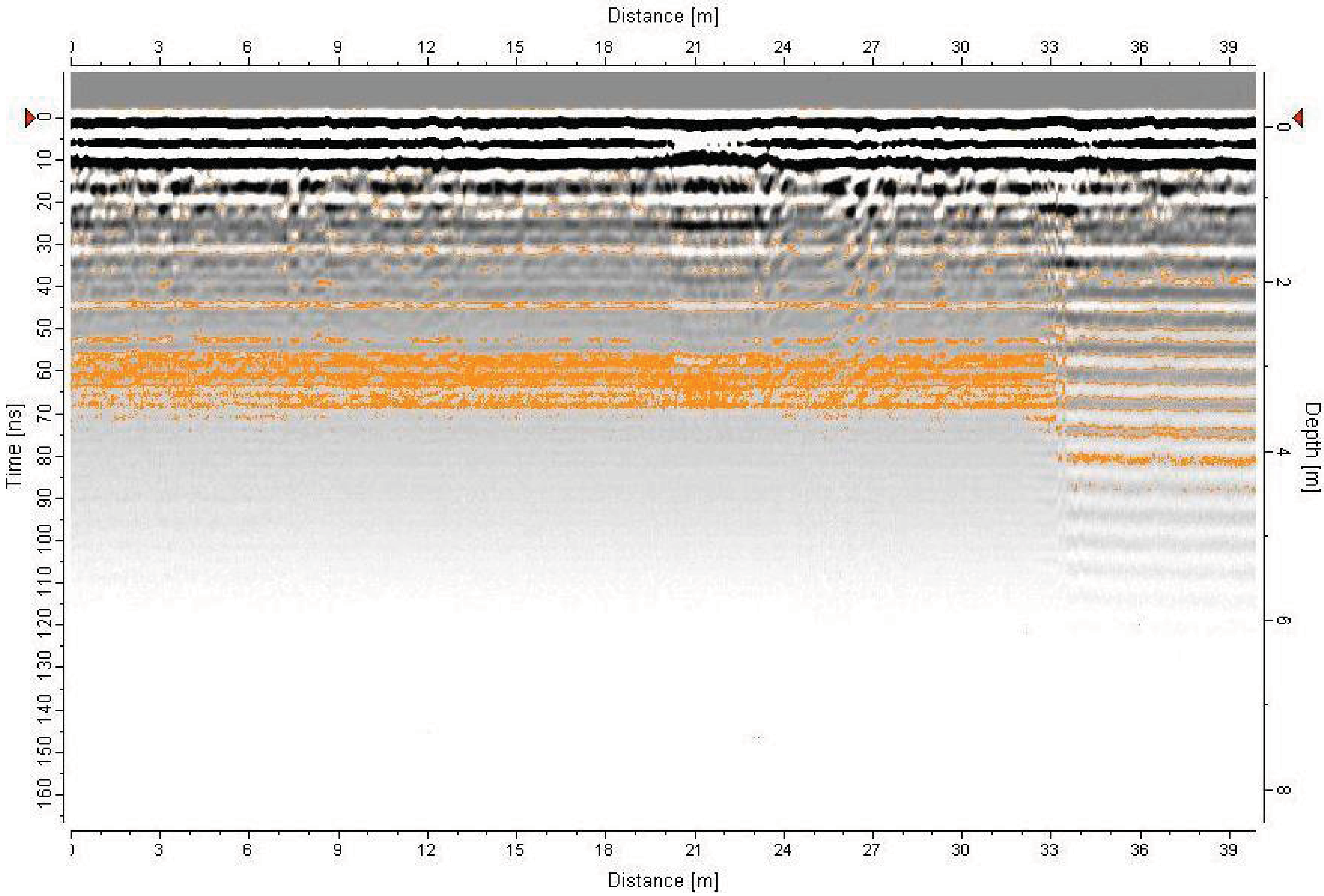
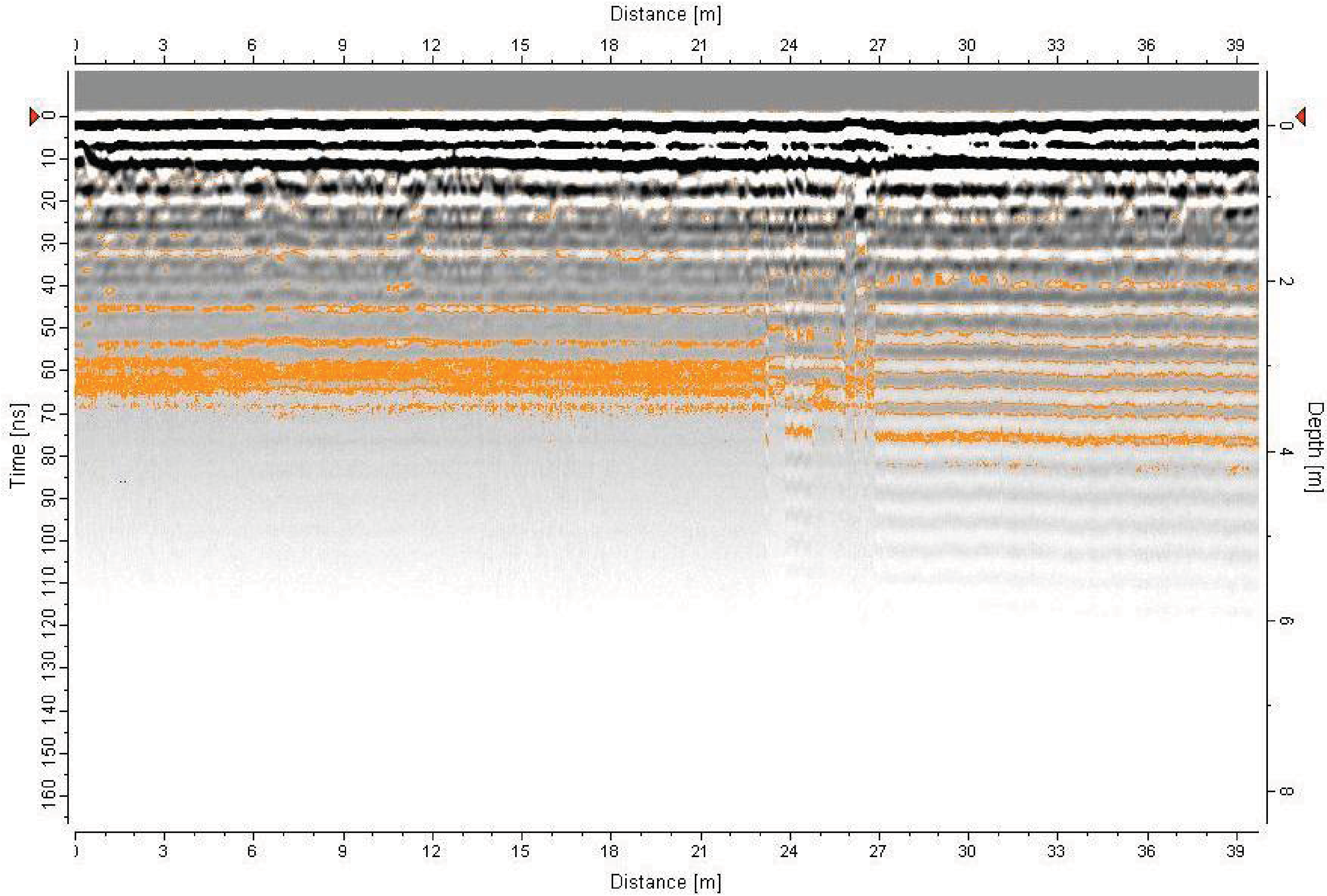
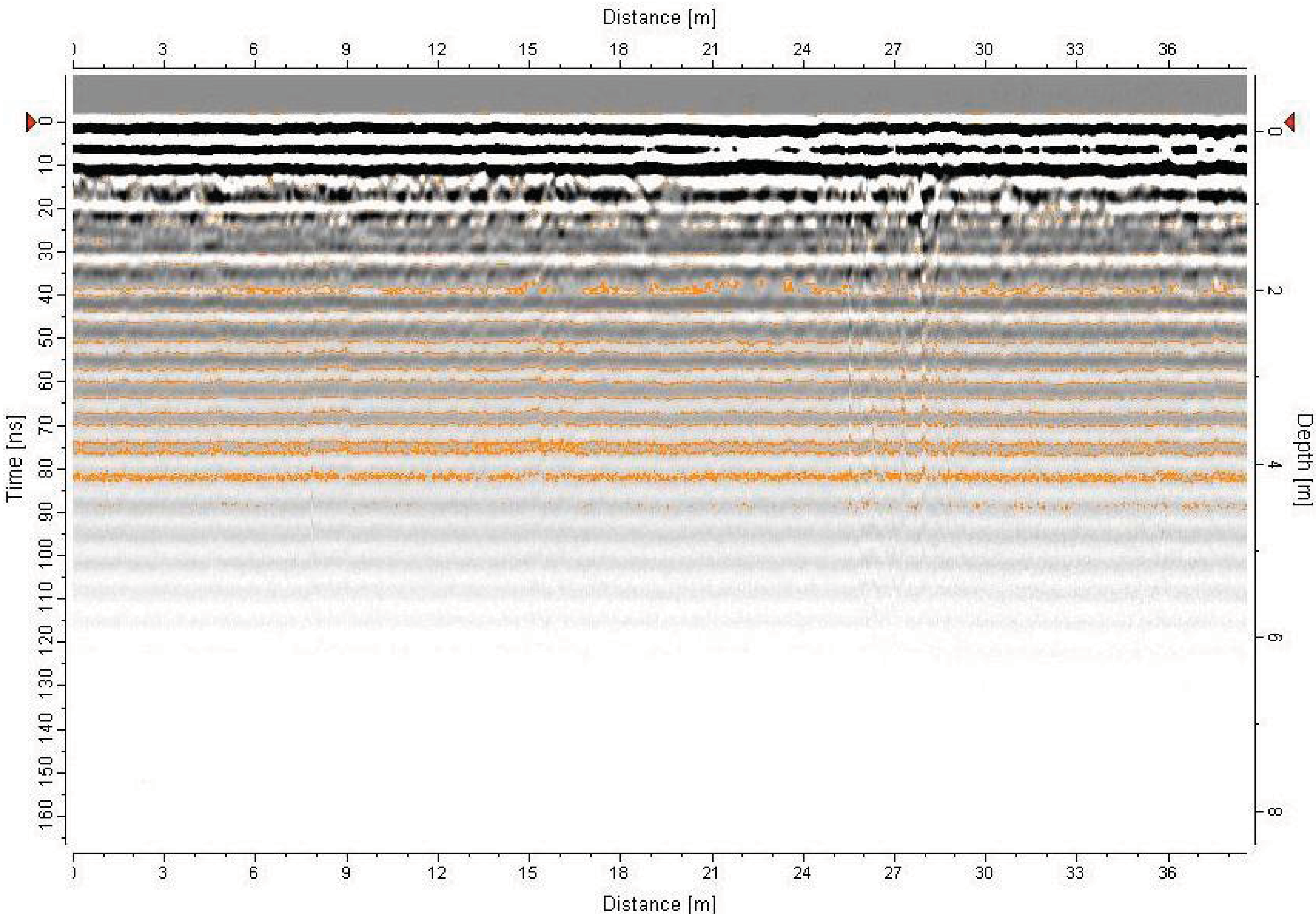


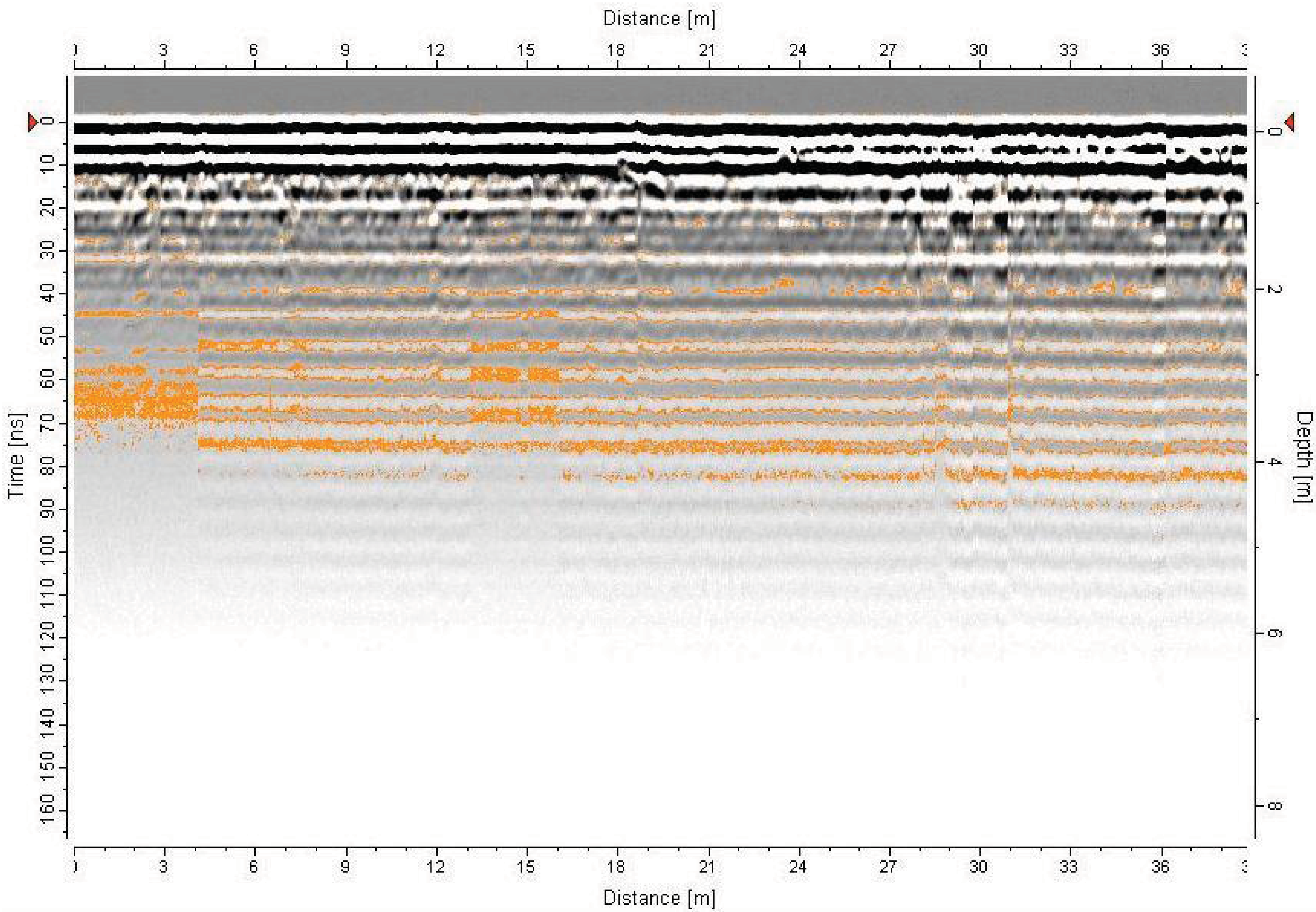
Profile 4 - Transect K to C



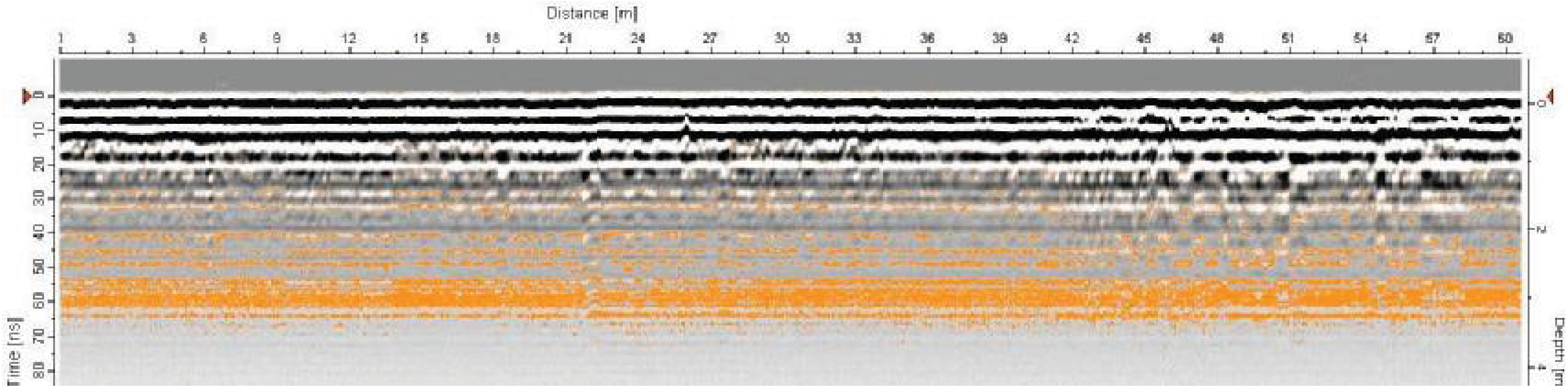
Profile 5 - Transect J to D

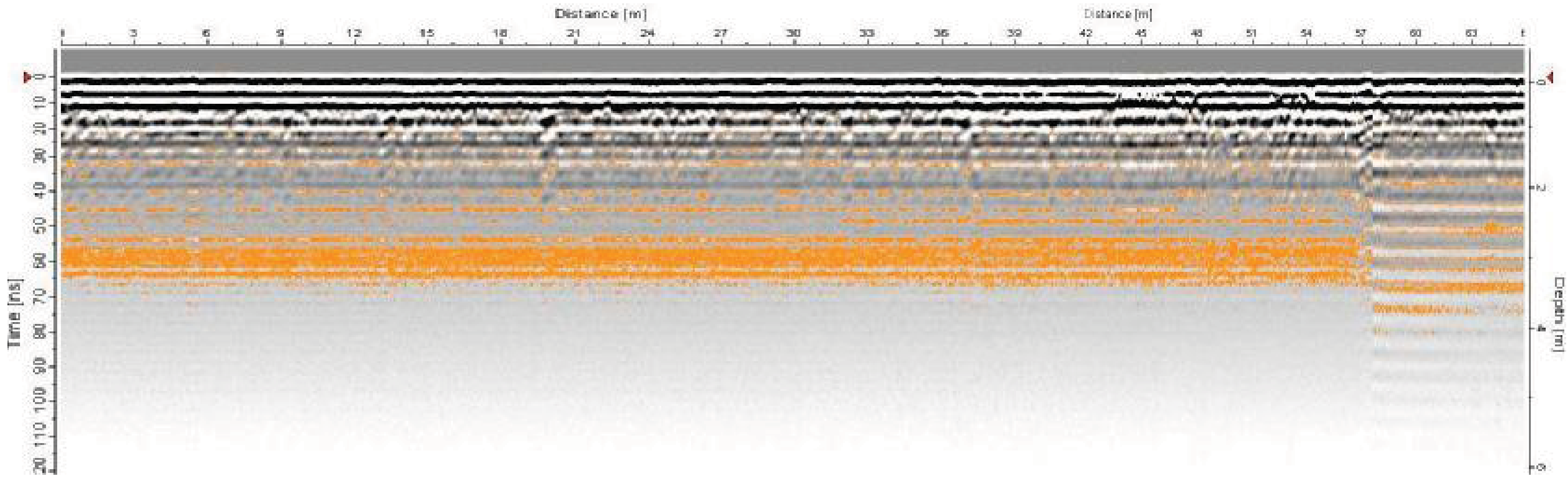


Profile 6 - Transect I to E

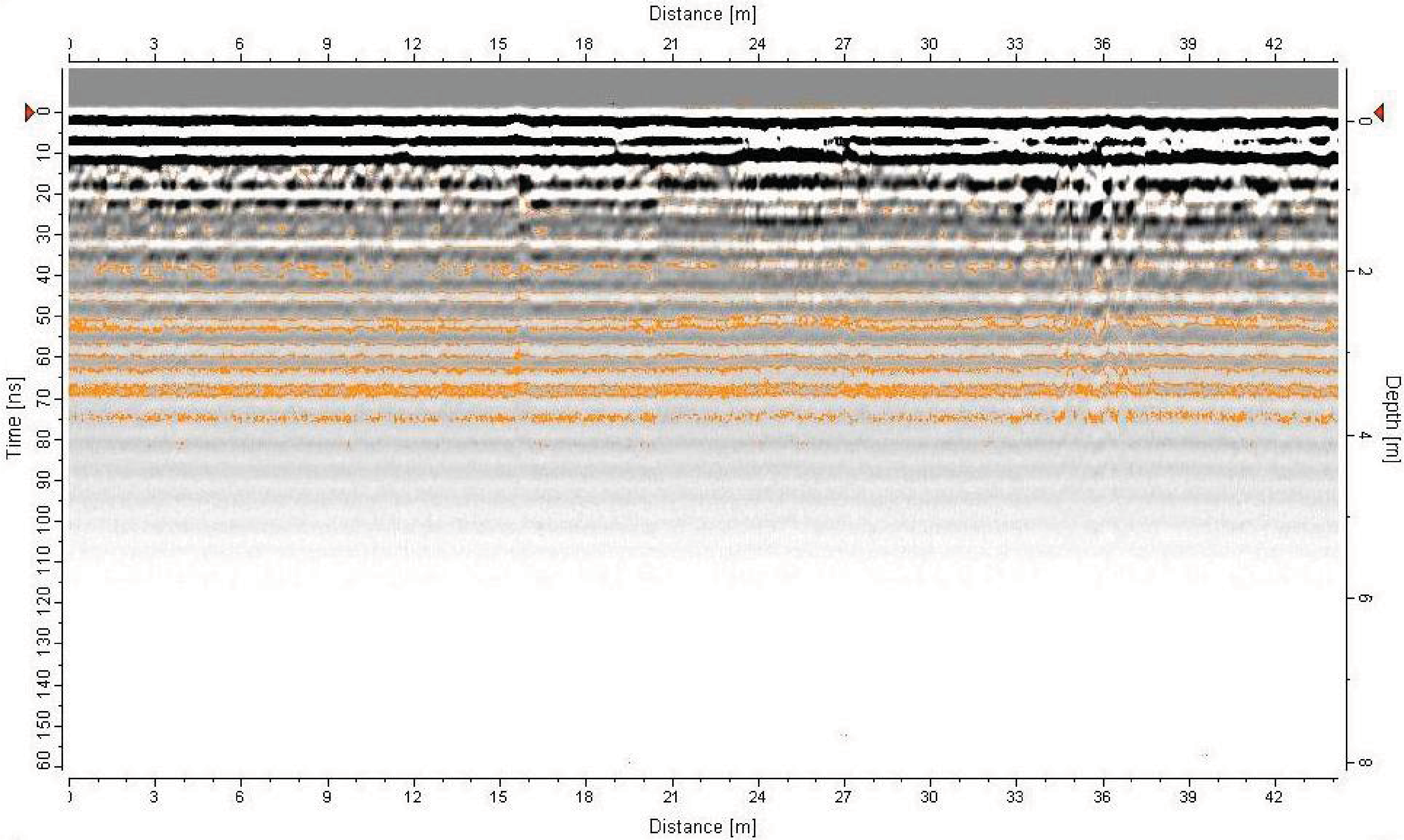


Profile 7 Transect G to F





Above: Profile S (south to North, Below: Profile R (south to north)



Profile Q (south to north)