8.4.9 ER transect T1K

Transect T1K was also undertaken on terrace 1 (Fig. 8.24) and was located in the same place as transect T1A (section 8.4.1). Unlike T1A, ER transect T1K used a 2m electrode spacing, running for 95m. The aim was to compare the data obtained from the 2m electrode spacing with that obtained by the 1m electrode spacing. A GPR section and gouge core transect (10m core interval) were also undertaken. The ER transect T1K has a much greater depth of penetration to c. 15.5m (Figs. 8.25 and 8.26), than using the either the 0.5m or 1m electrode spacings. For this reason there is little point in comparing the GPR data with the ER section, due to the relatively shallow depth of GPR penetration compared to the deep penetration of the ER survey.

The ER section still clearly shows an area of terrace with a palaeochannel (Fig. 8.25). The relationship with the gouge core stratigraphy is strong, with the lower resistivity palaeochannel values dipping away from the higher resistance terrace feature in approximate agreement with the gouge core stratigraphy. The palaeochannel is dominated by unit 18 (blue grey gleyed clay with Fe and Mn mottling), unit 19 (blue grey clay), unit 20 (olive brown/dark grey clay) and unit 21 (olive brown/dark grey medium sand) and these correlate well with the palaeochannel identified on the ER section through low resistivity values (Fig. 8.26).

The ER section provides limited data to interpret the stratigraphy of the above gravel deposits. A higher resistivity unit is seen above the palaeochannel (unit E), with the above terrace alluvium just interpretable (unit A). The palaeochannel is well defined (unit D), with the gravel body evident (unit B). The Mercian Mudstone is visible as unit C. From the interpretation it is clear that almost half of the section depth is surveying Mercian Mudstone geology, not the gravels and alluvium, which are the strata of archaeological interest. Using the 2m electrode spacing there is a loss of data resolution in the upper profile, which contain the archaeologically important deposits. This loss of data resolution in the upper profile is highlighted by comparison with the 1m electrode interval transect T1A (Fig. 8.27).

The most striking comparison between the interpretations of T1K and T1A is the ability to define the palaeochannel morphology. T1A gives an excellent definition to the palaeochannel morphology, with a sharp boundary being seen with the gravel junction at the terrace edge and below the palaeochannel. In contrast T1K only produces a generic picture of the main geomorphological units. Although the palaeochannel is visible the detail of its precise morphology and within channel variation is lacking compared to T1A.

T1K summary:

- T1K used a 2m electrode spacing that gave a much deeper depth penetration (c. 15.5m).
- Most of the ER section surveyed Mercian Mudstone bedrock, which is archaeologically sterile.
- The archaeologically important units were at the top of the ER section, with relatively poor data resolution.
- There was still a good correlation between the gouge core stratigraphy and the ER section.
- The main geomorphological units along the transect were identifiable, but the definition of their morphology is poor compared to the 1m electrode spacing T1A survey.

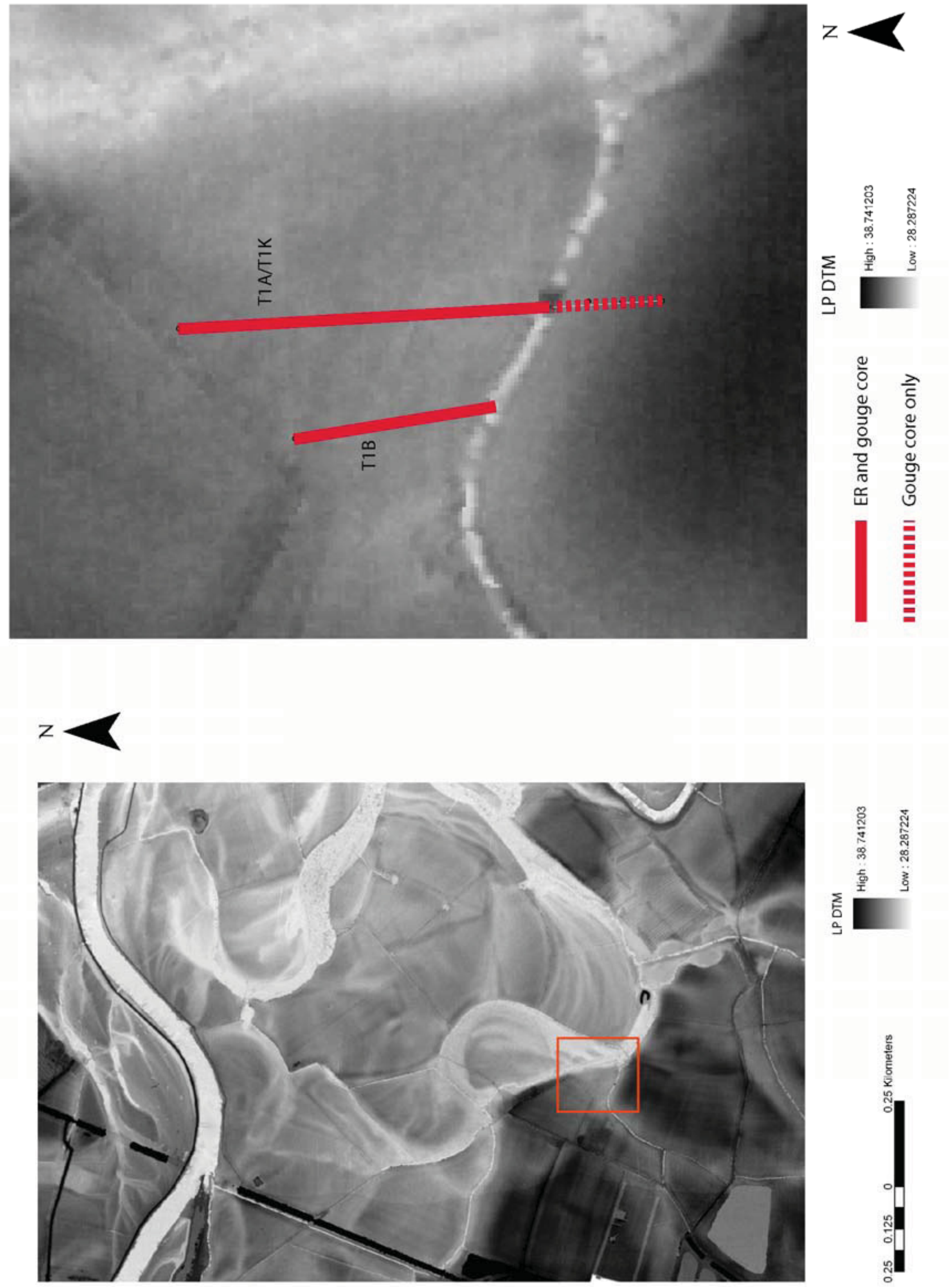


Fig 8.24: Location of ER transect T1K, on the same transect line as T1A.

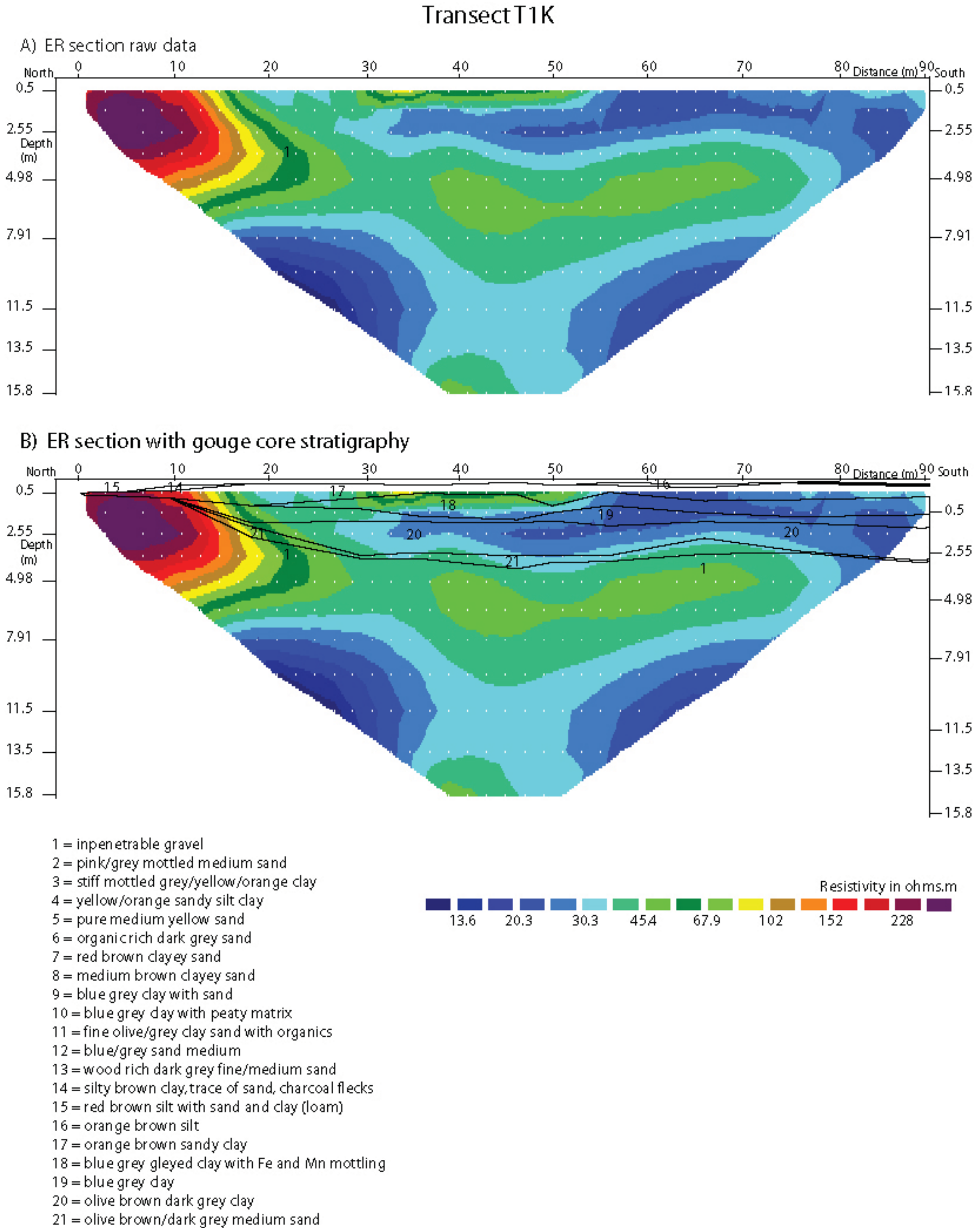


Fig 8.25: ER transect T1K, raw data (top) and with gouge core stratigraphy (bottom).

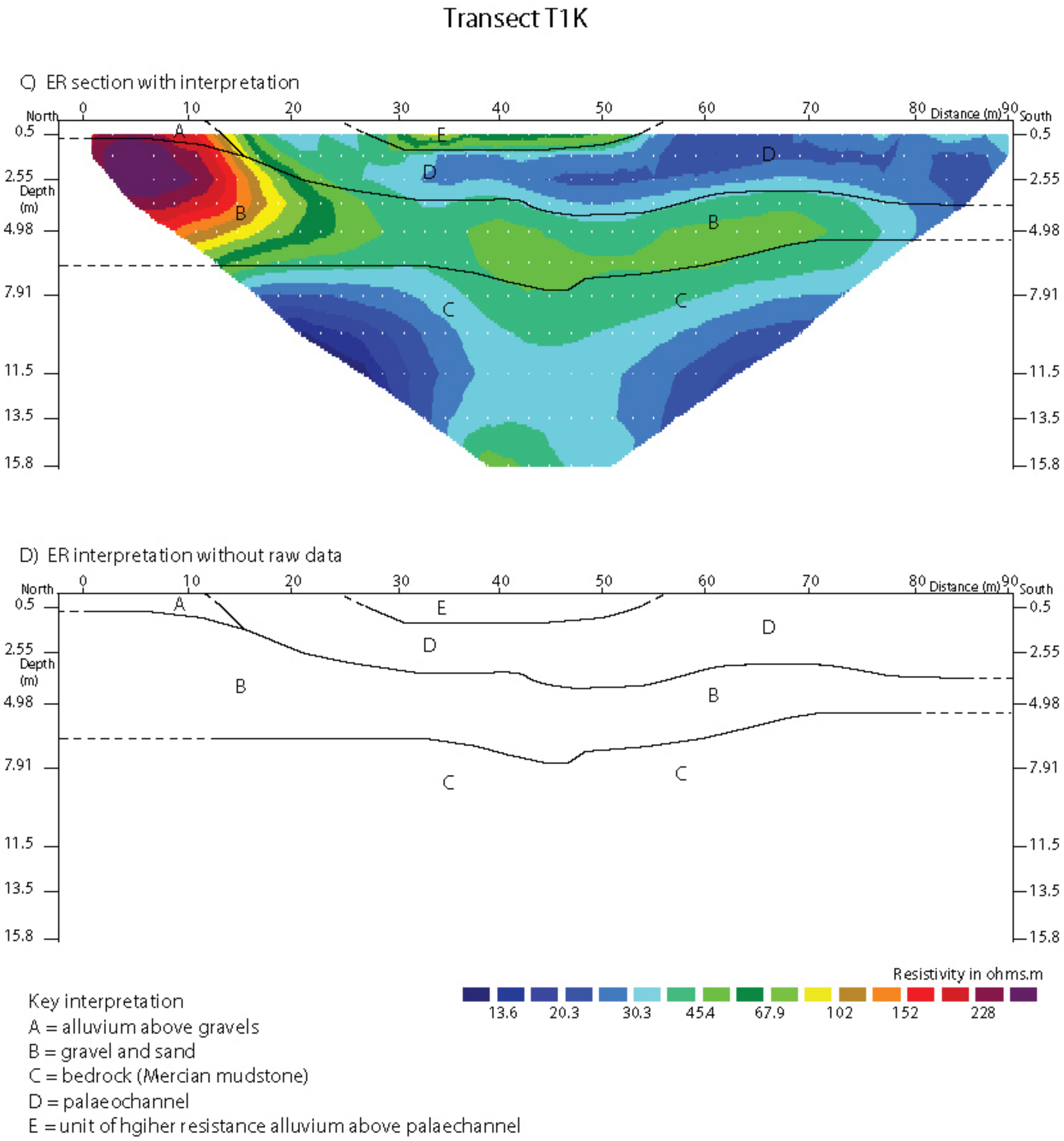


Fig 8.26: ER section T1K with interpretation.

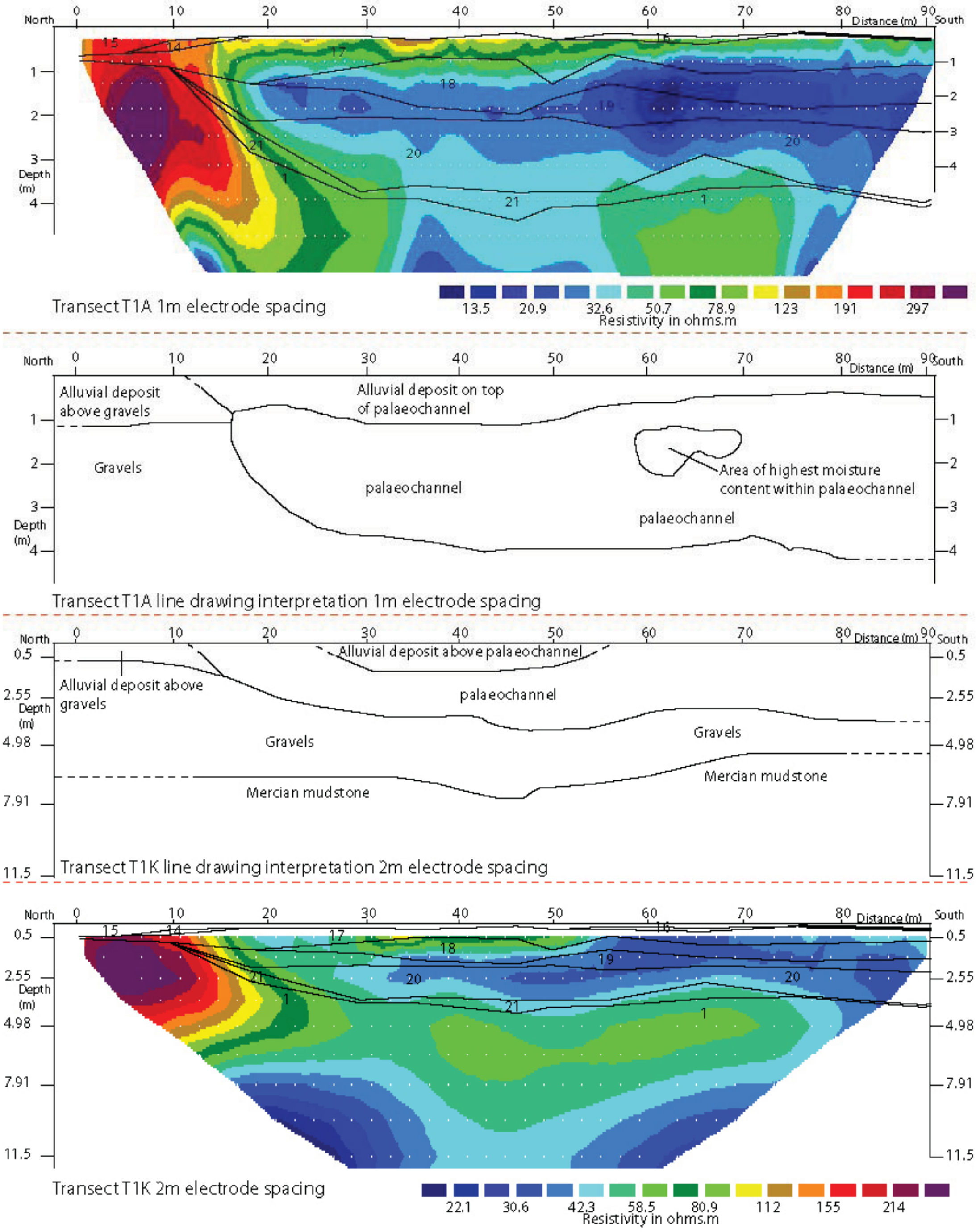


Fig 8.27: Comparison of the ER sections T1K and T1A, comparing the 2m and 1m electrode spacings. The 2m spacing has caused loss in data resolution in the upper section, with poorer definition of the main geomorphological units compared to T1A.

8.5 Modern Floodplain ER surveys

Two ER surveys were undertaken on a section of the modern floodplain. Both these sections followed the same transect but one was sampled with a 1m electrode spacing and the other with a 0.5m electrode spacing (Fig. 8.28).

8.5.1 ER Transect MFA 1m electrode spacing

The ER transect MFA was a long transect investigating two palaeochannels on the lower floodplain. The ER section clearly reveals the general morphology of the two palaeochannels (units A1 and A2), the general gravel body (units B and C), above gravel alluvium (unit D) and the boundary with the Mercian Mudstone (unit E) (Fig. 8.29).

The interpretation of the ER sections is relatively simple. The two palaeochannels are obvious as A1 and A2, separated by a bar at c. 50m, indicated as an area of deeper gravels, with shallow over gravel alluvium. This interpreted gravel bar occurs where unit C occurs, a higher resistivity value gravel unit, indicating either a clast supported gravel/lower water content gravel. Palaeochannel A1 is interpreted as being deeper than palaeochannel A2. Palaeochannel A1 has a relatively regular cross section, with the area of lowest resistance in the middle of the palaeochannel.

Palaeochannel A2 has a different morphology, with a steep bank on its southside indicating either an old river bank line or the edge of a chute channel. This morphology can be of use in deciding where to sample for palaeoecological remains. However, most of palaeochannel A2 is relatively high resistance and has a relatively low water content, indicating a lower biotaphonomic potential.

The two palaeochannels have little within channel variation evident at the 1m electrode spacing, acting as a guide to within palaeochannel sediment stratigraphy. However, based on the interpretation of this ER section palaeochannel A1 is deeper with lower resistivity values, indicating a higher biotaphonomic potential than palaeochannel A2. The over gravel alluvium is well defined (unit D) and is known to consist of an upper sediment unit of clayey silt, with a lower silty clay unit. The gravels are again clear, with the boundary with the alluvium, and the lower boundary with the Mercian Mudstone bedrock interpreted. Overall this ER transect reflects the general stratigraphy of this lower unit well, as ascertained in phase 1, with a generally low level of alluvium overlying terrace gravels

Transect MFA summary:

- Two palaeochannels (A1 and A2), the alluvium, gravels and junction between the bedrock and gravels are identifiable.
- The morphology of palaeochannel A1 shows a symmetrical channel form.
- The morphology of palaeochannel A2 shows a non symmetrical form, with a higher energy/erosive south bank and a lower energy/depositional north bank.
- Due to the deeper depth penetration the junction between the gravels and the bedrock is visible.

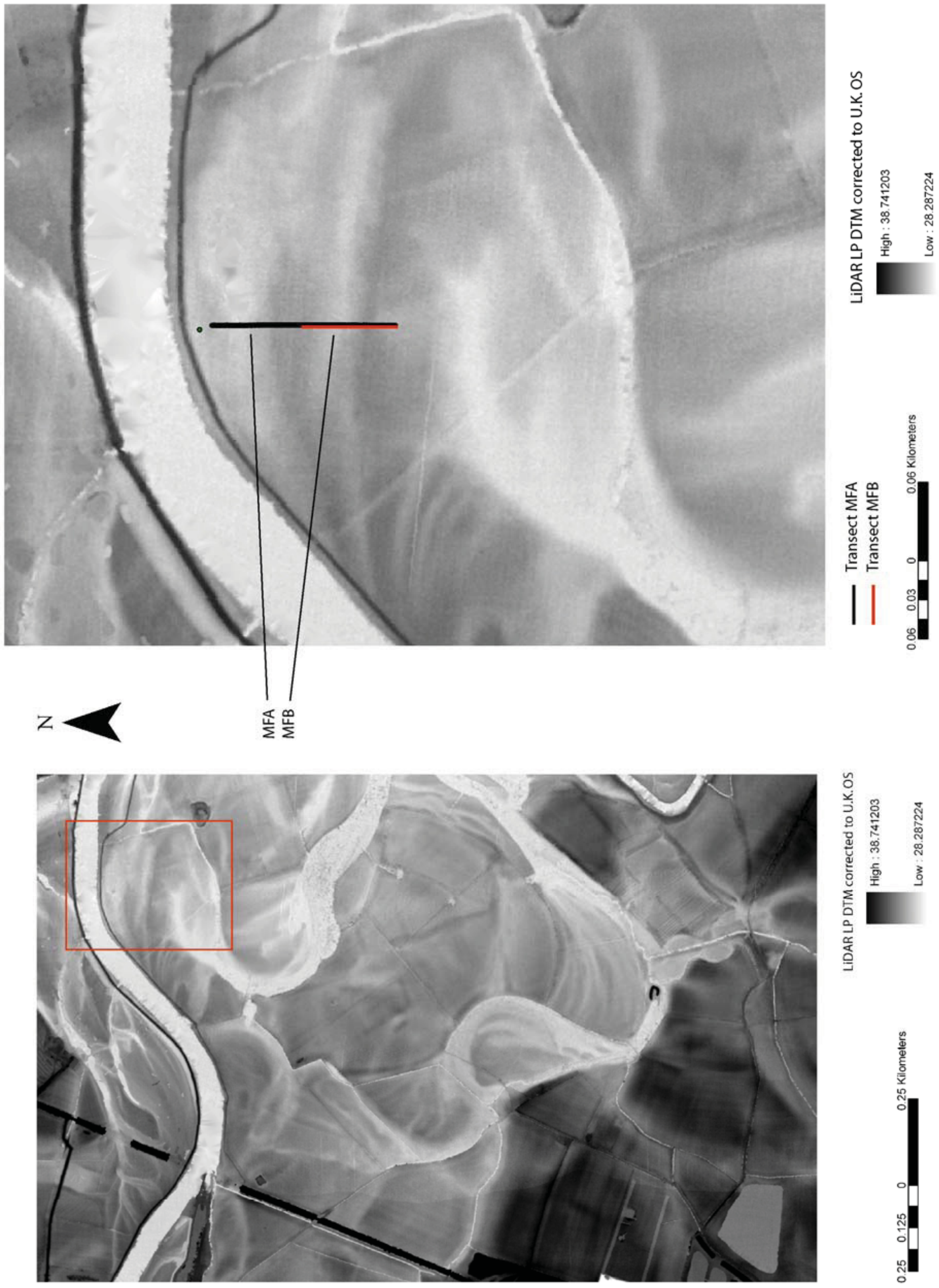
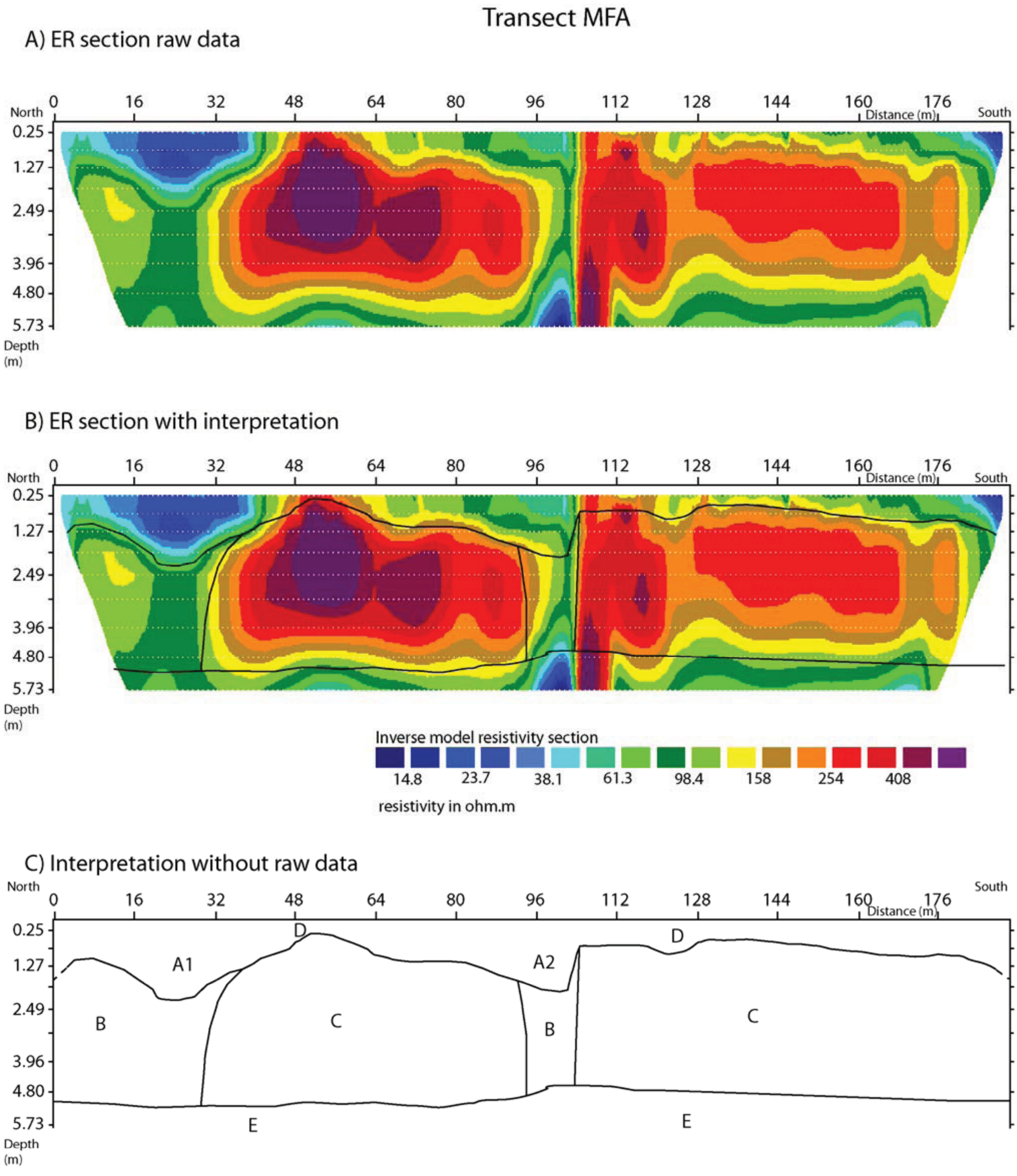


Fig 8.28: The location of transects MFA and MFB.



A = palaeochannel
B = gravel lower resitivity (matrix supported/higher water content)
C = gravel higher resisitivity (clast supported/higher water content)
D = above gravel alluvium
E = bedrock (Mercian mudstone)
F = area of lowest resitivity within palaeochannel

Fig 8.29: ER transect MFA.

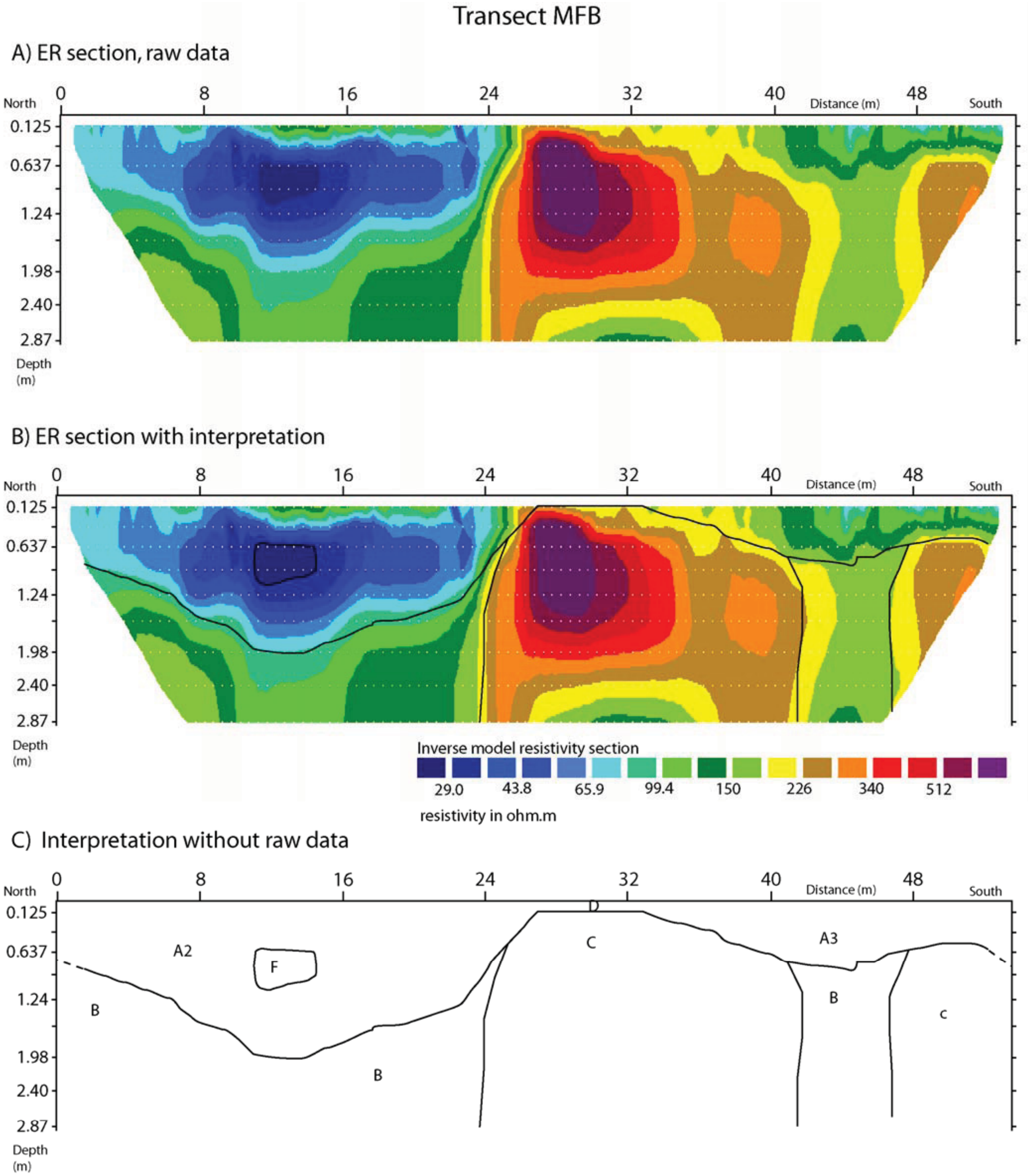
8.5.2 ER transect MFB 0.5m electrode spacing

The 0.5m electrode spacing MFB transect offers a useful comparison to the MFA 1m electrode spacing transect. The transect location relative to MFA is given (Fig. 8.28). Transect MFB started at 70m on the MFA transect and ran for 54m to 124m on the MFA transect, effectively covering palaeochannel A2. The aim of undertaking the 0.5m electrode spacing along the same transect line was so that a useful comparison could be made between the two. A general transect description will be given of transect MFB before a contrast with MFA.

The results from the 0.5m electrode spacing revealed a depth penetration to c. 3m (Fig. 8.30). The interpretation of the ER section is similar to transect MFA. Palaeochannel A2 has a much greater definition, with the palaeochannel morphology well defined and within channel variation evident. The junction at the base of palaeochannel with the gravels is clearly evident and the area of lowest resistivity value within the palaeochannel is highlighted (unit F). Again variation in the resistivity values of the gravels are evident, with another high resistivity value gravel bar (unit C) located just to the south of palaeochannel A2 and lower resistivity gravels located beneath the palaeochannels. Another shallow palaeochannel is also visible as unit A3.

Summary transect MFB:

- The morphology of palaeochannel A2 is more clearly defined than in transect MFA.
- The area of lowest resistance is seen within palaeochannel A2, indicating the area of highest biotaphonomic potential.
- Due to the shallower depth penetration the junction between the gravels and the bedrock is not visible.



A = palaeochannel
B = gravel lower resitivity (matrix supported/higher water content)
C = gravel higher resisitivity (clast supported/higher water content)
D = above gravel alluvium
F = area of lowest resitivity within palaeochannel

Fig 8.30: ER transect MFB.

8.5.3 Comparing 1m and 0.5m electrode spacing on the Modern Floodplain

The two ER transects on the modern floodplain provided a useful test for comparison of 1m and 0.5m electrode spacings. When Figs. 8.29 and 8.30 are compared there are several distinct differences between the two transects. These are summarised as:

- Both electrode spacings identified the main units of the palaeochannels (unit A), the above gravel alluvium (unit D) and the gravels (units B and C).

- Using both electrode spacings the gravel bar between the palaeochannels is evident.

- The 1m electrode spacing allows the junction between the gravel and the Mercian Mudstone to be interpreted. The 0.5m electrode spacing does not allow the depth of the bedrock/gravel interface to be seen, due to a shallower depth penetration.

- The 0.5m electrode spacing gives much greater clarity in palaeochannel morphology.

- The 0.5m electrode spacing brings out a much greater clarity of within palaeochannel variation when compared to the 1m, due to a greater data resolution at shallower depths.

- Although both diagrams are comparable there are differences in the general morphology between diagrams. For example the interface between the alluvium and gravel has much greater clarity from the 0.5m electrode spacing.

8.6 Methodological considerations of using ER

It is clear that ER survey has the potential to produce information for geoarchaeological assessments within alluvial environments. There are several methodological considerations when using ER is alluvial environments, which will optimise data capture and hence data usefulness. The following summary of ER methodology is derived only from the surveys undertaken on this project. Therefore, it is an assessment of ER applied to river confluences such as the river Trent, where alluvial sequences to the top of gravel is c. <4m. These can be summarised as:

1. Relationship of ER data to electrode spacings.
2. Relationship of ER data to stratigraphy.
3. Relationship of ER data to GPR data.

8.6.1 Relationship of ER data to electrode spacing

From the preceding discussions in chapter 8, it can be seen that three electrode spacings were experimented with for data capture, being 0.5m, 1m and 2m electrode spacings. Each of these three different electrode spacings provides different data capture characteristics. These are summarised (Tab. 8.1). To give an indication of cost/data capture ratios, each transect takes 50 minutes, regardless of electrode spacings at these intervals. Therefore, distance covered after 3 transects could also equate to distance covered after 2hrs 30mins

Electrode spacing	Maximum depth of penetration	Distance of first transect	Distance covered after 3 transects (2hrs 30mins)
2m	15.5m	94m	142m
1m	6m	47m	69m
0.5m	3m	23.5m	35.5m

Tab 8.1: Summary of field considerations of using different electrode spacings.

From this summary it can be seen that as electrode spacing increases, depth penetration increases, but there is an associated loss in data resolution. From the comparison it can be seen that the 2m electrode spacing allows rapid distance coverage and deep penetration. However, data resolution is generally poor in the gravels and alluvium, with most of the section detailing variation in bedrock, although features such as large palaeochannels are visible. Therefore, a 2m electrode spacing has very limited application in surveys within this type of alluvial environment, due to poor data resolution in the sediment units that are liable to contain archaeological materials dating from the Holocene.

The 1m electrode spacing provides good all round data capture, allowing features such as the bedrock/gravel junction and alluvium/gravel interface to be mapped. The detail in the above gravel alluvium is good, allowing identification of features such as palaeochannels and gravel/palaeochannel bounding surfaces to be identified. The whole gravel section is evident with using the 1m electrode spacing and variation in gravel structure is evident. Areas of higher and lower resistivity values can be identified, which has importance for identifying rare Pleistocene deposits that may contain organic material. The 1m electrode spacing allows a depth of penetration to 6m, which is sufficient within this environment and allows relatively rapid coverage. A 1m electrode spacing should be used for initial assessment of deposits.

The 0.5m electrode spacing allows a high level of data resolution within the upper gravels and the above gravel alluvium. The depth of gravels and the interface with bedrock is not evident, due to penetration being too shallow. However, the high level of data resolution in the upper deposits allows variations in resistivity values to become readily apparent, allowing areas of high biotaphonomic potential within palaeochannels to be identified. The rate of ground coverage is much lower than the 1m electrode spacing and therefore it is not suggested that the 0.5m electrode spacing is used for initial sediment assessment, but instead used selectively to target areas already identified though other techniques, e.g. gouge core survey or remote sensed data etc. A summary of the assessment of the different type of electrode spacings is given (Tab. 8.2).

Electrode spacing	Ability to identify above gravel alluvial variation (0 – 4m range), e.g. palaeochannel top of terrace	Ability to identify alluvial gravel interface	Ability to identify depth of gravels and variation within the gravel	Ability to identify gravel bedrock interface
2m	Low	Moderate	Moderate	Moderate
1m	Moderate	Moderate	High	Moderate
0.5m	High	High	Low/not possible	Low/not possible

Tab 8.2: Summary of the data capture properties of different electrode intervals.

8.6.2 Relationship of ER data to stratigraphy

The relationship of ER data to gouge core stratigraphy has shown that ER is successful in identifying large changes in subsurface sediment architecture, such as the difference between an area of terrace and a palaeochannel. ER sections do not have the ability to identify much smaller more discrete changes in stratigraphy, such as thin sand lenses interspersed by clay units in palaeochannel fills. The relationship of ER to sediment architecture, as revealed through gouge core survey, can be summarised under its ability to map 'macro-stratigraphy' and 'micro-stratigraphy'.

Macro-stratigraphy in this sense can be defined as the identification of major geomorphological units such as palaeochannels, gravels units, above gravel alluvium, etc. In this sense ER data can be used to identify these features and define their dimensions and morphologies. Numerous examples have been given of ER defining features such as palaeochannels, with these palaeochannels also revealed through gouge core survey. The relationship of the depth to gravels between the ER sections and the gouge core survey has also been very strong, with little disagreement between the two.

Microstratigraphy can be defined as the variation of sediments within macro-stratigraphic units, e.g. variation in the sediment architecture of a palaeochannel fill. In this sense ER is less useful, as slight changes between sediments e.g. a clay changing to a sandy clay, and also very thin sediment units, e.g. thin sand lenses in between clay units, were simply not evident in the ER data, even when using the 0.5m electrode spacing. However, some form of micro-stratigraphy was detected when changes in sediment composition between adjacent units were large, such as the change between a fine clay and a coarse basal sand in a palaeochannel.

Further to this changes in the composition of macro-stratigraphic features could be inferred based on resistivity values, although this would not directly relate to changes in sediment units as revealed through the gouge core survey. For example, palaeochannels had the areas of lowest resistivity values identified, and these were considered to be the areas of highest biotaphonomic potential. Such areas often corresponded to where the palaeochannel was deepest and therefore had a greater capacity to retain water. Such areas of low resistivity values did often correspond to recorded sediment units that had a high biotaphonomic potential, based on field observations.

In summary ER survey cannot be used to map individual sediment units. Macro-stratigraphic features such as palaeochannels are easily identifiable, as are large-scale variations within their composition. The depth to the gravels was consistent with that recorded by gouge core. However, if mapping individual sediment units is the goal of the survey it is essential to use gouge core stratigraphy combined with ER.

8.6.3 Relationship of ER data to GPR data

GPR had already been extensively tested within the Trent/Soar project, to assess its usefulness within alluvial environments. Its major shortcoming was its inability to penetrate and map the sediment within palaeochannels. Therefore, ER survey was used to investigate sediment stratigraphies of palaeochannel fills. As shown above (chapter 8), numerous transects were conducted using the duel approach of GPR and ER. This has allowed a comprehensive assessment of the two techniques working in tandem and the differences and similarities between them. Generally, the ER sections shown in this chapter were undertaken on palaeochannels or areas immediately adjacent to palaeochannels. From Phase I of this project it can be seen that these are the areas where GPR performed worse.

The comparison of the GPR data with the ER data is purely based on visualisation, not on numerical data values in this instance. It is acknowledged that mathematical modelling could be carried out between the two data sets, to investigate correlations between geomorphological features and numerical values. However, this is outside of the scope of the current discussion. Furthermore, as the identification of features was based on visual assessment of data, it is acceptable to compare data sets based on visualisation at this stage of the analysis.

Transect T1J is shown at a series of transparencies to illustrate the general comparisons between ER and GPR. From the four diagrams (Figs. 8.31 – 8.34) it is clear that both the GPR and ER reveal the depth to gravel, and both techniques correlate on this depth. The correlation between the ER and GPR data in the gravels is excellent, with both techniques identifying a series of higher reflecting/resistivity units in the gravels. The GPR reveals more of the internal structure of the gravel bodies, with the harder reflecting areas relating to the structure of gravel, i.e. a harder reflecting gravel equates to a larger clast size/drier gravel body. Likewise, the ER data displays areas of higher resistivity values where the GPR reveals units of higher reflectance in the gravels. Above the gravels the GPR reveals no real information on the stratigraphy of the alluvium. In contrast the ER section shows areas of lower resistivity values that define the morphologies of two palaeochannels.

This pattern has repeated itself throughout the combined ER and GPR transects. In all of the transects shown in this chapter GPR failed to map the sediments within the palaeochannels.
On the sides of the palaeochannels GPR has mapped the gravel bedrock interface, but generally not the alluvium above gravel. However, on areas of terrace GPR does have the ability to map individual sediment units, and as shown in Phase 1, this can be related to gouge core stratigraphies very closely. This is due to sharp boundaries between different units producing different RDP's and resulting in discontinuities. In contrast ER survey does produce data within palaeochannels. As discussed above (chapter 8) this does not necessarily relate to discrete sediment units identified through gouge core survey, but more generally changes in subsurface stratigraphy that reflect 'macro stratigraphy' not 'micro stratigraphy', i.e. a palaeochannel is identified, with areas of lowest resistivity values interpreted (macro-stratigraphy), but discrete changes in different sediment units in the palaeochannel fill as revealed through the gouge core are not revealed (micro-stratigraphy).

Thus the relationship between the two techniques and the data they can reveal is clear. ER sections can produce information on the morphology of palaeochannels and variation in resistivity values related to stratigraphy within palaeochannels. ER can also identify the depth to the alluvial gravel interface. In contrast GPR cannot be used to determine palaeochannel stratigraphy. It is of most use to map the depth to gravels and variations within the gravels composition. It can also be used to map areas of drier terrace to show changes in the above gravel stratigraphy.

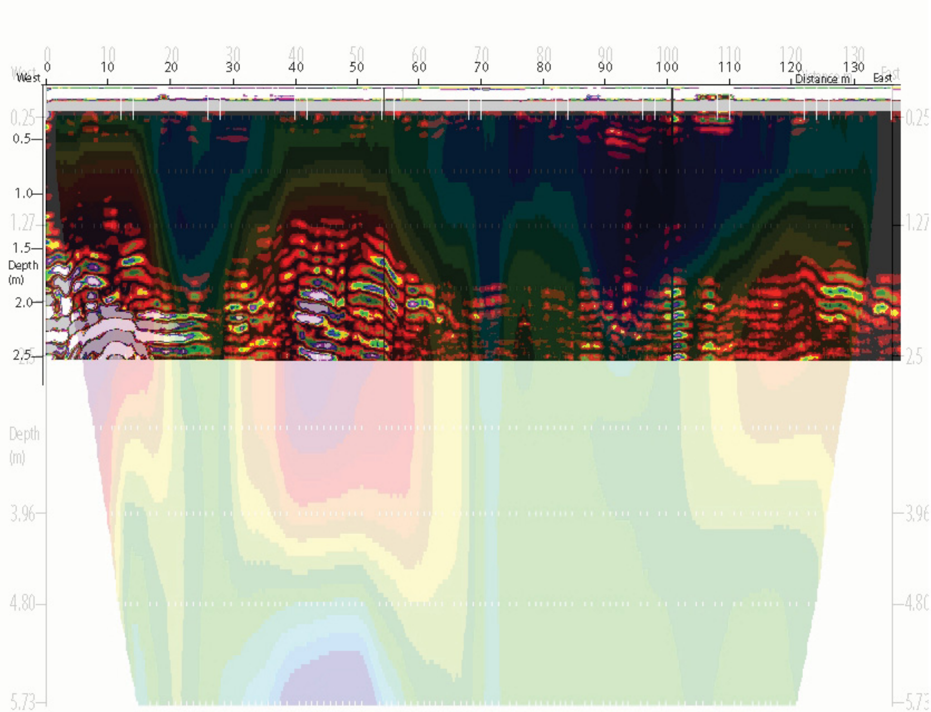


Fig 8.31: Combined visualisation of GPR and ER data, with the ER section at 80% transparency.

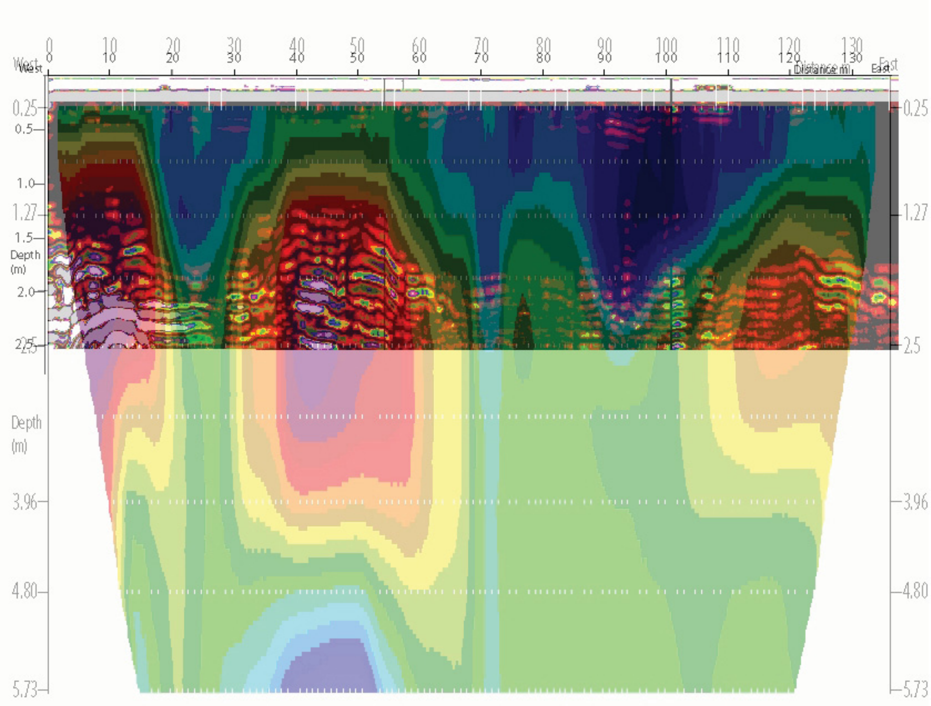


Fig 8.32: Combined visualisation of GPR and ER data, with the ER section at 60% transparency.

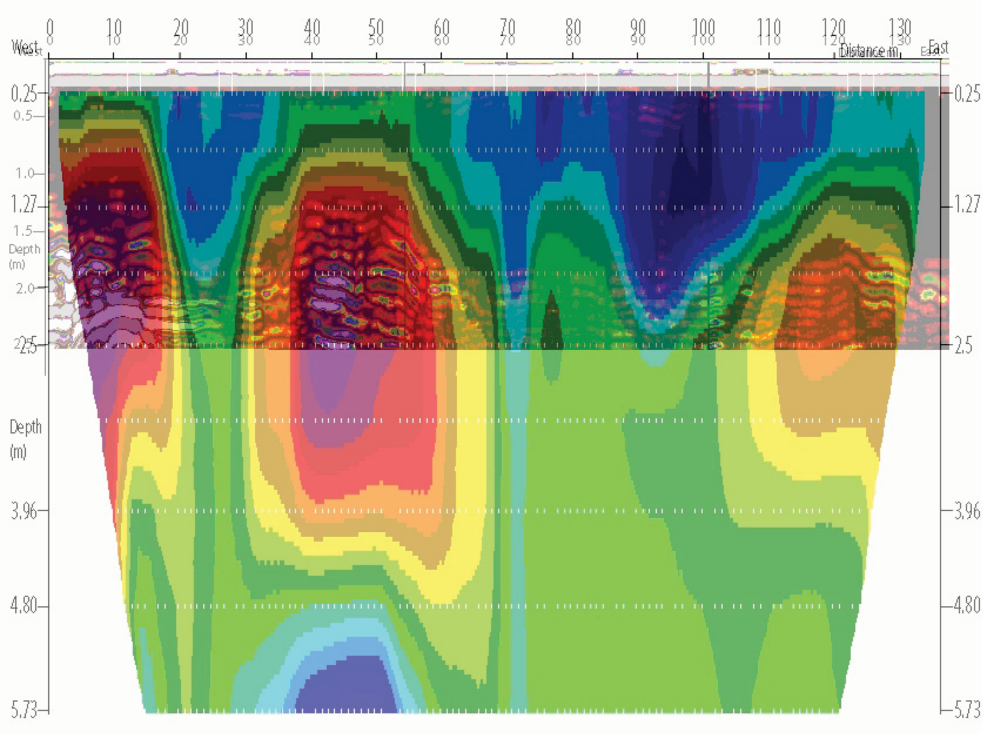


Fig 8.33: Combined visualisation of GPR and ER data, with the ER section at 40% transparency.

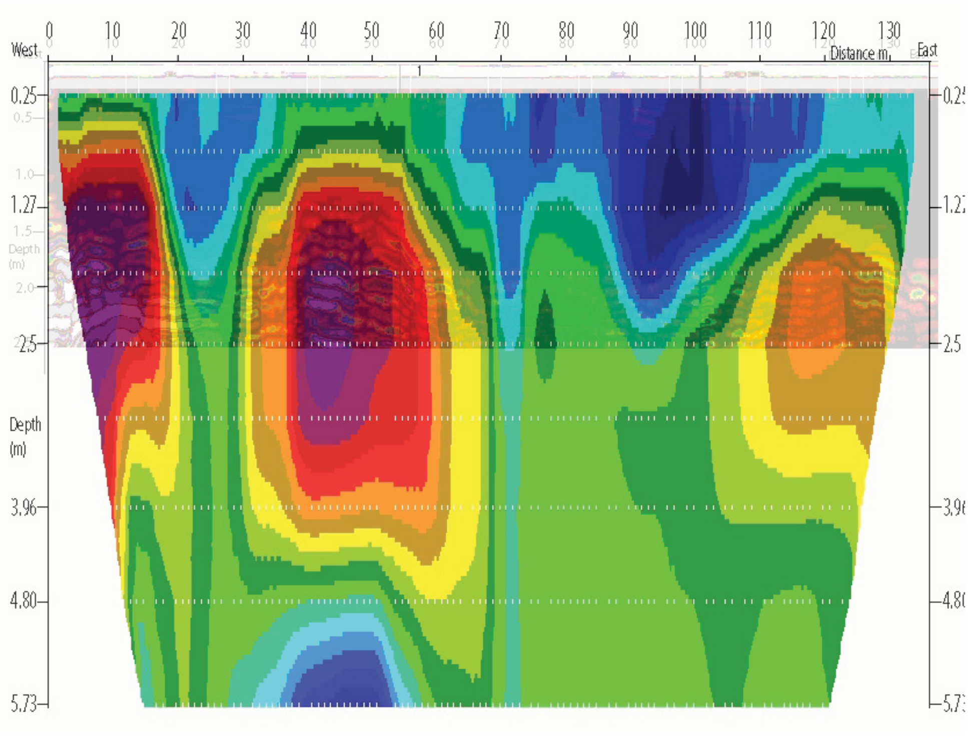


Fig 8.34: Combined visualisation of GPR and ER data, with the ER section at 20% transparency.

8.7 Ranking palaeochannels by biotaphonomic potential based on ER resistivity values

With the application of ER in this study, its ability to map palaeochannel and highlight variation in their composition has been discussed. However, is it possible to take this data further and rank the biotaphonomic potential of the different palaeochannels, based on their resistivity values? The resistivity values of the palaeochannels is partly a function of sediment architecture, although as discussed above, ER does not define discrete sediment units as mapped by gouge core survey. It is also a function of the depth and morphology of the palaeochannel and both of these have important taphonomic consequences for the preservation of organic remains.

Based on this logic it should be possible to rank the palaeochannels based on their lowest resistivity values and this ranking should relate to biotaphonomic potential. Although different electrode spacings were used, the resistivity values are given in ohm.m, and so it should be possible to compare between electrode spacings. This stated, a smaller electrode spacing gives better data resolution in the top 3m of the soil profile, which in this study is where the palaeochannels are located. Therefore, smaller electrode spacings are likely to produce lower resistivity values overall, due to their ability to map more variation in palaeochannel fills.

The ranking criteria is simple. The palaeochannel with the lowest resistivity value is considered to have the highest biotaphonomic potential. Whilst this is clearly a gross over simplification, it is known that palaeochannels display the lowest resistivity values where they are deepest. Thus factors such as depth and general channel morphology are already partly related to the resistivity value. However, it is obvious that it would be easier to provide a more complex model, factoring characteristics such as palaeochannel depth, palaeochannel width, etc.

From this simple criteria the palaeochannels are ranked (Tab. 8.3), with the palaeochannels at the top having the lowest value.

ER section	**Lowest within palaeochannel resistivity value**	**Electrode spacing**	**Biotaphonomic potential (based on resistivity values)**
T1E	5.1	1m	Highest
T1F	5.3	1m	
MFA	5.9	1m	
T1A	6.1	1m	
T1G	6.2	0.5m	
T1K	6.9	2m	
T1H	8.4	0.5m	
T1C	9.3	1m	
T1J	9.7	1m	
T2A	10.6 (gravel value)	1m	
T1D	12.7	0.5m	
MFB	14.2	0.5m	
T1B	15.6	0.5m	Lowest

Tab 8.3: Ranking of biotaphonomic potential of palaeochannels based on resistivity values.

From the table it can be seen that the resistivity values do show a broad trend in biotaphonomic potential. Palaeoenvironmental samples were taken from close to transects T1A/T1K, which were considered to have a high biotaphonomic potential. The palaeochannel in MFA A1 clearly has a higher potential than palaeochannel A2 in MFB.

From the ER transects within this study it can be seen there are a lot of palaeochannels with the range of between 6 – 10 ohms.m. This can be considered to be a median value, and any palaeochannels in this range should be cored for palaeoenvironmental samples. Palaeochannels with minimum values over this range of 10 ohm.m can be considered to have a low biotaphonomic potential. However, there are clearly factors that are also skewing this ranking order. Of prime importance is the degree of standing water within the palaeochannel. The palaeochannel investigated through ER transect F was interpreted 'in the field' as having a low potential, but it is very high in this ranking, primarily due to it holding standing water. In addition, the potential of a palaeochannel for palaeoenvironmental deposits is also a function of depth, which this particular model does not directly take account of. Thus although palaeochannel T1F is extremely shallow and has a low biotaphonomic potential in reality, based on this simple model it is given a high potential.

8.8 Overview and summary

Overall ER has been effective within this study. The main points of using ER within alluvial geoarchaeological assessments can be summarised as:

- Different electrode spacings produce different data outputs.
- A 1m electrode spacing should be used for initial assessment of subsurface floodplain features.
- A 0.5m electrode spacing should be used for more detailed investigations of specific features, e.g., detailed mapping resistivity variation of a palaeochannel.
- A 1m electrode spacing allows the alluvium/gravel junction, the depth of the gravel body and the gravel/bedrock interface to be seen.
- A 0.5m electrode spacing only allows the alluvium/gravel junction to be imaged, although greater data resolution is provided in the upper part of the profile.
- A 2m electrode spacing does not produce data of a sufficient quality to accurately map geomorphological features in this depth range (0 – 6m).
- ER can be used to map macro-stratigraphic features, e.g. palaeochannels, gravel bodies, etc.
- ER can be used to assess sediment variation within large geomorphological units, such as resistivity differences in palaeochannels and gravel units.
- ER is not effective at defining microstratigraphy, such as slight changes between thin layers of sediments within a palaeochannel.
- ER and GPR work well when combined together to model sub-surface stratigraphy.
- ER and GPR show good agreement on the depth to gravels on areas of terrace.
- ER works effectively with gouge core survey to define sub surface sediments.
- ER and gouge core stratigraphy show good agreement on the depth to top of gravels.
- ER is most effective at providing data on the morphology of palaeochannels and changes in their fill resistivities.
- GPR is most effective at defining sub surface stratigraphies on areas of terrace.
- ER cannot be used in absolute terms to define sub surface sediments, e.g. a reflective unit of 93.6ohms.m equates to a blue grey sandy clay unit. Rather, changes in subsurface sediments have to be interpreted from the contouring of ER section. This is a subjective process, rather than an exact science. Differences in interpretation between different human operators can occur!