Chapter 8: Electrical resistivity survey

The results for the ER surveys are broken down by geomorphological unit, with separate sections for terrace 2, terrace 1 and the modern floodplain. An assessment of the technique and methodological considerations will be given after the general description of results. The presentations of the results follows simple conventions. A location map shows the transect placed on the LiDAR LPDTM (last pulse digital terrain model) corrected to height above sea level. Gouge core stratigraphy is codified by numbers, whilst ER interpreted stratigraphy is codified by letters. The letters and numbers assigned to each sediment/geomorphological unit are unique in each transect, i.e. gouge core unit 20 is not the same in transects T1A and T1E, etc.

A term that will be used commonly throughout this chapter is biotaphonomic potential. This term is used to indicate areas within palaeochannel belts or along floodplain transects that are likely to have well preserved organic remains. The process of deposition and storage of organic remains is complicated, but can be broken down into two steps. Firstly, there is deposition of organic material within a sediment matrix. This is first affected by depositional factors, such as flow regime, rate of sediment accumulation and localised ecological habitats. ER cannot be used to produce data on these factors.

Secondly, there is the storage (or taphonomy) of organic remains within sediments. The conditions that affect the storage (or taphonomy) of organic remains are a product of sediment architecture. Factors such as Eh, pH and water logging are critical components of storage of the organic remains, and these are partly determined by the sediment architecture. ER can be used to provide data on the nature of the sediments fills of geomorphological units such as palaeochannels. Therefore, the term biotaphonomy is used to indicate areas of a palaeochannel where there is likely to be good preservation of organic materials. It cannot take into account deposition factors such as sedimentation rates. ER can be used to produce meaningful data on sediment architecture and below ground sediment conditions. It can therefore be used to partly elucidate preservation potentials and hence the use of term biotaphonomy.

8.3 Terrace 2 ER surveys

The primary aim of using ER within this study was to understand palaeochannel stratigraphy. From this perspective the application of ER survey on terrace 2 is limited, due to this terrace having no recorded palaeochannels of any significant depth recorded in this study through GPR survey (Phase I), gouge core survey (Phase I) or OSL sampling (Phase II). The general alluvial covering on top of the terrace gravels is known to be thin, c. <60cm over the terrace, as discerned by gouge core/GPR transect T2T1 (Phase I) and GPR grid plan survey T2G1.

8.3.1.1 Transect T2A

ER transect T2A is a good example of the application of ER on this type of geomorphological unit, of a thin alluvial covering on top of terrace gravels with no significant palaeochannels. The location of T2A is given (Fig. 8.1; it should be noted that it is the same field as survey T2G1 GPR survey from phase I) with the transect results (Fig. 8.2). The electrode spacing was 1m, giving a maximum depth penetration of c. 6m. The overall transect length was 80m.

The ER transect clearly shows the terrace gravels as an area of high resistance, which is the central band running across the centre of section (units B and C). The thin alluvial covering on top of the gravels is also evident (unit A). It should be noted that this very thin sediment unit is only just evident at this electrode spacing and a smaller electrode spacing, such as 0.5m, would have a given better data resolution and interpretative potential of this above gravel alluvial unit.

Within the gravel body areas of higher resistance are identifiable (unit C), interpretable as areas of either higher clast size or less matrix (sand) dominated. Conversely, areas of lower resistance are also identifiable (unit B) within the gravels, interpretable as areas that are matrix (sand) dominated or have lower gravel clast sizes. The interface between the gravel body and the Mercian Mudstone (unit D) can be interpreted from the sections, due to the gravel body having a relatively high resistance when compared to the immature Mercian Mudstone, with its relatively high clay and water contents.

The ability to identify units of lower resistance within gravel bodies has importance on terrace 2. As demonstrated by Greenwood *et al* (2003, 18) organic horizons dating from the Upper Palaeolithic have been identified within late Pleistocene gravels on the middle Trent such as at Hemington. At Hemington Trichoptera (the insect Order containing Caddis fly) larval assemblages were used to indicate a cut off channel system with slow flowing/standing water. This is a scarce palaeoecological resource that can allow late Pleistocene/early Holocene climates and habitats to be reconstructed.

Therefore, having the ability to identify areas of lower resistance within the terrace 2 gravels allows units to be located that have a higher potential of organic survival. The lower resistance of these sediment units is due to smaller clast sizes/matrix dominated architectures. These factors both promote water retention/saturation in negative redox conditions. Whilst it is not suggested that the lower resistance areas of gravel in this transect represent areas of high organic survival, it highlights the potential of using multiple ER transects across terrace 2 to find the areas of lowest resistance gravels within the terrace and thus the highest potential for organic survival.

Transect T2A summary:

- The main sediment units of above gravel alluvium and gravels were identifiable from the ER section.
- Identification of areas of lower resistance within the gravels was possible, allowing the possibility of areas of higher palaeoecological importance within the gravel body to be identified.

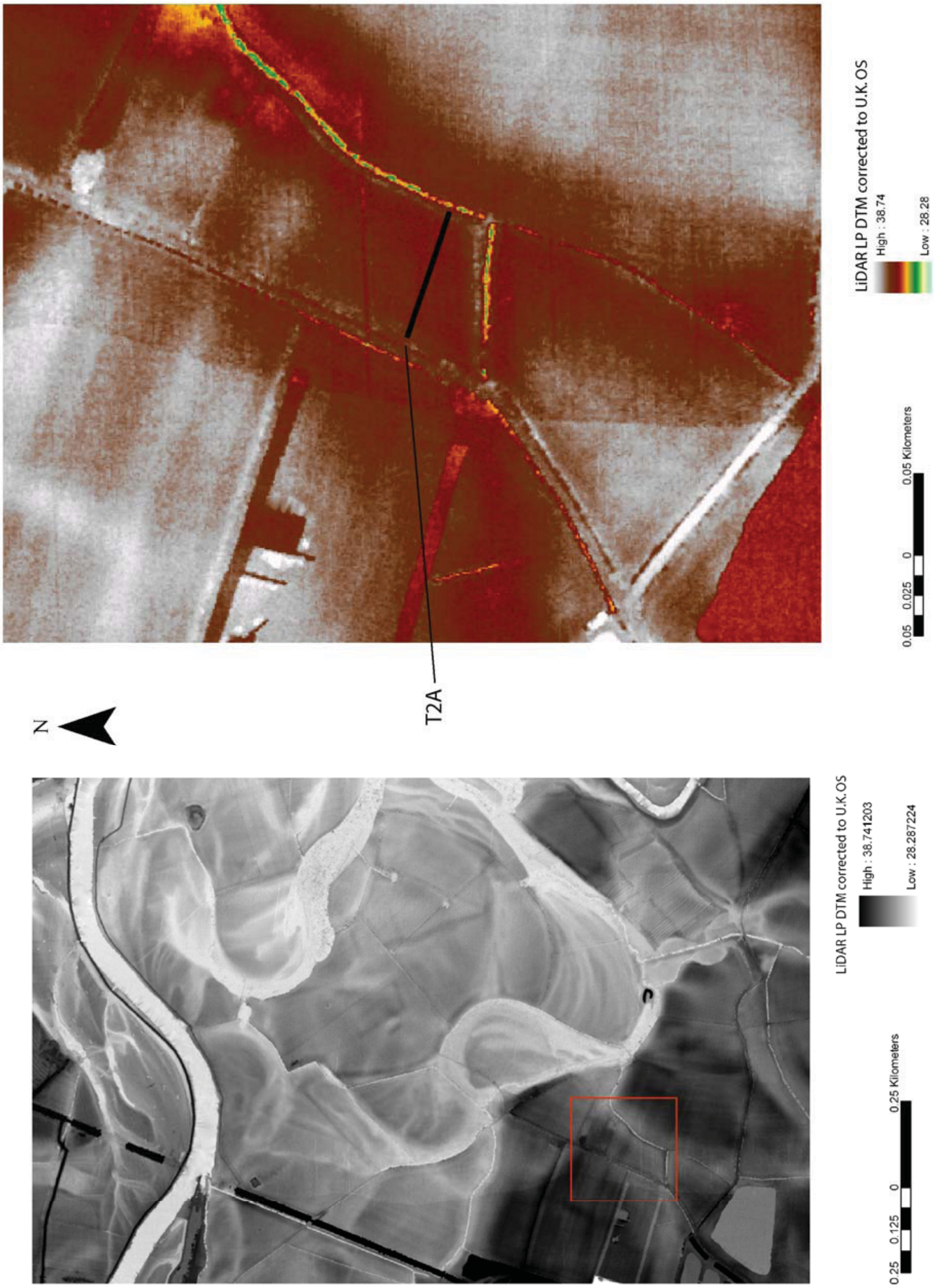


Fig 8.1: The location of T2A on the upper Devensian Holme Pierrepont terrace 2.

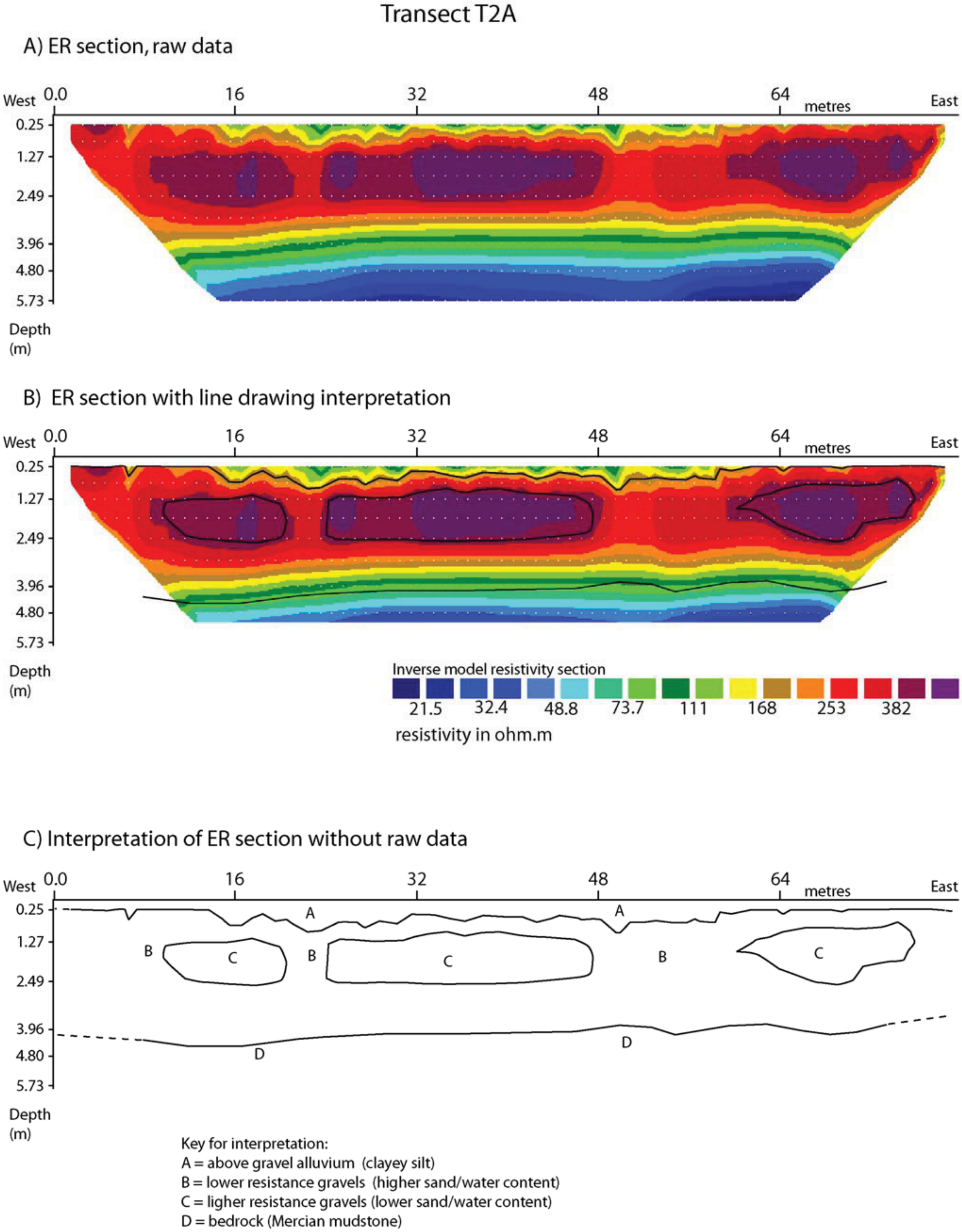


Fig 8.2: Transect T2A ER section. The junction between the gravels and the Mercian mudstone is clearly visible, as is the thin covering of alluvial soil on top of the gravel body.

8.4 Terrace 1 ER surveys

In contrast to terrace 2, it was already known that terrace 1 had a series of relatively deep palaeochannels (<3m), through the results of gouge coring in phase 1. Therefore a variety of targets were chosen for ER survey on terrace 1, in order to explore how effective ER can be for elucidating palaeochannel stratigraphy and palaeoecological and cultural archaeological potential.

8.4.1 Transect T1A

The ER transect T1A was located on what was originally interpreted as an area of terrace adjacent to a large palaeochannel, defining the junction between terrace 2 and terrace 1 (Fig. 8.3). However, during OSL sampling a relatively deep alluvial sequence above gravels was found (c. 4m) and therefore provided an ideal opportunity to test ER in alluvial environments. A gouge core transect of this area along the ER section revealed a palaeochannel with a relatively deep and complex stratigraphy (Fig. 8.4). This palaeochannel is somewhat anomalous within the study area, as it is deeper than any of the other palaeochannels encountered (see chapters 4 and 5). The within palaeochannel stratigraphy was complex, formed of several discrete sediment units. The LiDAR LP DTM reveals little in the way of topographic variation to identify the presence of a palaeochannel in this field. The ER section was 91m long, using a 1m electrode spacing, with a complimentary GPR transect and gouge core transect (cores at 10m intervals).

The T1A transect reveals the presence of a palaeochannel within the section, a palaeochannel not definable from ground surface topographic expression (Fig. 8.5). The GPR transect clearly demonstrates the limitation of using GPR in investigating water filled/clay filled palaeochannels (Fig. 8.5). The terrace gravels are definable at the start of the GPR transect, but as soon as the edge of the palaeochannel is encountered the GPR produces no interpretable data. The alluvium/terrace gravel interface and edge of palaeochannel/terrace gravel junction closely correlate between the gouge core and GPR survey. No within channel sediment stratigraphy is revealed through the GPR. Definition of the terrace stratigraphy is possible from the GPR section.

In contrast the ER section shows the two major units of the terrace (high resistance features, units A and B) and the palaeochannel (low resistance features C and D). The interface between the top of alluvium and the gravels is not precise from the ER section, when compared to the gouge core stratigraphy. The boundary between the palaeochannel and the terrace gravels as derived from the ER section agrees with the gouge core survey. The GPR section produces better data on the depth of the alluvium above gravels on the terrace and the general sediment architecture of the terrace.

However, in contrast to GPR, the ER section produces good quality data within the palaeochannel, although the data does not define stratigraphy directly. The comparison of the gouge core data against the ER sections reveals that ER data is relatively poor at defining the within palaeochannel sediment stratigraphy. The palaeochannel sediment units of 18 (blue/grey gleyed clay with Fe and Mn mottling), 19 (blue grey clay), 20 (olive brown dark grey clay) and 21 (olive brown/dark grey medium sand) are not identifiable as discrete entities within the ER section. Of these unit 20 (olive brown dark grey clay) and unit 19 (blue grey clay) are known to have high biotaphonomic potentials (see chapter 6). The boundaries and interfaces between the different sediment units defined through gouge coring within the palaeochannel are not interpretable on the ER section. The silt and sand clay units at the top of the palaeochannel are partly identified by the ER section (unit C). The area of the lowest resistance within the palaeochannel is identifiable (unit D). There is good agreement between the depth of the palaeochannel , defined by the depth to gravels, between the gouge core stratigraphy and the ER section.

The interpretation of the ER section allows the area of highest biotaphonomic potential within the palaeochannel to be defined, based on the identification of the lowest resistance area within the palaeochannel. This area approximates with the deepest section of unit 20, as defined by the gouge core stratigraphy. This olive brown clay (unit 20) had a very high organic content and was shown to contain a good palaeoecological record. This lowest resistance area of the palaeochannel is a product of a small grain size coupled with high water content. The ER section does not define the stratigraphy of the palaeochannel fill as recorded by gouge core, but it does allow an assessment of biotaphonomic potential across the channel, based on resistivity. Therefore, if this ER section was the only information available before sampling for palaeoecological remains, then the first area to investigate within this palaeochannel would be the area of highest moisture content (unit E).

Transect T1A summary:

- The correlation of the identification of the main geomorphological units between the ER section and GPR section is good, i.e. both techniques identify an area of terrace, a palaeochannel and above gravel alluvium on the terrace.
- The GPR section produces good definition of the gravels and above gravel alluvium.
- The GPR section produces no real definition of the palaeochannel.
- The ER section provides definition of the depth and width of the channel and the boundary between the base of the palaeochannel and gravels.
- The ER section does not define the internal palaeochannel stratigraphy/sediment architecture, as witnessed by the gouge core transect.
- The ER section locates the area of lowest resistance within the palaeochannel fill. This is liable to be the area of highest biotaphonomic potential.

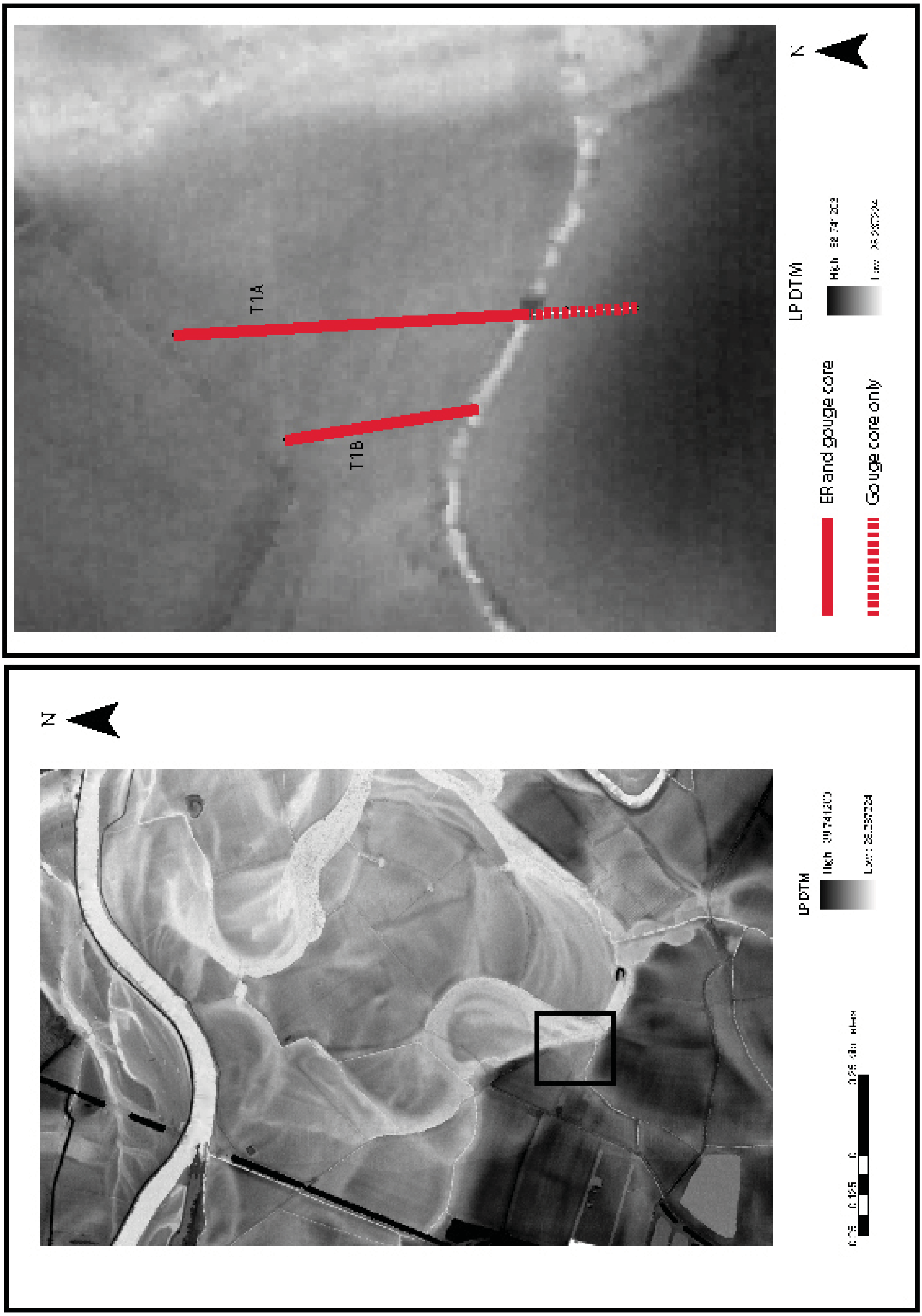


Fig 8.3: The location of transects T1A and T1B, at the junction between terrace 2 and terrace 1.

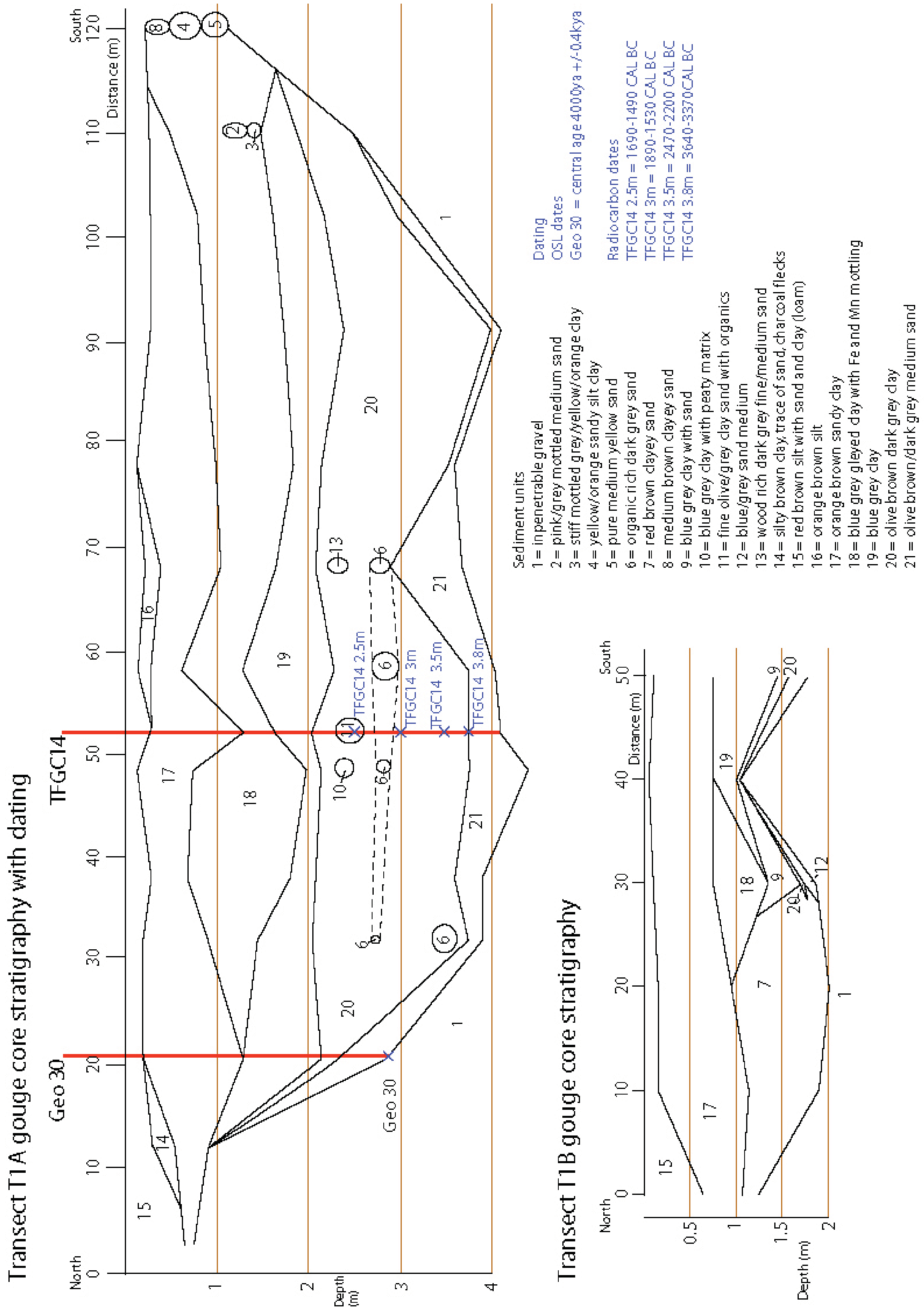
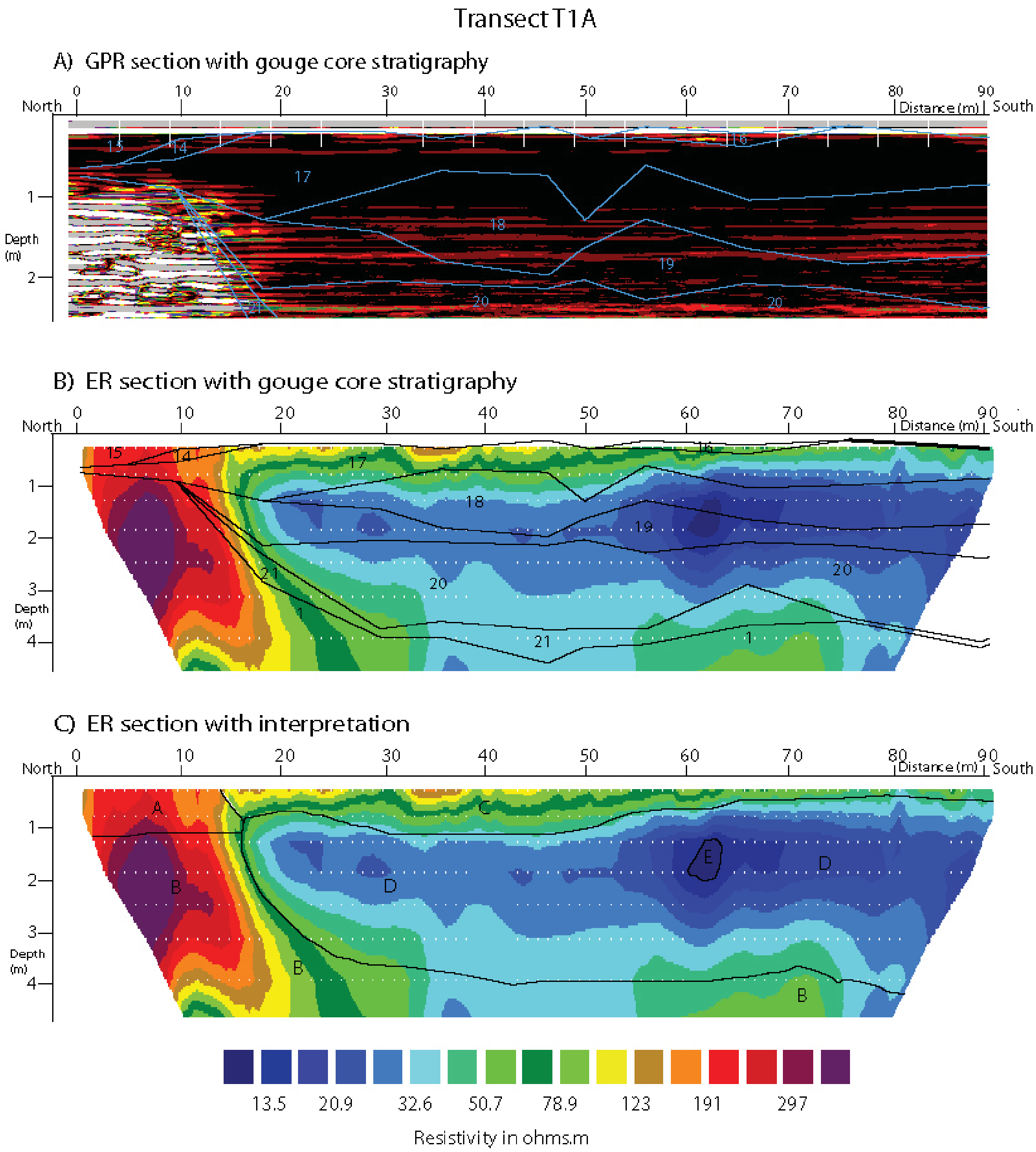


Fig 8.4: The stratigraphy of transects T1A and T1B. This palaeochannel was shown to have the deepest stratigraphy (c. 4m) of any of the palaeochannels sampled within the study area.



Key for interpretation:
A = alluvium above gravel (silty clay)
B = gravels
C = alluvium above palaeochannel fill
D = palaeochannel
E = area of lowest resistance within palaeochannel

Key gouge core stratigraphy:
1 = inpenetrable gravel
2 = pink/grey mottled medium sand
3 = stiff mottled grey/yellow/orange clay
4 = yellow/orange sandy silt clay
5 = pure medium yellow sand
6 = organic rich dark grey sand
7 = red brown clayey sand
8 = medium brown clayey sand
9 = blue grey clay with sand
10 = blue grey clay with peaty matrix
11 = fine olive/grey clay sand with organics
12 = blue/grey sand medium
13 = wood rich dark grey fine/medium sand
14 = silty brown clay, trace of sand, charcoal flecks
15 = red brown silt with sand and clay (loam)
16 = orange brown silt
17 = orange brown sandy clay
18 = blue grey gleyed clay with Fe and Mn mottling
19 = blue grey clay
20 = olive brown dark grey clay
21 = olive brown/dark grey medium sand

Fig 8.5: ER transect T1A. A large palaeochannel is clearly evident within the section as a low resistance feature. There is a strong correlation of features between the ER section and the gouge core and GPR sections.

8.4.2 Transect T1B

After transect T1A had been conducted, it was clear that this palaeochannel had significance, due to its depth, its potential age and quality of the palaeoecological resource within it. In order to further understand this palaeochannel and its biotaphonomic potential, a second ER transect was undertaken (transect T1B, Fig. 8.3). T1B was 47.5m in length and utilised a 0.5m electrode spacing, in order to provide better data resolution in the depth range of 0-3m. Again a GPR transect and a gouge core transect (10m core spacing) were run alongside the ER transect for inter-technique comparison and also to aid in the interpretation of the ER data. Like with transect T1A there was no surface expression of the palaeochannel.

The ER section revealed (Fig. 8.6) a greater data resolution in the top 3m of the alluvial profile compared to the 1m electrode spacing used on transect T1A, although there is less depth penetration. Again the gouge core transect shows good agreement with the GPR data. The top of the terrace gravels defined by the GPR agrees with the gouge core data at the start of the transect. However, as soon as the transect encounters the palaeochannel fill nearly all data definition is lost in the GPR. The exception to this is the rise in gravels seen within the palaeochannel (within palaeochannel bar, unit F), which is visible within the GPR trace as a faint reflector. This shows excellent agreement with gouge core transect.

The GPR section does not reveal any definition of within palaeochannel stratigraphy. The GPR transect is appearing to define the difference between a red brown clayey sand (sediment unit 7) and an orange brown sandy clay (sediment unit 7) on the edge of the terrace, although both are relatively weakly reflecting units. The alluvium/gravel interface is not definable from the GPR transect and overall the GPR transect is over limited use for definition of subsurface sediment architecture on this particular section.

In contrast, the ER section clearly defines the major geomorphological units of the terrace and the palaeochannel. The terrace/palaeochannel boundary is more clearly defined in the ER section than the GPR, with a close correlation between gouge core palaeochannel stratigraphy and the ER section. The rise in height of gravels within the palaeochannel is clear within the ER section, interpreted as a within palaeochannel bar (unit F). It is interesting how the gouge core spacing distorts the relatively small feature of the within channel bar, making the depth of gravels artificially appear to rise either side of the bar, a product of the 10m gouge core spacing. The ER section gives a much better definition of this feature. The alluvium above the palaeochannel, consisting of a orange brown sandy clay (unit 17) is partially discernable in the ER section.

In this instance the ER section provides the depth of the palaeochannel more clearly than either the GPR or gouge core transects. The stratigraphy of the terrace sediments is unclear based on the ER data in isolation. Likewise, the within palaeochannel stratigraphy detailed in the gouge core sections is not interpretable based on the ER data. The palaeo stratigraphy can be defined as units 18 (blue grey clay with Fe and Mn mottling), 19 (blue grey clay), 9 (blue grey clay with sand), 20 (olive brown dark grey clay) and 12 (blue grey medium sand). None of these units are definable as discrete entities from the ER section. The units are labelled the same as transect T1A and the units with the highest biotaphonomic potential are units 20 and 19.

From the ER section the main geomorphological units of the terrace alluvium (unit A), palaeochannel (units D and E) and gravels (units B and F) are identifiable. The area of the lowest resistance is again clearly identifiable within the palaeochannel (unit E). This area will have the highest water content within the palaeochannel and as a result is likely to have the highest biotaphonomic potential. Again the areas identified as unit E correlate closely with the units of 19 and 20, with the palaeochannel at it maximum depth at these points. From the ER section it is also apparent that the palaeochannel is smaller on transect T1B than it is on transect T1A, both in terms of width and depth.

T1B summary:

- The GPR section does not produce a clear correlation with the gouge core data and in isolation the GPR data would be difficult to interpret.
- The GPR section produces very poor definition of the within palaeochannel stratigraphy, although a within palaeochannel bar is evident as a weak reflector.
- The ER section provides definition of the depth and width of the channel and the boundary between the base of the palaeochannel and gravels, and the location of a within palaeochannel bar (unit F).
- The ER section does not define the internal palaeochannel stratigraphy/sediment architecture, as witnessed by the gouge core transect.
- The ER section locates the area of lowest resistance within the palaeochannel fill. This is liable to be the area of highest biotaphonomic potential.
- The ER section provides a more accurate representation the palaeochannel morphology, particularly the depth to the gravels, when compared to either the gouge core or GPR transects.
- The ER section provided information on a palaeochannel that was not evident through topographic expression.

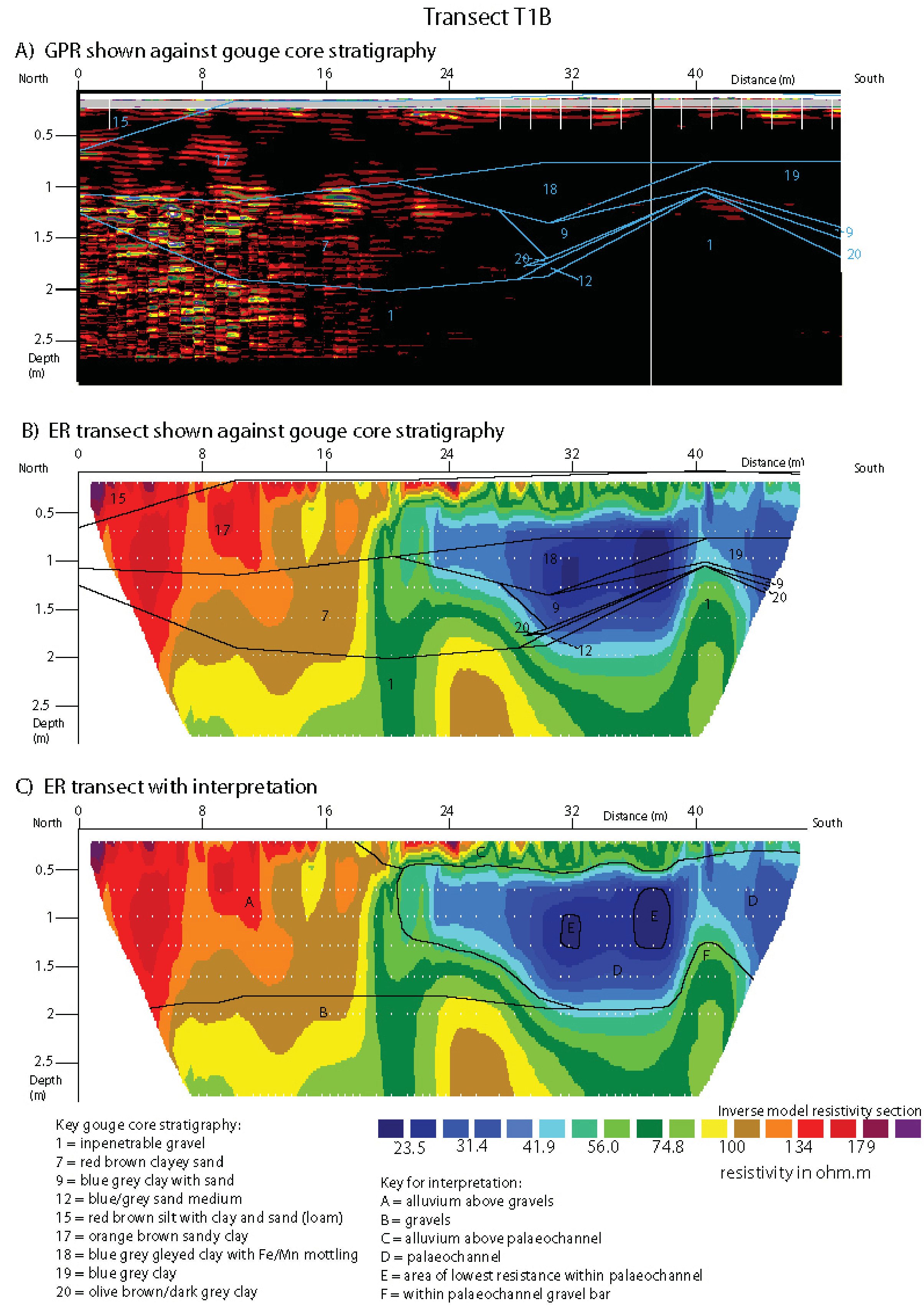


Fig 8.6: ER transect T1B. The palaeochannel in the section is an obvious feature.

8.4.3 Transect T1C and T1D: comparison of electrode spacing

A single transect was conducted on an area of terrace 1, that utilised two electrode spacings (1m and 0.5m). Both ER sections were compared to GPR and gouge core transects. This experimentation allows comparison between the types of data obtained by the two different electrode spacings. Each of the transects will be described, then a comparison of the electrode spacings will follow.

8.4.3.1 Transect T1C

Transect T1C was undertaken at the junction between a palaeochannel and an area of terrace 1. Both the terrace and palaeochannel are evident through topographic expression, as shown through the LiDAR LP DTM (Fig. 8.7). The ER transect ran for 47m, using a 1m electrode spacing. GPR and gouge core sections (10m core spacing) were run along the same transect. The terrace gravels are evident on the GPR section (Fig. 8.8). The depth to the impenetrable gravels correlates closely between the GPR and gouge core sections. The above terrace alluvial stratigraphy and the within palaeochannel stratigraphy cannot be seen from the GPR section.

The ER section has a good correlation with the stratigraphy revealed by the gouge core transect. The ER section identifies unit A above terrace gravels, which correlates with unit 2, a red brown silty clay. Below this is a higher resistance unit B, which approximates to unit 4 (red brown clayey sand), unit 7 (brown grey clay with sand) and unit 8 (blue grey sandy clay). These units all have higher sand content and are shown to have higher resistivity values.

The palaeochannel is dominated by units 6 (brown grey clay with Fe and Mn mottling), 8 (blue grey sandy clay), 9 (brown grey clayey sand) and 10 (red brown sand, small Fe nodules). The junction between the palaeochannel (unit 6 brown grey clay with Fe and Mn mottling) and the terrace alluvial deposit (unit 2 red brown silty clay) lies somewhere between 20m and 30m on the transect. However, due to the spacing of the gouge cores this is not clearly defined and an estimated break is placed at 25m on the gouge core stratigraphy.

In comparison the ER section defines the palaeochannel (units C, D and E) clearly, with the junction between the palaeochannel and the terrace silty clay (unit A) and sandy clays/clayey sands (unit B) clearly defined. Again the area of lowest resistance within the palaeochannel is located (unit D), correlating with the greatest depths of 6 and 8, both clay units. Thus unit D is suggested to have the highest potential for biotaphonomic potential preservation within the palaeochannel. The ER section also appears to define the basal sands within the palaeochannel (unit E).

As a 1m electrode spacing was used on this transect the entire depth of Holocene alluvial gravels is evident (units G and F). There is a clear boundary between the sand (units B and E) and the gravels (units F and G). Unit G has a higher resistivity and is located under the terrace deposit. Unit F is a lower resistance gravel and partially correlates with the area below the palaeochannel (units E, C and D). This lower resistivity value in unit F is probably a function of increased water retention, itself probably caused by the palaeochannel above it. The junction between the Mercian Mudstone (unit H) and the gravels (units G and F) can also be interpreted.

Transect T1C summary:

- The GPR provided no definition of the palaeochannel stratigraphy.
- The ER section allowed an interpretation of the palaeochannel, terrace alluvium, gravels, and gravel/bedrock junction.

- There was a good correlation between the general stratigraphy recorded by gouge core transect and the ER transect.

8.4.3.2 Transect T1D

The ER transect T1D was collected in the same location as T1C (Fig. 8.7), with the same orientation. T1D was 48m long and this time used a 0.5m electrode spacing. GPR and gouge core sections (10m core spacing) were run along the same transect. In order to avoid repetition the GPR transects and the gouge cores transects are the same as T1C (section 8.4.3.2). The GPR reveals no internal palaeochannel stratigraphy and only reveals the depth of basal gravels on the terrace section. This interpretation is confirmed by the gouge core transect (Fig. 8.9).

The ER section only penetrates to c. 3m and the depth to the gravel/bedrock junction is not evident, as seen in the 1m electrode spacing (transect T1C). The palaeochannel is well defined by this electrode spacing (unit C), which again relates to the sediment units 6 (brown grey clay with Fe nodules), 7 (blue grey sandy clay with Fe nodules), 8 (blue grey sandy clay), 9 (brown grey clayey sand) and 10 (red brown sand with Fe nodules). The palaeochannel has a fill consisting of clay dominated sediments in its upper fill and the clayey sands in the lower fill. Due to the sediment architecture of these fills containing clay, the palaeochannel is evident as a feature with low resistivity values.

The terrace deposits are evident as higher resistance features, with the terrace deposit mainly defined by unit 2 (red brown silty clay with a trace of sand), which approximates with unit A in the interpretation. The higher resistance units at the junction between the terrace alluvium and gravels are units 3 (gleyed grey clay with Fe and Mn mottling), 4 (red brown clayey sand), 5 (coarse red/brown/pink sand) and 7 (blue grey sandy clay with Fe nodules). These sediment units approximate with unit B on the interpretation, an area of intermediate resistance between the gravels and the terrace alluvium.

Overall the interpretation of the ER section is straightforward. The main units of the palaeochannel (unit C), gravels (unit F and D) and terrace alluvium (units A and B) are identifiable. The palaeochannel morphology is well defined. The areas of lowest resistivity within the palaeochannel are highlighted (unit G), and as discussed above, these are likely to be the areas of highest biotaphonomic potential within this section of palaeochannel. The variation of the resistivity values within the gravels is depicted more clearly using the 0.5m electrode spacing, with the lower resistivity unit D more tightly defined. As was seen through the identification and subsequent dating of oak trees in Warren Farm Quarry (section 5.4), the gravels may contain a significant geoarchaeological resource dating from the Neolithic onwards. Therefore, the identification of lower resistivity areas within the gravels can help to identify areas with higher geoarchaeological potentials.

The palaeochannel morphology is not visible through the GPR or gouge core transects. It is the ER section that provides information on the palaeochannel. However, the ER section does not provide a section where the individual sediment units are identifiable, as in the gouge core transect. Broader changes in resistivity values are evident that reflect geomorphological units.

Transect T1D summary:

- The GPR provided no definition of the palaeochannel.
- The ER section defined the morphology of the palaeochannel well and identified the areas of lowest resistivity within the palaeochannel.

- The floodplain units of the terrace alluvium, gravels and palaeochannel were interpretable from the ER section.
- There was a relationship between the sediments identified through the gouge core transect and ER section, although the ER section did not identify the individual sediment units.
- Variation in resistivity values were seen in the gravels, with areas of higher and lower resistance visible.

8.4.3.3 A comparison between ER transects T1C and T1D

The two transects T1C and T1D allowed a comparison between the two electrode spacings and the types of information that can be gained using each. By comparing Figs. 8.8 and 8.9, a series of differences are obvious between the two transects. These can be summarised as:

- Using a 1m electrode spacing allows a much greater depth penetration (c. 6m).
- This greater depth penetration allows loss of data resolution in the upper part of the profile.
- The 1m electrode spacing allows the gravel/bedrock interface and the extent of the gravels to be seen.
- The 0.5m electrode spacing gives greater data resolution in the upper c. 3m of the profile.
- The 0.5m electrode spacing produces better definition of the palaeochannel morphology, the terrace alluvium and the variation in upper gravel body.
- Both electrode spacings identify the main geomorphological units in the section.

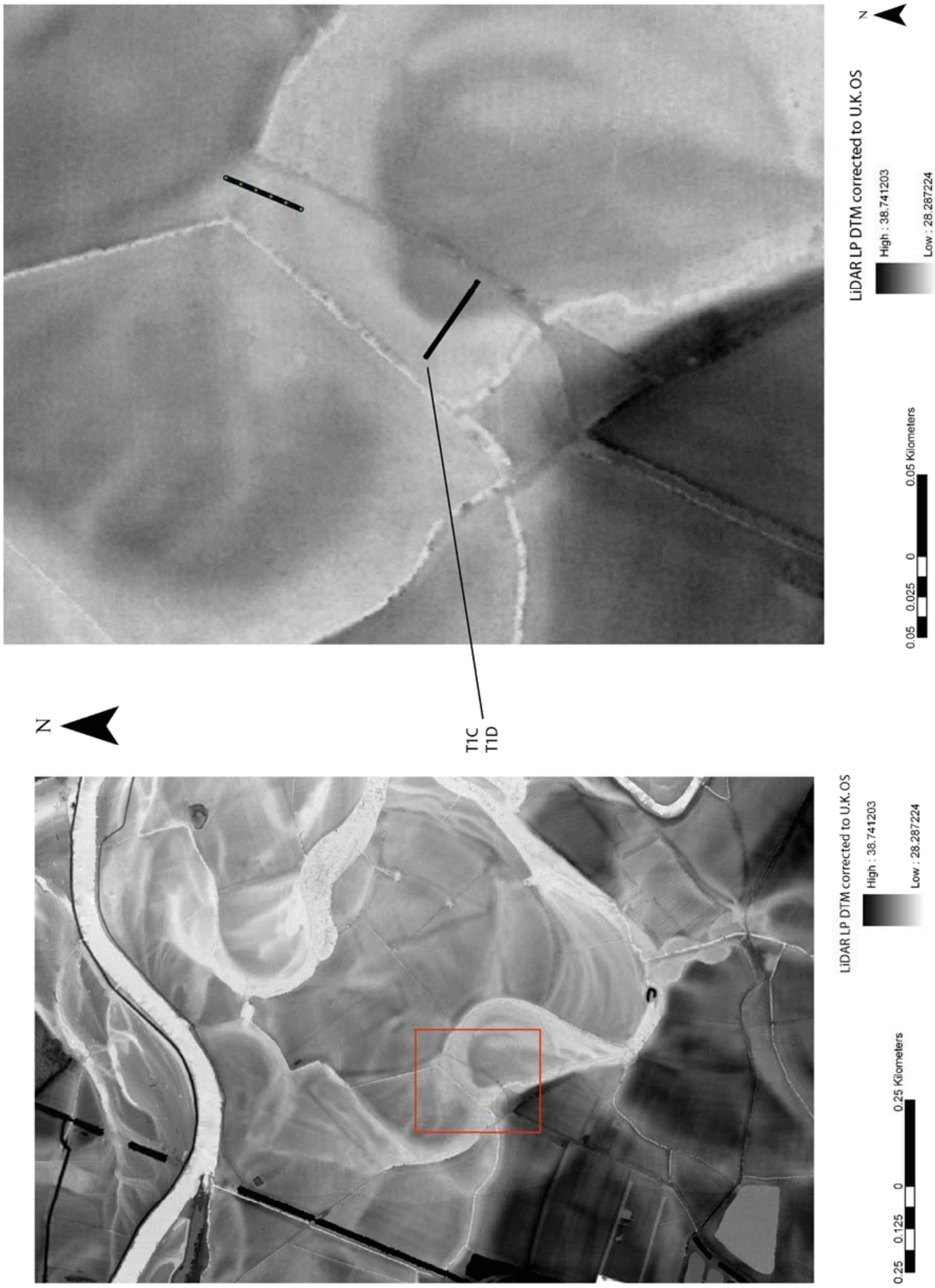


Fig 8.7: The location of ER transects T1C and T1D.

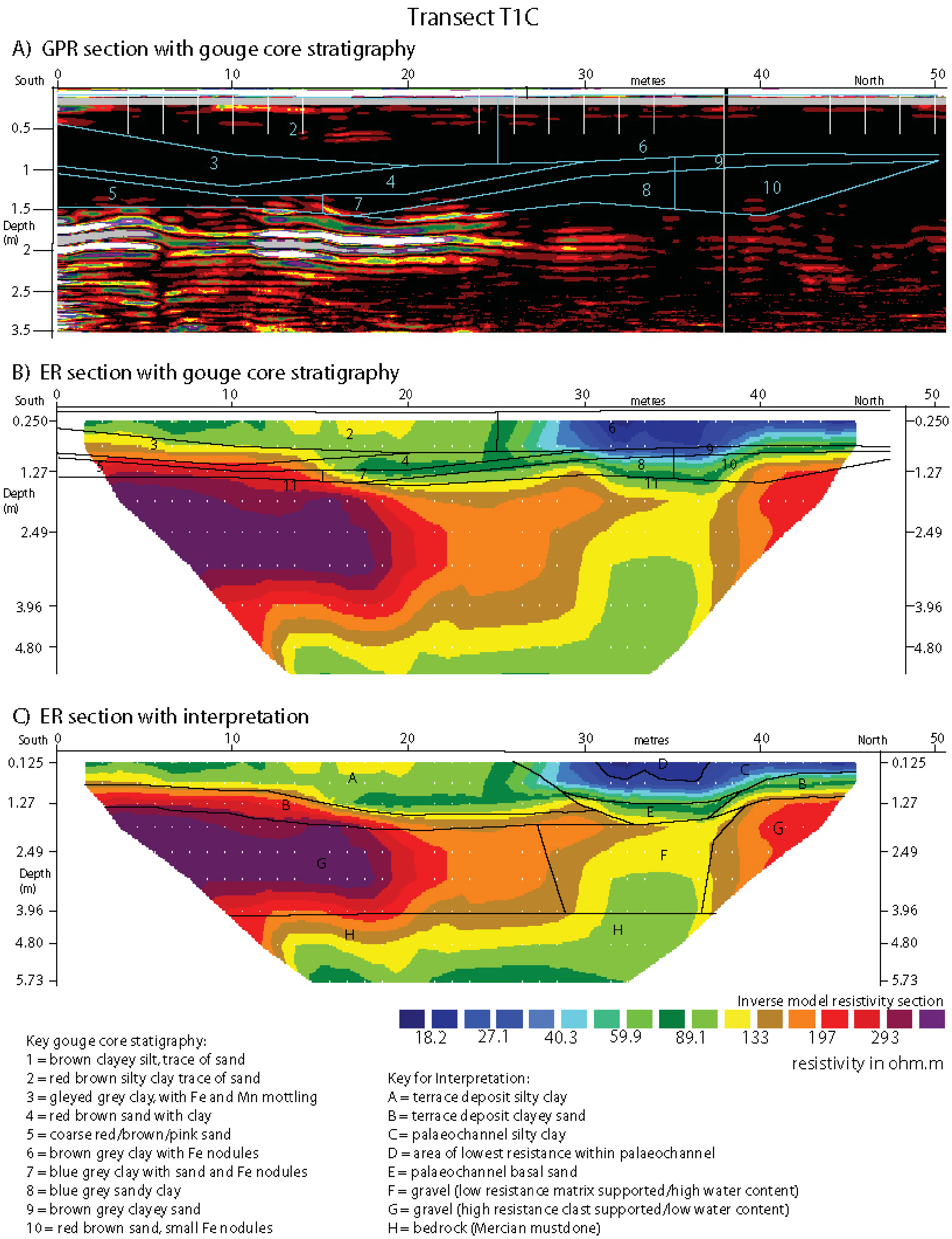
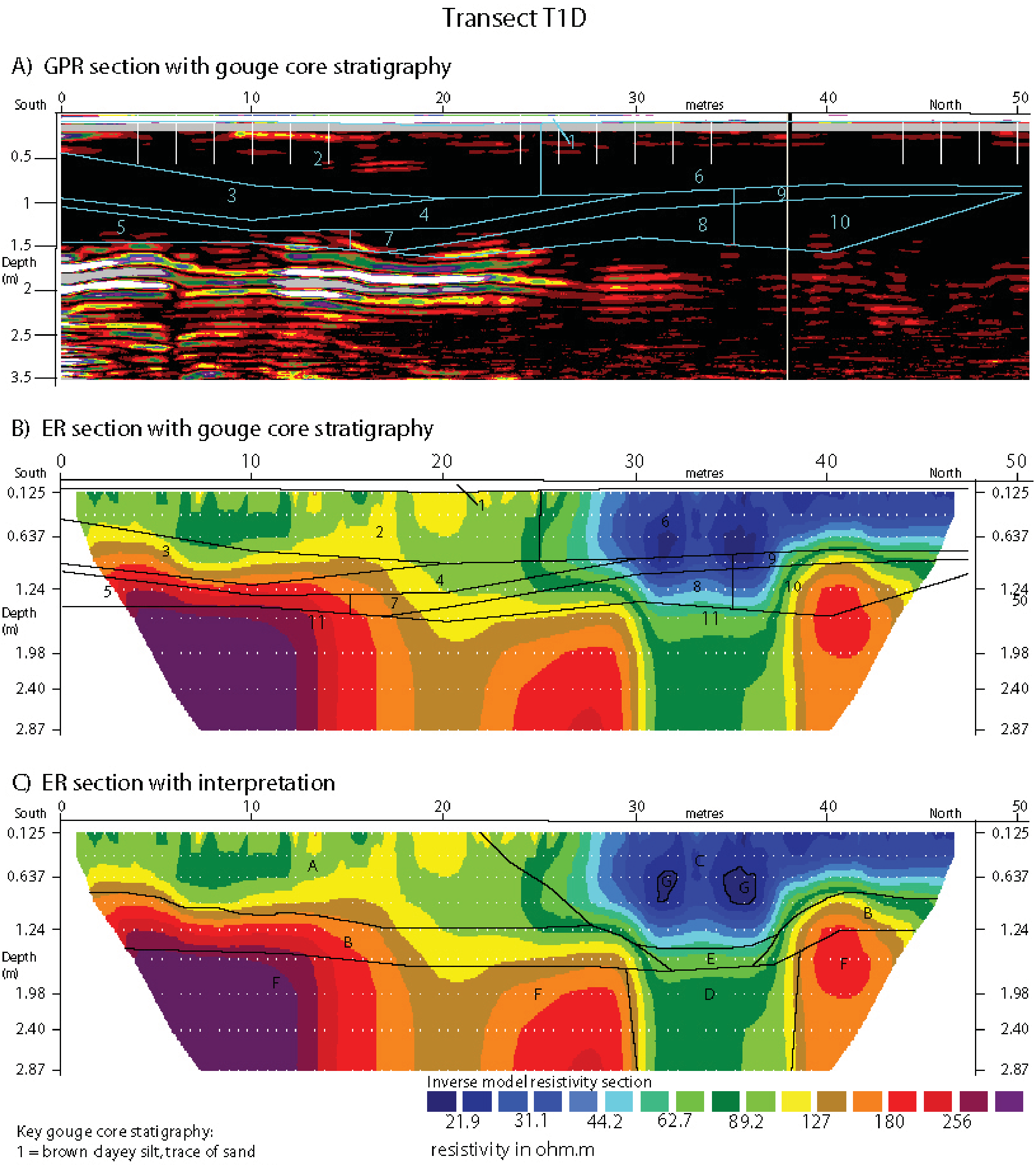


Fig 8.8: The ER transect T1C. The correlation in features between the GPR and gouge cores sections and the ER section is again high.



Key gouge core statigraphy:
1 = brown clayey silt, trace of sand
2 = red brown silty clay trace of sand
3 = gleyed grey clay, with Fe and Mn mottling
4 = red brown sand with clay
5 = coarse red/brown/pink sand
6 = brown grey clay with Fe nodules
7 = blue grey clay with sand and Fe nodules
8 = blue grey sandy clay
9 = brown grey clayey sand
10 = red brown sand, small Fe nodules

Key for Interpretation:
A = terrace deposit silty clay
B = terrace deposit clayey sand
C = palaeochannel silty clay
D = gravel (low resistance matrix supported/higher water content)
E = palaeochannel basal sand
F = gravel (higher resistance clast supported/lower water content)
G = areas of lowest resistivity values within the palaeochannel

Fig 8.9: The ER transect T1D.