Part 1: Palaeofluvial Analysis of the Confluence Zone of the Rivers Trent, Tame, and Mease, Staffordshire.

1. Introduction

The River Trent is the third longest river in the United Kingdom, measuring 274 km in length. It extends from its source in north Staffordshire, at Biddulph Moor, to the Humber Estuary where it enters the North Sea. The Trent is generally divided into three arbitrary reaches – the lower Trent Valley (extending from the mouth of the river to Newark, Nottinghamshire), the middle Trent Valley (between Newark and Burton-upon-Trent, Staffordshire), and the upper Trent Valley (between Burton-upon-Trent and the river source). Although a number of studies exist regarding the physical nature of the Trent and its deposits in the middle and lower reaches (e.g., Straw, 1963; Salisbury *et al.*, 1984; Salisbury, 1992; Large & Petts, 1996; Howard *et al.*, 1999; Mitchell *et al.*, 1999; Brown *et al.*, 2001), there has been comparatively little research conducted on the geomorphology and sedimentology of the upper Trent Valley. However, subsequent to the discovery of numerous archaeological features and the proposal to extract a large volume of fluvial aggregates at the confluence of the Rivers Trent, Tame and Mease, an opportunity to rectify the paucity of studies of the upper Trent was presented. This came about when the *Where Rivers Meet* Project was developed, funded by a grant from the Aggregates Levy Sustainability Fund. The aspect of the *Where Rivers Meet* project detailed in this report aims to describe the evolution of the three rivers based on geomorphological and sedimentological evidence. This analysis has implications for a better understanding of both the archaeology of the area and the fluvial dynamics of a part of the Trent Valley that has previously been neglected by research.

THE STUDY AREA

The confluence of the tributary rivers Tame and Mease with the main channel of the River Trent is located in the vicinity of the village of Alrewas, between Lichfield and Burton-upon-Trent, in south Staffordshire (Figure 1). A study area was delineated focusing on these confluences, which occur within a 400m stretch of the main river, and the location of this area is shown in Figure 1 (a more detailed geomorphological map of the study area is shown in Figure 2). The study area extends southwards for 5 km from the village of Barton-under-Needwood in the north, and eastwards for 3.5 km from the village of Alrewas, in the east. Both the A38 road and the main Birmingham-Edinburgh railway line extend southwest-northeast through the study area, and the major land uses in the area are arable farmland to the west of the railway line with quarrying to the east. Topographically, the area is largely flat and low-lying, although a prominent hill, consisting of glacial drift, is present in the northwest corner of the field area (see Figure 2). Other than this, the only topography of note is the river terrace of the Trent, which is raised between 1-2 m from the current active floodplain of the river (see Figure 2). The River Trent enters the study area from the west, flowing eastwards for 2 km before diverting its course northwards out of the area. Just upstream from this change in river direction are the two confluences, with the Tame joining to the west and the Mease joining to the east. The sites within the study area that are focused on in this report are the floodplain of the Trent near Alrewas, the raised river terrace in the vicinity of Catholme, and the two major quarries in the area. These quarries are Barton East, which extracts aggregate from the active floodplain of the Trent at Borough Holme, and Whitemoor Haye, which quarries predominantly terrace material to the east of the confluence of the Trent and Tame.

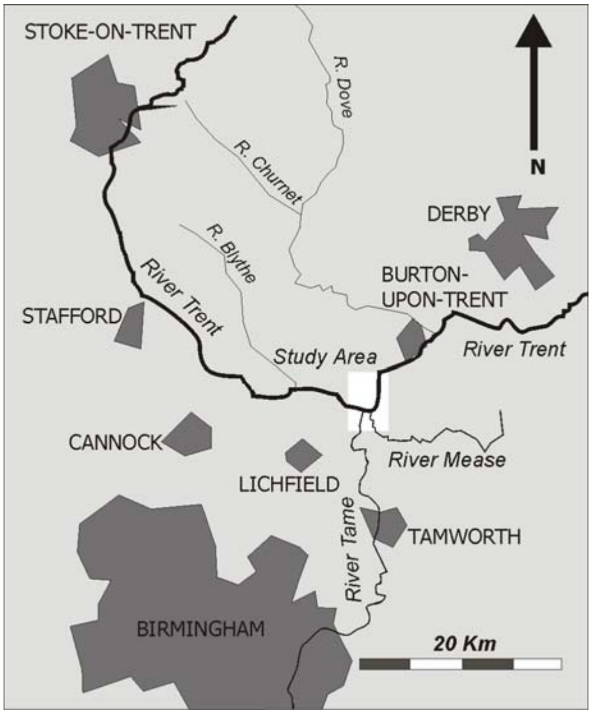

***FIGURE 1** – Map of the upper River Trent, highlighting the location of the study area.*

STRUCTURE OF THE REPORT

The aim of this report is to highlight the characteristics of the geomorphology and sedimentary deposits of the study area and, from this information, to detail the palaeofluvial evolution of the Trent/Tame/Mease confluence zone. It is structured into three main parts, followed by a discussion and conclusion chapter. **CHAPTER 2** presents a geomorphological analysis of the area, drawing on both fieldwork and secondary sources, such as maps and LiDAR data. This chapter provides an understanding of the changes in channel plan form and highlights the location of key geomorphological features at the study area. **CHAPTER 3** outlines the detailed work completed on a study of the sedimentary deposits of the confluence zone, utilising outcrop data from the quarries at Barton East and Whitemoor Haye and Ground Penetrating Radar surveys at sites on the Pleistocene terrace and on the modern floodplain. The first section of the chapter describes and interprets the type of sediments and the sedimentary environment in which they were deposited, and the second half of the chapter details the architecture of the sedimentary deposits and the implications this has for the study of the palaeofluvial evolution. **CHAPTER 4** then synthesises the information presented in the previous two chapters in order to provide a history of the fluvial system, from the Ice Age to the present day. Finally, **CHAPTER 5** compares the fluvial activity in the study area to the more downstream reaches of the Trent, and discusses the implications of the data in this report. A glossary of technical terms (shown in bold italics the first time they are used in the main text) is included as an appendix to the report.

2. River Channel Planform and Geomorphology

Channel planform is the pattern of the river system along a horizontal plane. It influences resistance to water flow, and is controlled by a number of factors, such as slope, sediment load, water discharge, sediment size, and bank stability (e.g., Knighton, 1998). The current planform of any river is also influenced by its historical development, and, thus, changes in the extrinsic controls on the fluvial system through time. Therefore, in order to fully understand the evolution of a fluvial landscape, it is necessary to evaluate the extrinsic controls, the physiographic setting (including antecedent conditions), and the historical development of the river system.

The River Trent has been active in the study area since before the ***Devensian*** glaciation (e.g., Straw, 1963; Gibbard & Lewin, 2003). Its deposits may be divided into those of a ***Pleistocene*** age (the river terrace), and the fluvial gravels overlain by alluvium which occur where the river has migrated laterally during the ***Holocene***. Both the Pleistocene and Holocene successions contain geomorphological data which can be used to ascertain previous channel planforms and extrinsic controls on the channel pattern, and these are highlighted on the map in Figure 2. The various geomorphological features that are listed in the legend of this figure were determined from a variety of sources, listed below:

- *The Current River Course and Villages, Roads etc.* – Compiled from 1:10,000 (1974) and 1:25,000 (current series) Ordnance Survey maps, as well as aerial photographs from 1964, and LiDAR data collected in February 2003.
- *Solid and Drift Geology* – Compiled from 1:50,000 British Geological Survey Maps; Nos. E140 Burton-on-Trent (1982), and E154 Lichfield (1926).
- *Palaeochannels* – Primarily interpreted from 1964 aerial photographs (which give coverage prior to the extensive quarrying activity to the east of the railway line), but also from more recent LiDAR data. Also from observations of visible elongate depressions in the field and from the field observations of Barrow *et al.* (1919) and Stevenson & Mitchell (1955), who worked in the southern part of the study area that now largely consists of flooded former quarries, and the geophysical survey of Raines *et al.* (1995).
- *Scroll bars* – 1964 aerial photographs plus field observations.
- *Palaeocurrent directions* – Measurements of direction dip of cross-stratification made at outcrops in Barton East and Whitemoor Haye quarries.
- *Ground Penetrating Radar Survey Sites* – Location of surveys (see Chapter 3).
- *Course of rivers/Additional Channels from 1884* – Taken from first series 1:25,000 Ordnance Survey maps (1884).
- *Course of rivers/Additional Channels from 1685* – Taken from large scale map within Robert Plot's *"The Natural History of Staffordshire"* (1686).

As can be seen in Figure 2, the landscape of the River Trent has not always maintained its current morphology, with multi-channel systems and different confluence points on the rivers having existed in the past. The following sections of this chapter discuss the main

geomorphological features of the study area; namely, the current river planform, the ***river terrace***, palaeochannels, islands, confluence zones, ***scroll bars***, and meanders, by describing the way in which the fluvial landscape has changed from the Pleistocene up until the present day.

CURRENT RIVER CHANNEL PLANFORM

The River Trent and its tributaries are all predominantly single-channel meandering systems. The Trent enters the study area from the west, flowing towards the east as two separate channels, which rejoin into one before the confluences with the Tame and Mease. However the bifurcated channel form in this part of the study area is not necessarily a natural state for the river system, as the northern channel has undergone extensive human modification, having been managed with concrete and sluices, in order to maintain a link with local canals.

Where the River Trent diverts to a northwards course, its planform is more typical of a meandering system, and exhibits a relatively high sinuosity[*] of 1.4. A number of the meanders along this stretch of the river also appear to be actively migrating outwards, as can be inferred from Figure 2 by the proliferation of widely spaced scroll bars on the inner bends of the meanders and the way in which the outer bends cut into the Pleistocene river terrace.

The River Tame is also a single-channel system, but shows less meandering than the Trent, with a sinuosity of 1.2. The sinuosity of the Mease has a value of 1.3, but its width and discharge are of a much smaller scale than the other two rivers.

Another important influence on river channels is the gradient of the slope on which they rest, and this varies across the study area. For the lower reach of the Trent between the Mease confluence and north of Fatholme, the gradient is just 1%, and this is not greatly different from the gradients of the Tame (2%) or the Mease (3%). However, at the upper reach of the Trent, between Alrewas and the Mease confluence, the average gradient is much higher, with a value of 6% (perhaps also partially accounting for the bifurcated form).

CHANNEL PATTERN CHANGES THROUGH TIME

Pleistocene Channel Pattern

During the Pleistocene, the width of the river system was much greater, and had incised a valley extending from the fluvio-glacial drift in the west, near Wychnor, to the ***Mercia Mudstone Group*** outcrop in the east, near Croxall (see Figure 2). The age of this incision has been dated by Straw (1963) to correlate with the end of the Devensian glaciation in the region. ***Palaeocurrent*** measurements taken from sedimentary structures within the Pleistocene deposits indicate that the fluvial system flowed towards the north-

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[*] $S = \dfrac{\text{channel length}}{\text{straight-line valley length}}$

east through this valley (see arrow on Figure 2), transporting and depositing reworked glacial drift sediments.

The fluvial system was primarily sourced by glacial meltwater discharge during the Devensian, and the study area was dominated by ***proglacial streams*** (see Chapter 3). Due to a lack of extensive stabilising vegetation in such an environment, bank stability is poor, and river systems can migrate laterally with greater ease and frequency. Hence, at this time, the river would have been a multi-channel ***braided*** system, characterised by channel instability. From comparison with modern proglacial streams (e.g., Smith, 1985), it may also be said that the system would have been highly seasonal, with discharge controlled by the different amounts of glacial meltwater released, and the transport of large blocks of detached melting ice. The large amount of water supplied by melting glaciers also results in much wider (up to 100 m) channels, as can be seen when comparing the green (Pleistocene) palaeochannels with the purple (Holocene) palaeochannels and modern channels in Figure 2.

Towards the end of the Pleistocene, two terraces were cut into the fluvio-glacial deposits due to the high discharge levels associated with warming climatic periods (Bridgland, 2000). The oldest of these was cut during the late Devensian (Straw, 1963) but is not present in the study area (although it can be seen both upstream and downstream on the Trent). The younger terrace was incised at the very end of the Pleistocene (Salisbury *et al.*, 1984; Brown *et al.*, 2001) and is present in the field area, raised above the active floodplain by 1-2 metres (see Figure 2). This terrace is now only submerged during extreme flooding events, and is the only part of the study area where archaeological artefacts are found.

Early Holocene Channel Pattern

After the development of the river terraces, the width of the area of fluvial activity diminished, resulting in the separation of the rivers Trent and Tame in the south-western part of the study area (see Figure 2).

Numerous palaeochannels are located within the areas of Holocene fluvial activity, and these have been highlighted on Figure 2. Unfortunately there is little dating evidence available to state with any certainty whether or not these channels existed contemporaneously with one another, although the presence of teardrop-shaped islands within palaeochannels to the south of Borough Holme appears to indicate that the river did bifurcate and merge in at least some of its reaches.

The presence of stable islands within the fluvial system indicate that both the Trent and Tame adopted an ***anastomosed*** planform subsequent to the ***Younger Dryas***. This would have been a consequence of the stabilisation of ***bars*** and river banks by vegetation as the local climate became more temperate, as well as a diminished discharge and runoff from early field systems resulting in the transport of more fine-grained alluvium which aided stabilisation. Thus, with reference to modern anastomosed streams, it can be said that channel changes would have been less frequent and probably related to major flooding events (e.g., Smith & Smith, 1980). It certainly appears that this anastomosed planform was the dominant channel pattern up until at least early human occupation, as can be determined from the –*holme* suffix of many of the local place names (i.e., Catholme, Fatholme, Borough Holme, Cherry Holme), which is a Norse or Old English suffix denoting an island of stable land within a river or marsh (Gelling, 1984). Hooke (1983) has also highlighted 7th Century manuscripts which refer to the building of churches on (presumably stable and mature) islands in the Trent near Burton, suggesting that the anastomosed planform was typical of much of the upper Trent until at least 1300 years ago.

Documented Channel Pattern Changes (1685 – Now)

The first series Ordnance Survey maps from 1884 and the maps within Plot (1686) provide documentary evidence of the most recent changes in channel planform. The river pattern in 1686 (see Figure 2) was still predominantly anastomosed, with an additional channel in the west of the study area, immediately north of Alrewas. The main channel of the Trent was also different, situated 500 m east from the present day course at Borough Holme, and incising into the river terrace deposits at Fatholme and Catholme. The final major difference at this time was that the River Mease was not a tributary of the Trent, but of the River Tame, with a confluence due east of Alrewas.

By 1884, a number of changes had occurred to the channel pattern (see Figure 2): the additional channel at Alrewas had been abandoned, the Trent had shifted to its current course at the east of Borough Holme (with an additional bifurcating channel in its northern stretch), and the Mease had diverted to its current confluence with the Trent. The former of these three changes may be due to agricultural land drainage and the management of the rivers in the west of the area, however the latter two changes represent relatively major ***avulsions***. River avulsion occurs when a bank of a river is breached during a flood, leading to a sediment splay and a new channel course establishing itself on the lowest part of the floodplain. This then leads to the abandonment of the original channel, as discharge is transferred to the new channel over a period of years (e.g., Smith *et al*., 1989). Flood records for the River Trent basin (Law *et al*., 1998; Brown *et al.*, 2001) indicate that there were three potential floods (in 1754, 1770, and 1795) that could have triggered the avulsions of the Mease and Trent, (Table 1), with the latest of these was the largest river flood ever recorded in Britain (Acreman, 1989). It is thus likely that the rapid reoccurrence of major floods during the late 18th Century was the driving force behind at least two known major avulsions on the River Trent.

Since the late 19th Century, the study area has undergone extensive land drainage in association with agriculture and quarrying. The original main channel at Borough Holme has been fully dredged, and the floodplain has been quarried. Due to river management, the upstream reach of the Trent has been relatively stable (except one incident of natural meander cut-off to the west of the Tame confluence), and there has been no change in the course of the Tame or Mease. Thus, the river has become a predominantly single channel system and the effects of this have been an increase in sinuosity in the downstream reaches of the study area, where the river has developed scroll bars and meanders in order to accommodate the discharge that was previously held by the second Borough Holme channel.

Year	Recorded Location	Rank
1255	Unspecified	
1309	Nottingham	
1315	Unspecified	
1322	Unspecified	
1346	Unspecified	
1570	Staffordshire	
1697	Unspecified	
1700	Unspecified	
1706	Unspecified	
1754	***Trent and Tame***	
1766	Nottingham	
1768	Nottinghamshire	
1770	***Widespread***	
1795	***Widespread – UK's Largest***	***1***
1852	Nottingham	
1852	Near Lichfield	
1855	**Middle Trent**	**8**
1869	Nottingham	
1872	**Burton-upon-Trent**	
1875	**Burton-upon-Trent/Nottingham**	**2**
1876	**Burton-upon-Trent**	
1878	Burton-upon-Trent	
1880	Alrewas	

Year	Recorded Location	Rank
1881	Burton-upon-Trent	
1883	**Burton-upon-Trent**	
1886	**Burton-upon-Trent/Tame**	**10**
1887	Burton-upon-Trent/Nottingham	
1888	Burton-upon-Trent/Nottingham	
1889	Burton-upon-Trent	
1895	Beeston	
1897	Beeston	
1900	Nottingham	
1901	**Chellaston/ Nottingham**	**9**
1902	Burton-upon-Trent	
1907	Unspecified	
1909	Chellaston	
1910	Nottingham	
1910	Chellaston	
1911	Chellaston	
1913	**Burton-upon-Trent**	
1930	**Burton-upon-Trent**	
1932	**Unspecified**	**7**
1946	**Middle Trent**	**6**
1947	**Middle Trent**	**3**
1952	**Middle Trent**	**4**
1960	**Middle Trent**	**5**

TABLE 1 – *The major floods for the Middle and Upper Trent valleys (compiled after Law et al. [1998], and Brown et al. [2001]). White cells show floods only known to have affected the Middle Trent; grey cells also affected Upper Trent. Most severe floods shown in bold; ranking of 10 most severe floods is that of Brown et al. [2001]). Candidates for avulsion trigger shown in white, bold and italicized font.*

SUMMARY

The planform of the River Trent has varied substantially since the Pleistocene. In its earliest form, the river was fed by seasonal glacial meltwater and had a high discharge and sediment load, resulting in a braided planform with high lateral mobility. As vegetation began to colonize the floodplain and the proportion of suspended sediment load increased, the bank stability became stronger, leading to the adoption of an anastomosed channel pattern. The anastomosed channels had less mobility than the braided channels and only avulsed when triggered by extreme flood events. This pattern was maintained until human activity began to influence channel pattern, through land drainage and river management. This led to the river adopting its current single-channel form with sinuous meanders developing in the downstream part of the study area.

3. Fluvial Sedimentology and Architecture

The previous chapter of this report was concerned with the development of the large-scale fluvial landscape of the study area, and this chapter aims to look in greater detail at the composition of the sediments that the evolving river deposited. By determining the characteristics and ***architecture*** of the sediments that make up the geomorphological features discussed in Chapter 2, it is possible to determine in greater detail how the fluvial landscape developed, in relation to river conditions, local physiography, and climate.

The sediments deposited by the fluvial systems in the study area consist of gravel, sand, mud and clay, which rest within a broad valley that was scoured into the Triassic bedrock during the Pleistocene (Straw, 1963). The thickness of these deposits across the area is 1.3-12.7 m, with an average thickness of 6.1 m. Given that the aerial extent of the fluvial deposits in the study area is c. 12 km^2. This means that there are approximately 7560^4 m^3 of fluvial sediments in the area.

Two techniques were employed to study the key parts of this large volume of sediment. Firstly, visits were made to the two quarries in the study area. Each quarry exposed different types of sediments, and the accessible outcrop at the two quarries was as follows:

- ***Barton East Quarry***: (Hanson Aggregates) Extensive three-dimensional exposures cut down to depth of bedrock (c. 8 m) in the south-eastern corner of the quarry, near Cherry Holme. Pleistocene and Holocene sediments exposed.
- ***Whitemoor Haye Quarry***: (Lafarge Aggregates) Less extensive exposures than Barton East, and age of uppermost deposits uncertain. Bulk of the succession is Pleistocene. Only one gravel pit was available for study, where the thickness of the deposits was c. 5 m.

The quarry studies enabled much sedimentological and architectural data to be gathered, but these were obviously geographically restricted by outcrop availability. Thus a second technique was employed to ensure that the outcrop data was typical for the entire study area, through the use of Ground Penetrating Radar (GPR). The use of GPR is becoming increasingly common as a tool for surveying sedimentary deposits (e.g., Jol & Bristow 2003, for a review of the technique), and may be particularly useful where outcrop exposures are limited. For the purposes of this study, a total of 6.9 km of lines of GPR data were collected using a 200 MHz *Geophysics Survey Systems Inc. (GSSI)* single-unit antenna and receiver, and processed using the *GSSI RADAN* computer software. This allowed a set of radar facies to be developed which could be compared with outcrop data to assess the subsurface architecture of non-quarried areas of the floodplain.

OUTCROP DATA

The outcrop at Barton East and Whitemoor Haye quarries was studied using a variety of field sedimentological techniques, including the collection of ***sedimentary logs***, lateral tracing of sediment bodies and ***bounding surfaces***, palaeocurrent analysis, and identification of grain-size trends and sedimentary structures. These data enabled a series of descriptive sedimentary ***facies*** to be developed, highlighting the different types of sediment which make up the fluvial deposits of the study area. The details of these facies are shown below, in Table 2.

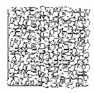
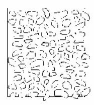
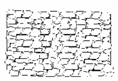
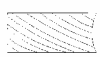
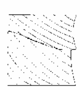
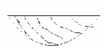
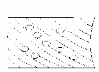
FACIES	APPEARANCE	DESCRIPTION	INTERPRETATION
G1		Fine clast- and matrix-supported gravel (1-8 cm clasts) with a filled framework of sand (and a minor component of mud/silt).	Deposition during low water stage of waning flow.
G2		Matrix-supported gravel (3-20 cm clasts) with infilling fine gravel and sand.	Deposition during intermediate water stage of waning flood flow.
G3		Coarse clast-supported gravel (5-30 cm clasts), with crude horizontal imbrication.	Deposition during high water stage of a flood flow event.
G4		Fine clast-supported gravel (1-8 cm clasts).	Deposition by minor flood surges or intersurges.
S1		Trough cross-stratified sands.	Deposition of sand bars and dunes by waning in-stream traction currents.
S2		Stacked trough cross-stratified sands with erosive bases.	Deposition and reactivation of sand bars and dunes by multiple waning in-stream traction currents.
S3		Trough cross-stratified lenticles of sand within gravel deposits.	Deposition by waning traction currents, within scours.
S4		Trough cross-stratified sands with pebbly foresets.	Deposition as a sand bar, where fluctuations in flow stage occur over the crest of the bar.
M1		Black clay-rich silts.	Overbank deposition of fines by settling from suspension.
M2		Inclined lenticles of black clay-rich silts within gravel deposits.	Settling from suspension onto gravel bedforms prior to raised water stage and bedform reactivation.

***TABLE 2** – Table showing the description and interpretation of the ten different sedimentary facies identified at outcrop.*

These sediments form varying proportions of the fluvial sediments in different parts of the study area, and are discussed in further detail in the following sections. However, Figure 3 gives some idea of how the types of sediment vary vertically when expressed as sedimentary logs.

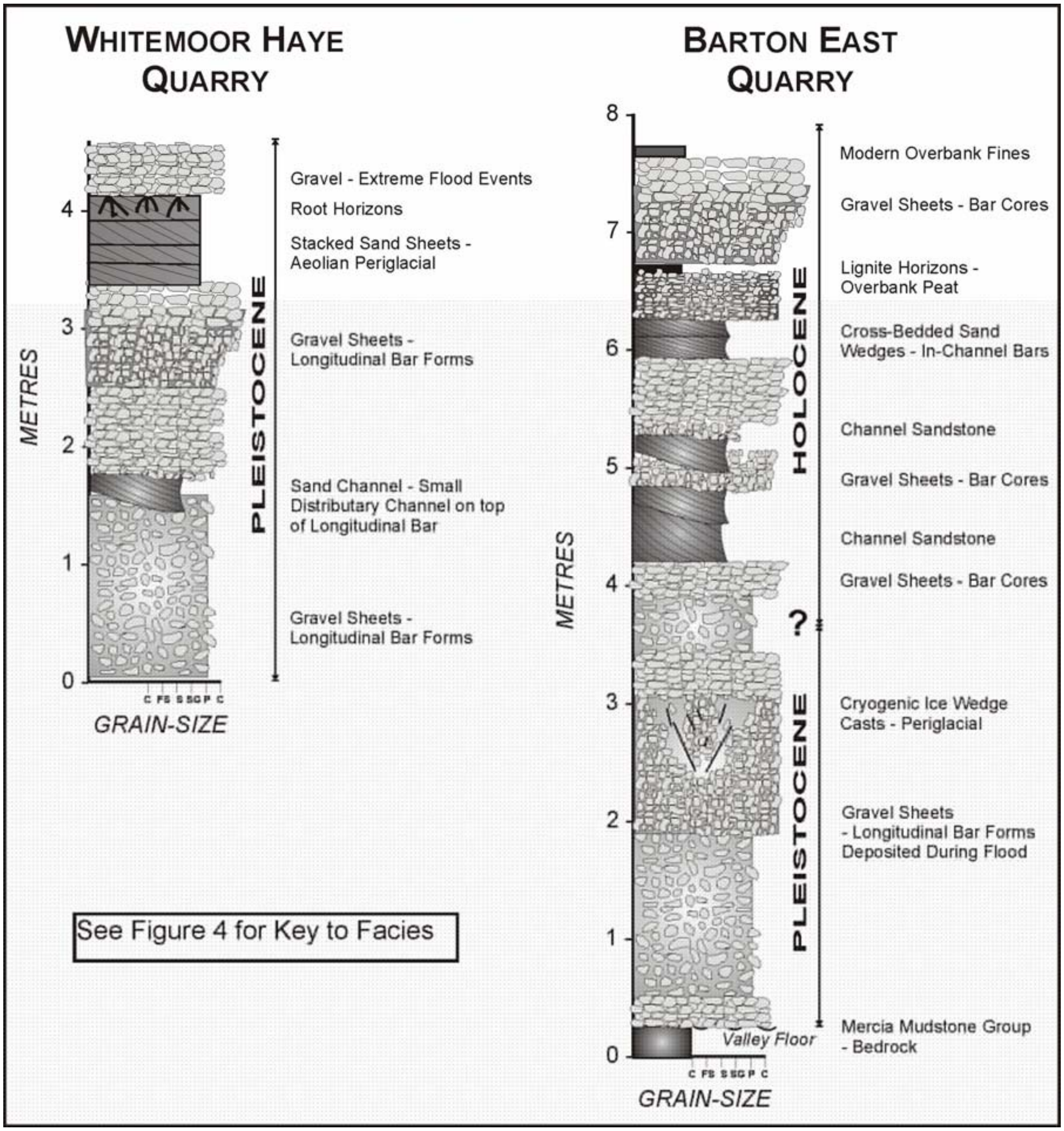


***FIGURE 3:** Composite sedimentary logs showing typical vertical sections through the fluvial deposits at Whitemoor Haye and Barton East quarries.*

PLEISTOCENE DEPOSITS

The Pleistocene deposits within the study area consist of facies G1-G4 (c. 80% of the total succession), S1 (c. 15%), and M2 (< 5%) and are overlain by well-developed soil on the river terraces, and by Holocene sands and gravels on the active floodplain. They are stained red, due to the weathering out of ***hematite*** from the underlying Mercia Mudstone Group, and contain isolated ***cryogenic*** features, such as ***ice-wedge casts*** (Figure 4). The presence of ice-wedge casts can be used to infer the former presence of ***permafrost*** within the study area (Murton & Kolstrup, 2003).

FIGURE 4 – *Photograph of cryogenic ice-wedge cast within facies G2 of the Pleistocene succession. Barton East Quarry, near Cherry Holme. Camera case (18 cm) for scale.*

Three major architectural elements may be witnessed within the Pleistocene succession (see Figure 7); namely, (1) Gravel Sheets, (2) Channels, and (3) Sand Sheets – the characteristics and significance of which are discussed below:

Gravel Sheets

Thick (up to 2 m) gravel sheets consisting of a combination of G1-G3 facies, and thin (< 0.7 m) gravel sheets consisting of G4 facies, account for around 70-80% of the architectural elements witnessed within the Pleistocene succession. The sheets are laterally continuous, and occasionally grade into one another, such that it becomes impossible to trace a bounding surface for a long distance. The bounding surface at the base of the gravel sheets is typically gently undulating, indicating an erosional boundary which has removed the top layer of the underlying sediments. Where the gravel sheets are thickest, it is possible to see a series of facies sequences grading upwards from G3 to G2 to G1, and reflecting deposition by major episodic pulsed flood events.   The thinner gravels sheets consist solely of G4 facies and reflect more minor flood events. The presence of such flood deposits in sequential order attests to the pulsed seasonal deposition that is typical of streams in proglacial environments (Smith, 1985), and these gravels would have remained in the fluvial systems as longitudinal braid bars.

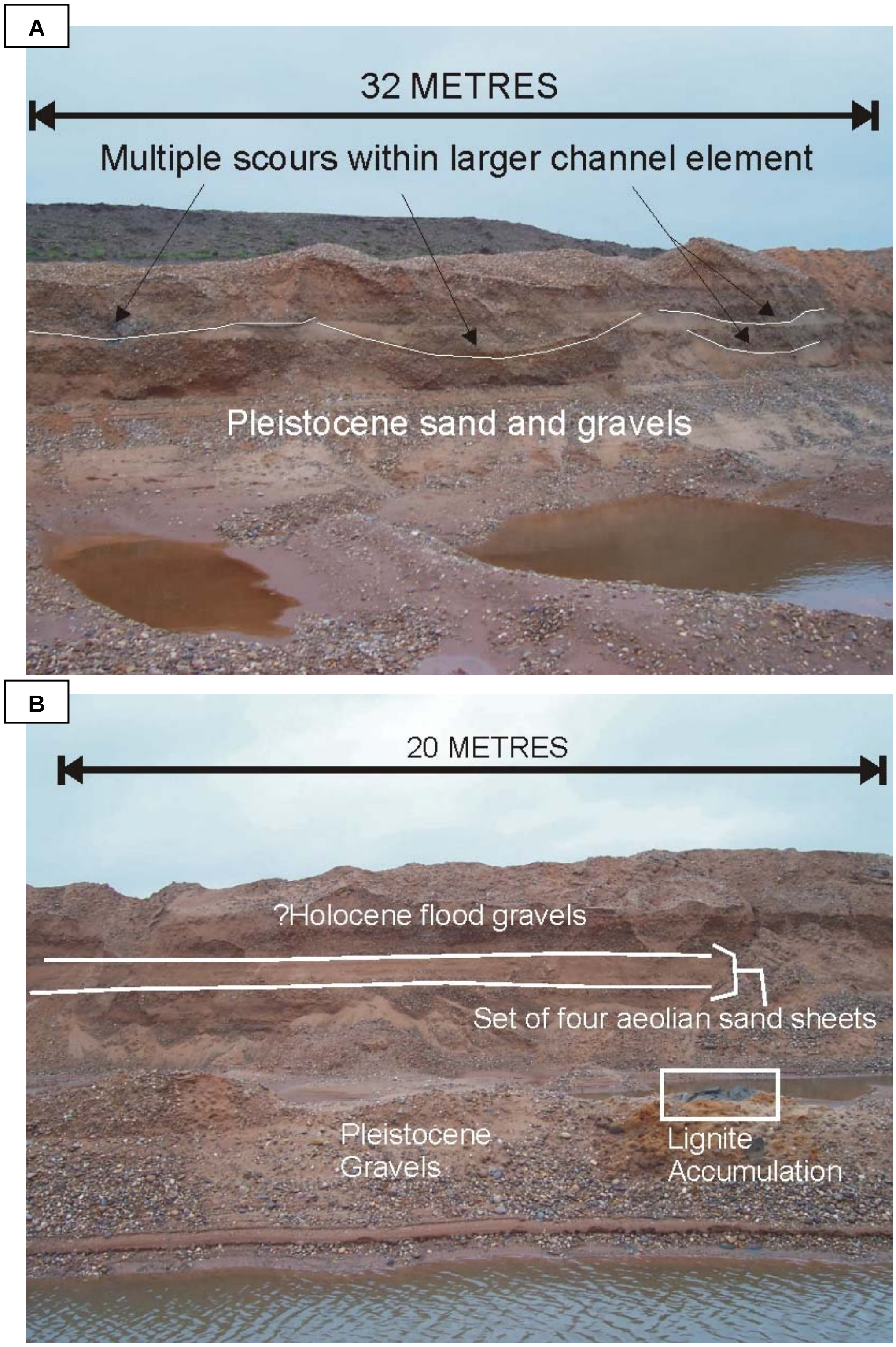


FIGURE 5 *- Photographs showing typical outcrop of the 5 m of Pleistocene deposits at Whitemoor Haye quarry: (A) Lower part of the succession, exhibiting multiple scours at the base of a larger channelised architectural element; (B) Stacked sand sheets within the gravel deposits of the upper part of the succession.*

Channels

Concave-upwards bounding surfaces within the Pleistocene succession may mark the base of either S1 or G1-G3 facies, and thus reflect channelised deposits of different types of sediment. The channels with sand infill have widths of 5-16 m, and an average width:depth ratio of 9:1. The margins of these sand filled channels are typically cross-bedded, although the central parts of the channels may be massive or have more horizontal laminae, and the sand grains are fine and sub-angular in texture. In contrast, the channels which have a gravel-infill have a much greater dimension, with thicknesses of 1.5 m or more. The lateral dimensions of these channels are often too great to be seen in outcrop (i.e., a much greater width:depth ratio, up to c. 25:1), and can only be identified by the way in which a diagonal bounding surface cuts across planar bounding surfaces, indicating the edge of a channel. The presence of facies G1-G3, which occur within the channels in a repetitive sequence akin to that of the gravel sheet elements, suggests that the gravel channel elements are the lateral equivalents of the sheets, and that the large dimensions of the channels mean that they only appear sheet-like in the central parts of the channels (see also the remarks on the width of the palaeochannels in the previous chapter). Such channels may be typical of proglacial braided river systems with sparse vegetation cover, which have a sheet-like appearance because the absence of stable banks mean the rivers can migrate with extreme lateral mobility. The sand channels likely represent small overspill channels, perhaps transporting fine-grained sediment across bars within the fluvial system.

Sand Sheets

In the uppermost 3-4 m of the succession at Whitemoor Haye Quarry a number of stacked, laterally continuous and unchannelised sand sheets can be witnessed, truncated against one another by laterally persistent planar bounding surfaces. Each individual sheet is no more than 0.4 m thick, but stacked sets of such elements may be up to 1.5 m. The sheets exhibit low angle (< 30°) planar ***cross-stratification***, and the sand from which they are comprised is medium-grained and red coloured. The sand grains are extremely well-rounded, and – many are almost completely spherical – suggesting a different origin to the Pleistocene channelised sands, and all the Holocene sands described later. The sand sheets are also unique in that they also show evidence for having been colonized by vegetation, and laterally extensive horizons of blackened plant rootlets can be seen at the upper bounding surface of many of the units (Figure 6).

The features of this architectural element, detailed above, can be used to infer an ***aeolian*** origin for the sand sheets at Whitemoor Haye Quarry. Wind-deposited sand sheets are common in permafrost areas as where there is a limited availability of loose, dry sand and it is therefore impossible for sand dunes to form (Lea, 1990). Such aeolian sand sheets are typified by the very well-rounded sand grains, reddened colour, and low-angle cross-stratification witnessed in the Whitemoor Haye sand sheets. The truncation of each of the sand sheet elements by the laterally persistent planar bounding surfaces reflects horizons where the depth of aeolian ***deflation*** has been limited by subsurface permafrost (Good & Bryant, 1985). Further evidence for the environment of deposition may be found in the presence of root horizons within the sand sheets, indicating that they were at least sparsely vegetated. However, vegetated permafrost-influenced sand sheets are rare in low lying areas adjacent to active rivers, because this is where deflation is most severe (Dijkmans & Törnqvist, 1991). Therefore, these vegetated aeolian sand-sheets are likely to have been deposited immediately subsequent to the commencement of river terrace incision, when the topography at Whitemoor Haye would have been slightly raised from the braided rivers that deposited the gravel sheets and channels.

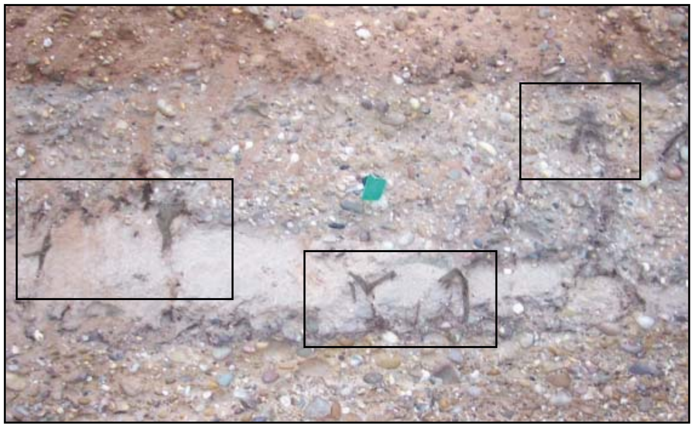


***FIGURE 6** – Photograph showing blackened rootlets (highlighted within boxes) within a sand sheet. Whitemoor Haye Quarry. Key fob (7 cm) for scale (centre of photo).*

HOLOCENE DEPOSITS

The Holocene deposits of the study area consist of facies G1-G4 (c. 50-60% of the total succession), S1-S4 (c. 40%), and M1-M2 (c. 5-10%), which are overlain with recent alluvium and occur in the tract of low-lying land between the modern river and the raised terrace areas. Unfortunately, due to a lack of dated horizons, the exact boundary between the Holocene deposits and the underlying Pleistocene deposits is unknown. Unusually, there is no major bounding surface separating the differently aged sediments, as may have been expected to have developed subsequent to the terrace incision. This suggests that the nature of the Holocene-Pleistocene boundary is either merely ***disconformable***, or that the upper part of the Pleistocene succession has undergone reworking to an extent that the boundary has become indistinguishable on the basis of an erosive surface (deep reworking of sediment at confluence zones along the Trent is common [Large & Petts 1996]). For the purposes of this study the boundary has been defined on the basis of colour, as it appears that the lower red-stained (hematite-rich) gravels and sands may be Pleistocene in age while the less reddened sediments above are likely Holocene. This reflects the Pleistocene-Holocene colour trends also seen in other sedimentary successions of the River Trent (Brown *et al.*, 2001). The colour contrast also coincides with a subtle change in the facies architecture of the deposits and the vertical termination of sediments containing cryogenic signatures. On this basis, the best outcrop of Holocene-aged sediment in the study area is found within the accessible outcrop at Barton East Quarry.

Four major architectural elements may be witnessed within the Holocene deposits (Figure 7); namely, (1) Gravel Sheets, (2) Sand Wedges, (3) Channels, and (4) Silt/Clay

Horizons. These elements are usually smaller in dimensions than those in the Pleistocene deposits, meaning that the Holocene succession is far more heterogeneous than the strata which it overlies. The characteristics and significance of the elements which comprise it are as follows:

Gravel Sheets

The gravel sheets within the Holocene succession are both thinner (only up to 1 m) and less laterally extensive than those within the Pleistocene succession, although they are still comprised of facies G1-G4. This is likely to be a result of reduced fluvial discharge, associated with the retreat of the Pleistocene glaciers. The Holocene gravel sheets would have been deposited only during extreme discharge events, but may have subsequently been reworked as longitudinal bars. The gravel sheets are interpreted here as representing the sediment core of gravel islands and bar forms that occurred within the channels of the fluvial system.

Sand Wedges

Wedge-shaped units of S1, S2, and S4 facies are seen within the Holocene succession, and are usually bounded at the top and base by planar surfaces (Figure 8). The wedges have a thickness of < 0.5 m and comprise sand-grade sediment of fine- or medium-grain size, the individual grains of which are angular or sub-angular in shape. Such elements are interpreted to represent mid-channel barforms or scroll-bars that formed in sections of the fluvial system which had a diminished flow. Where the sand wedges are separated by thin gravel layers (see Figure 8), the bar sediments have been deposited by shallow (c. 1 m) flows, where flow separation and particle over-passing has occurred on the bedform crest (Carling, 1990).

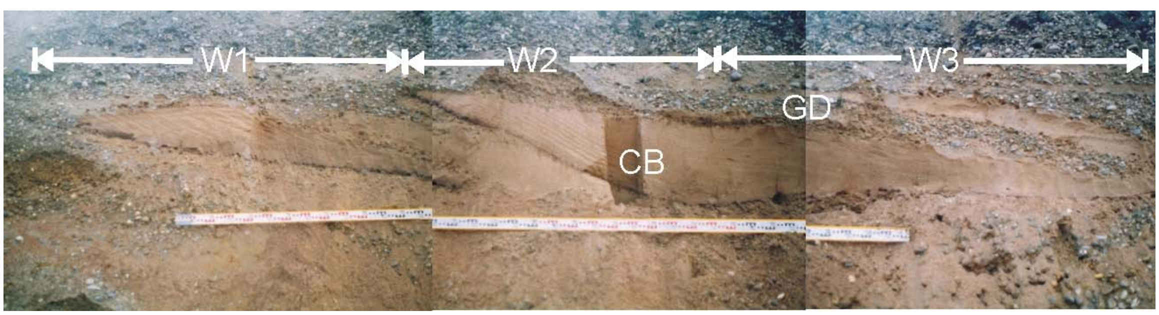


Figure 8 *- Photograph showing three sand wedge architectural elements (tops of wedges illustrated as W1, W2, and W3). Photograph also highlights cross-stratification within each element (CB) and gravel drapes (GD) where flow separation and particle over-passing occurred. Barton East Quarry. Ranging pole (4 m) for scale.*

Channels

Unlike the Pleistocene succession, only sand-grade sediment (facies S3) occurs in channels within the Holocene succession (Figure 9). The dimensions of the channels are also smaller, with widths of less than 12 m, and depths of less than 1 m, and the width:depth ratio has an average of 8:1. These channel deposits represent the main channels of the fluvial system subsequent to the diminishment of discharge associated with the development of a more temperate climate throughout the Holocene.

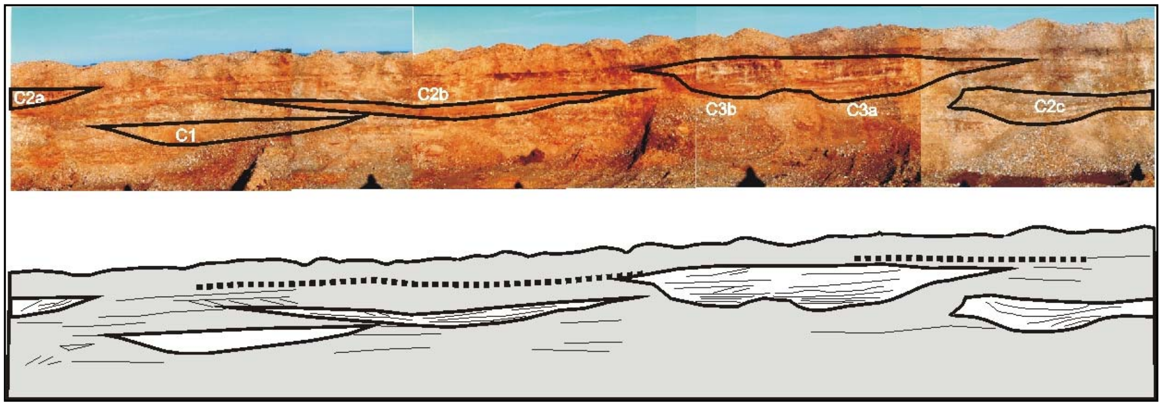


FIGURE 9 – Photomontage and sketch showing a number of sand-filled channels and their internal structure at Barton East Quarry. Three generations of channels can be seen within 4 m of deposits, with the oldest being C1, then three approximately contemporaneous channels (C2a-C2b) and finally two laterally amalgamated channels, C3a and C3b. At the same time at which the C3 channels were active, peat was forming in overbank areas, resulting in the laterally extensive lignite horizon that can be seen in the photograph and is shown as a dotted line in the sketch. The width of the field of view is approximately 50 metres.

Silt/Clay Horizons

Within the upper 2 m of the Holocene succession, around three silt/clay horizons may be witnessed. The horizons are never more than 0.2 m thick, and although they are laterally discontinuous because of the undulating erosional nature of overlying bounding surfaces, they may repeatedly be seen along the same level of the succession (see Figure 9). The horizons are dark grey or black in colour, and are composed predominantly of ***lignite***. This element thus represents ***overbank*** deposition of peat, which would have accumulated in poorly drained tracts of land with a high water table level. It is likely therefore that the lignite horizons are the remnants of peat accumulations that occurred on wetland islands and river banks when the river was maintaining an anastomosed planform, as discussed in the previous chapter.

GROUND PENETRATING RADAR DATA

Over 6 km of lines of GPR data were gathered in order to assess the 3-D geometry of the fluvial deposits where there was no exposure (i.e. mainly on the Pleistocene terrace, where the archaeological artefacts are found). The lines were divided into four grid squares which were located to provide a wide geographic spread of data coverage. The locations of these grids, which can also be seen on Figure 2, were as follows:

1. ***GPR Grid Square #1 (GPRGS #1)*:** 300 X 100 m grid square, with lines collected at 20 m spacing, located to the north-east of Catholme, within the same field as the hengiform archaeological site. GPR survey of Pleistocene terrace.

2. ***GPRGS #2*:** 100 X 100 m grid square, with lines collected at 20 m spacing, located in the topographic hollow directly north of the railway embankment between Catholme and Barton East Quarry. GPR survey of Pleistocene terrace.

3. ***GPRGS #3*:** 40 X 76 m grid square, with lines collected at 8 m spacing, located on a block-shaped cutting of Holocene sediment within Barton East Quarry, to the north-west of Cherry Holme. GPR survey tested and calibrated against visible outcrop (Table 3).

4. ***GPRGS #4*:** 100 X 100 m grid square, with lines collected at 20 m spacing, located on the southern promontory of Pleistocene terrace, north of the confluence between Trent and Tame, and west of the railway junction. GPR survey over palaeochannels identified from aerial photographs.

The GPR data retrieved from these survey sites enabled further analysis of the sedimentary architecture of both the Pleistocene terrace and the more recent deposits of the Trent (although, unlike outcrop sections, could not be used to accurately differentiate between different sediment types). GPRGS #3 was particularly important, as it allowed GPR lines to be run across cuttings where the sedimentary geometry was known, and thus enabled common reflector types to be identified and grouped into radar facies that could be interpreted to reference with actual sedimentary architectural elements (Figure 9). Figure 10 shows how seven major horizons were identified and correlated with both outcrop photographs and sedimentary logs in one line from GPRGS#3, and confirms that GPR is a successful tool in subsurface imaging of the river gravels.

RADAR FACIES	DESCRIPTION OF REFLECTORS	INTERPRETATION
R1	Shallow dipping reflectors, arranged in trapezium-shaped packages of three or more.	Sediment bodies with a sheet or wedge geometry - sand wedges, sand sheets, or thin gravel sheets.
R2a	Concave upwards reflector displacing horizontal reflectors on its inner and outer arc.	Channelised sediment body containing horizontal laminae.
R2b	Concave upwards reflector forming the lateral termination of horizontal reflectors on its outer arc, and hosting packages of dipping reflectors on its inner arc.	Channelised body of cross-stratified sediment.
R3	Undisrupted horizontal reflectors.	Laterally continuous sheet bodies: Gravel Sheet architectural elements?

TABLE 3 - *The radar facies and interpretations made from GPR survey at the GPRGS#3 site, Barton East Quarry.*

Three major radar facies – recurring orientations of radar reflectors – were identified and interpreted within 2D survey lines; (RF1) clusters of dipping reflectors along the same horizon and tapering out laterally, (RF2) smaller reflectors hosted (and terminating) within a larger concave-upwards reflector, and (RF3) flat or very gently inclined, laterally extensive reflectors (Figure 11). These were interpreted as representing, respectively, wedge-shaped cross-bedded architectural elements, channelised architectural elements, and sheet-like architectural elements (e.g., as may be seen in Figure 7). Significantly, the proportions of these elements in survey lines within different types of sedimentary deposits varied (Figure 12). Within the Pleistocene terrace material, the reflectors were dominated by RF3 (except where the survey grid was located over known palaeochannels, i.e., GPRGS #4, and RF2 also formed a significant proportion of the radar signal). Only within the more recent Holocene deposits was there a more even distribution of different types of radar facies – reflecting the distribution of architectural elements within the Holocene outcrop.

The uniformity of the RF3 radar signal within the Pleistocene terrace material also confirms what was known from outcrop studies – that the early river deposits were predominantly extensive gravel sheets, of various thicknesses. The isolated Pleistocene palaeochannels identified from aerial photographs are picked up by the GPR surveys, but their dimensions are greater than the younger palaeochannels and do not fit within a 100 X 100 m grid, thus limiting the ability to create 3D reconstructions (Figure 13). Also, these broad palaeochannels appear to be the exception rather than the rule within the terrace deposits, and are less significant as architectural elements than the sheet deposits.

As has already been described from outcrop data, the architecture of the Holocene deposits of the River Trent is more complex, with a variety of sheet deposits, cross-bedded deposits, and channelised deposits. This reflects the increase in the extrinsic constraints on the fluvial system that prevented the river from being as laterally mobile, and thus architecturally simple, as it was prior to the development of vegetation and entrenchment. This trend is also witnessed within the GPR data, with a mixture of RF1, RF2, and RF3 elements within the survey signals from GPRGS #3. In contrast to the Pleistocene terrace surveys, the RF2 elements are also smaller, enabling 3D reconstructions of river channel width, depth, and sinuosity. Such a reconstruction in shown in Figure 14, and highlights two channels composed of RF2, with RF1 elements comprising bar forms at the channel margins. In this instance the reflectors that form the bulk of the first channel terminate obliquely against reflectors of the second channel, suggesting an abrupt erosional boundary rather than two connected channels. This suggests that at least some of the palaeochannels picked out in the geomorphological map in Figure 2 were not contemporaneous channels of a braided system, but were discrete single-channels which migrated through lateral avulsion.

SUMMARY

Outcrop data indicates that the Pleistocene fluvial system was a proglacial gravel-bed braided river with high lateral mobility, which deposited architecturally simple sand and gravel deposits under a seasonal discharge regime. GPR surveys of the river terrace confirm the simplicity of these fluvial deposits across the rest of the study area where there is no outcrop, and are able to pick out 3-D architectural elements where palaeochannels locations are known.

Subsequent to the entrenchment of the river, and the development of the river terrace after the late Devensian glaciation, topographically raised deposits were covered with aeolian sand sheets, whilst discharge diminished within the river channels resulting in smaller barforms which became stabilised by vegetation. During the most recent Holocene, these barforms developed into mature, stable islands, which provided sites for extensive peat accumulation. Thus, vertical changes can be seen in the sedimentology, architecture, and radar facies of the fluvial deposits which confirm the way in which the planform of the River Trent changed from a braided to an anastomosed system, prior to recent land drainage.

4. Evolution of the Fluvial Systems

This chapter combines the data discussed in previous chapters in order to present a history of the evolution of the fluvial systems in the study area. A summary of this, as well as details about sedimentary facies deposited at each stage of the rivers evolution, is presented in Figure 15, at the end of the chapter.

THE FIRST DRAINAGE: *THE "RIVER TRENT" DURING THE ICE AGE (2 MA BP – 18 KA BP)*

The tectonic uplift of the southern part of the British Isles during the late Tertiary (c. 2 ma BP) is known to have created the necessary palaeoslope for river drainage from the midlands towards the east coast of Great Britain (Gibbard & Lewin, 2003). There is no geological record of this proto-River Trent in the study area, and, although such fluvial systems would have been an important precursor to modern drainage, their exact geographical location remains unknown. The first time period in which fluvial activity is definitely known to have occurred in Staffordshire is at the end of the Devensian glaciation, during the Pleistocene. Straw (1963) has shown how, at this time, a 2.4 km-wide valley was incised into the Mercia Mudstone Group bedrock, providing a determined course for the middle Trent. Given that this valley incision occurred downstream of the study area, it is more than likely that incision of the north-east trending valley evident in the bedrock of the study area had already commenced. The fluvial system at this stage of the Pleistocene would have been fed by glacial meltwater, and the rivers would thus have had high discharge and sediment concentrations. Water discharge from the glaciers would have been seasonal; therefore, whilst in the summer months fluvial activity would have been associated with prolonged intense floods, winter months would have seen the system relax to a shallow braided river wetland, with fewer active channels. In such conditions, and particularly during the peak of an ***interglacial***, the environment may have been favourable for grazing fauna, such as the woolly rhinoceros and other animals discovered during excavation at Whitemoor Haye Quarry.

AFTER THE LAST GLACIATION: *A PROGLACIAL BRAIDED RIVER (18 KA BP – 10 KA BP)*

Subsequent to the initial glacio-fluvial system, the study area was glaciated once again at the end of the Pleistocene. This Younger Dryas glaciation removed much of the pre-existing fluvial sediment, and the area was covered with glacial drift, some of which is still preserved in the vicinity of Barton-under-Needwood and Wychnor. Once these glaciers had retreated, the study area returned to a proglacial stream environment. The course of the river had now altered slightly and, whilst still flowing towards the north-east, the active floodplain had shifted slightly towards the south-east, allowing the preservation of the glacial deposits near Barton-under-Needwood. Due to the fluctuations in discharge and sediment, the active channels were prone to constant lateral migration, so that the river was characterised by an unstable braided form with very broad, shallow channels and aerially exposed bar forms. The discharge was still great enough at this point for the system to be a gravel-bed stream, so the architecture of these sediments is typically seen to be sheet-like gravel deposits. The local climate during this period resulted in the development of large areas of permafrost, and the continual freezing and thawing of subaerially exposed areas of ground surface (e.g., bars and islands within the fluvial system) resulted in the development of ice wedge casts within the fluvial gravels, some of which can still be seen in the lower 2-3 metres of sediment at Barton East Quarry.

THE DEVELOPMENT OF THE RIVER TERRACE: *SEPARATION OF TRENT AND TAME (C.10 KA BP)*

As the climate became more temperate, and the discharge of the streams diminished. With a reduction in sediment supply the width of the active fluvial system narrowed, and a river terrace was cut into the Pleistocene gravels during the early Holocene. Again, this resulted in a change in palaeoflow direction, to one more akin to that of the present day river. Rather than the fluvial activity taking the form of one large braided river which flowed north-eastwards, the incision and development of the river terrace resulted in the upstream separation of the fluvial system into two discrete rivers, each with their own drainage area; thus, at the start of the Holocene, the Trent and Tame became two separate rivers. The Trent now flowed from the west into the study area, before flowing in a north-east direction to the east of Alrewas. Bars and islands can be seen on aerial photographs, suggesting that the fluvial system was still braided, but the lateral mobility of the system was more restricted and the channels more stable, resulting in the development of channelised sand and gravel bodies within the sedimentary deposits of the system. Likewise, the Tame was also a multichannel system, acting as a tributary to the Trent, but was even more restricted by a reduced discharge and was less laterally mobile than the Trent. Further division of the drainage area occurred at Elford, 5 km south of the study area, where the River Mease had also been separated and was acting as a tributary of the River Tame.

STABILISING EFFECTS OF VEGETATION: *FROM BRAIDED TO ANASTOMOSED STREAMS (<10 KA)*

As the braided river systems continued to evolve, certain channels became the dominant water discharge routes. This led to the abandonment of some of the former braided channels, which were quickly colonised by vegetation and stabilised by roots. In fact, much of the floodplain was becoming vegetated, as evidenced by the occurrence of peat and lignite in the upper part of the sedimentary sequence. This vegetation served to further stabilise the fluvial system, making it less easy for channel switching and the development of further braiding. Gradually the river systems adopted a more anastomosed multi-channel form, with each of the channels being relatively mature entities, separated by vegetation-stabilised islands where peat and wet soils developed. Only during extreme flood events, when the river exceeded its ***bankfull*** discharge, did these islands become submerged. After such events, former islands would be covered by a layer of gravels and the anastomosed system would gradually redevelop, relaxing at a stage with new courses for its multiple channels. Thus this period was characterised by rare catastrophic changes in the river course, rather than the constant migration of the glacial and post-glacial periods.

EARLY SETTLEMENTS BY THE RIVER TRENT: *THE RIVER AND ARCHAEOLOGY (4000-400 BP)*

Throughout much of the latter part of the Holocene, reduced discharge meant that the dominant sediment transported was sand or silt-grade alluvium material, and the River Trent maintained its anastomosed plan form, existing as discrete channels and vegetated wetland islands, until at least the early human occupation of the area. All the archaeological sites, as may be expected, are found on the river terrace, where there was a reduced risk of flooding (although another reason for this could be that any sites that may have existed on the active floodplain have been destroyed by later fluvial activity). The sites which are Iron Age, Roman, or Anglo-Saxon in age show a trend of moving towards the north-east, which also appears to be the general direction of the migration of the river system, as inferred by the way the modern river is cutting north-eastwards into the river terrace and bedrock. This suggests that the early occupants of the area migrated in the same direction as the river, presumably utilising it as a resource. The Anglo-Saxon site at Fatholme is particularly interesting in terms of human-river interaction, as it occupies the very edge of the river terrace. Maps from the 17th century and aerial photos suggest the river has previously taken a course immediately adjacent to this site, suggesting either that the site was actually on the banks of the river, or that the 17th century course had previously eroded westwards, destroying some of the archaeology on what had formerly been a river terrace.

LAND DRAINAGE AND RIVER MANAGEMENT: *APPROACHING THE SINGLE CHANNEL (400BP+)*

An historic record is available to chart the channel pattern changes within the study area over the last 400 years. In 1685, the River Trent can be seen to have still maintained a relatively anastomosed form, with additional channels to its modern course. Other channel planform differences included; at Borough Holme, the main channel was 500 m further west than its present location, and, in the south of the study area, the Mease was still a tributary of the Tame, joining that river to the east of Whitemoor Haye. By 1884, a number of drains and irrigation ditches existed in the area as a result of intense farming. It is likely that these were at least partially responsible for the complete abandonment of the additional channel between Alrewas and Wychnor. The remaining multiple channel system at this location in the study area was a deliberate result of river management; with locks, sluices, and bank-lining having been installed for canal boats. Elsewhere, the Mease had by this stage avulsed to its current confluence with the Trent, leaving the Tame with no tributaries within the study area, and the original main channel at Borough Holme was now less significant than a new eastern subsidiary channel. Both of these changes were the result of an avulsion event that occurred during one of three major floods during the 1700's. By 1974, the river had reduced its upstream sinuosity, with noticeable ***meander loop cut-off*** to the east of Alrewas. At this time, the original course of the Trent at Borough Holme was also stagnating and the former subsidiary channel was now the only active channel of the Trent at its northwards course. Since then, the Borough Holme subsidiary channel has been drained completely and since excavated for quarrying, and minor additional channels such as that to the west of Cherry Holme have also become abandoned. Thus, the effects of land drainage and river management have served to create a predominantly single channel fluvial system within the study area, and the effects of this are currently being accelerated as entire channels are dredged in preparation for aggregate extraction.

THE COURSE OF THE FUTURE: *WHAT NEXT FOR THE RIVER TRENT? (NOW-???)*

The actively eroding reaches of the fluvial systems in the study area give some idea of how they will continue to develop into the future. The Tame and Mease have remained relatively stable over the last 100 years, and due to their heavily vegetated banks do not seem to be likely to migrate much in the near future, unless a flooding event results in an avulsion. The downstream part of the Trent, near Alrewas, is also unlikely to change significantly. This stretch has been gradually straightening through meander loop cut-off, possibly as a result of river regulation, and may continue to do so where the few meanders remain. It is more likely that the northern subsidiary channel at this location will become completely abandoned, as recent maps show it is progressively becoming less significant. However, where the Trent diverts to its northern course more channel pattern changes are likely. The river is already actively eroding into the eastern river terrace as upstream changes have resulted in an increase in sinuosity. The prolific scroll bar features in the area suggest that these changes have been rapid, and should they continue it is likely the River Trent will gradually become a more straightened single channel system upstream, whilst developing a very sinuous reach further downstream, actively migrating eastwards and eroding away the Pleistocene terrace.

5. Conclusions

DISCUSSION

Previous research regarding fluvial activity along the River Trent has been primarily focused on its middle and lower reaches (e.g., Straw, 1963; Salisbury *et al.*, 1984; Salisbury, 1992; Large & Petts, 1996; Howard & Macklin, 1999; Howard *et al.*, 1999; Mitchell *et al.*, 1999; Brown *et al.*, 2001), and so it is important to compare and contrast the data presented in this study with data from the earlier studies of the downstream reaches, in order to better understand the palaeofluvial evolution of the River Trent as a whole.

The characteristics of the upper River Trent during the Pleistocene bear many similarities to its middle and lower reaches, with previous studies having highlighted the presence of extensive gravel sheets, hematite-rich sediments, and cryogenic sedimentary structures (e.g., Brown *et al.*, 2001). Studies of the Holocene River Trent, such as those of Howard *et al.* (1999), have highlighted how major changes in the middle and lower Trent occurred only during the last 5000 years, with earlier Holocene systems being relatively stable. This trend for only more recent extreme channel changes has been suggested to be due to human activity and the climatic effects of the 'Late Medieval Climatic Deterioration' (see Taylor & Lewin [1997] and Brown [1998] for details). However, whilst there is certainly evidence for anthropogenic triggering of channel changes within the study area, the degree of change appears to be much less than in the downstream part of the Trent. For example, the main confluence zones in the middle and lower Trent have been associated with extreme instability over the last 1000 years (Large & Petts, 1996), and certain reaches, such as that near Colwick, Nottinghamshire, have experienced such an intensity of channel pattern change that they have changed planform from single channel meandering to braided to anastomosing and back to a single channel meandering state in periods of just a few hundred years (Salisbury *et al.*, 1984; Brown *et al.*, 2001). This level of fluvial change is not witnessed in the study area, despite its association with a confluence zone, and a likely reason is that it is only located downstream of one other major confluence (with the River Blythe tributary, north of Lichfield) - many areas of channel instability in the middle and lower Trent have been immediately downstream of many other confluence zones and thus subject to extrinsic changes in a much wider upstream drainage area (Brown *et al.*, 2001). Therefore, the relative stability of the reach of the River Trent studied for this report is most likely due to its upstream location, although it has been affected by human activity of secondary importance.

CONCLUSIONS

A palaeofluvial analysis of the River Trent near Alrewas has been made possible by the study of the sedimentology of the river deposits, GPR surveys, documentary evidence, and geomorphological mapping. This analysis reveals that fluvial systems have been active within the study area since at least the early Pleistocene, and have undergone extensive channel pattern changes since then.

The earliest fluvial systems were braided proglacial streams, the main influences on which were the periglacial climate and discharge fluctuations from melting glaciers. As climate warmed and the glaciers finally retreated, the braided system became colonised by vegetation, providing relative stability to the fluvial system until it developed and anastomosed planform. The additional controls on the fluvial system that were imposed by this development resulted in much smaller sedimentary architectural features, and an increase in the proportion of finer sediment in the river. The final stage of river development came when human activity, in the form of land drainage and river management, resulted in the modern single channel planform.

With the exception of irregular catastrophic triggers to fluvial change (e.g., the ?1795 flood), the main controls on fluvial planform have altered throughout the history of the River Trent; from the early predominance of climate as a major control, to the later influence of human activity. However, neither has affected the river system to such an extent as has been the case further downstream in the River Trent, predominantly because the cumulative upstream drainage area is much smaller.