4.3 High resolution 3D stratigraphic modelling at Warren Farm Quarry

4.3.1 Background

During the January 2006, the opportunity arose to record a series of palaeochannels that had become exposed during the extraction of aggregates in the Warren Farm area of Lockington Quarry, owned by Lafarge Aggregates Ltd (Fig. 4.6). Consent had been granted to begin extraction at the Lockington site in 1995, with an estimated 2.77 million tonnes of sand and gravel projected to be removed by the scheduled infilling date of the quarry in late 2006 (Leics. County Council:1995). The exposure of sections within Warren Farm Quarry displaying a variety of floodplain components, such as palaeochannels and terrace deposits, afforded the opportunity to record detailed, high resolution stratigraphic information. This data could then be compared to the more general stratigraphic knowledge of the study area obtained through boreholes, coring transects and the various remote sensing techniques employed in the project. Importantly, part of the Warren Farm quarry is situated within the vicinity of the mapped interface between the Devensian and Holocene terraces and is therefore an area with considerable geoarchaeological potential. Permission to access the quarry and record the sections was kindly granted by Lafarge Aggregates Ltd, the company currently working the extraction area.

4.3.2 Methodology of stratigraphic recording

In total six channels were identified and recorded within the exposed quarry faces, numbered 1, 2, 3, 4a, 4b and 5. These channels were all located towards the northern extent of the extraction area, between Lockington Grounds Farm to the west, Grounds Farm Cottages to the south and Warren Lane to the north and east (Fig. 4.7). It was particularly fortunate that the quarry was developed since LiDAR had been flown, as this provided a comparison between quarry exposure stratigraphy and the LiDAR data. The recording of the channels was undertaken using two methods; hand-drawn recording of sedimentary sections and the digital recording of stratigraphic information (heights of boundaries, etc) using dGPS. The section drawings were produced at a scale of 1:50 using a temporary datum line positioned against the quarry face and with the datum points surveyed in using the dGPS. The drawings were produced on permatrace overlain on a gridded drawing board and using standardised sediment descriptions consistent with the stratigraphic terminology employed during coring. The position of samples removed from the quarry faces, for either radiometric dating or palaeoenvironmental assessment, were recorded on the drawings and also with dGPS. The drawings were scanned and digitised to provide digital copies of the quarry faces, allowing the vertical exaggeration of the sections where necessary for display purposes.

The recording of the sections using dGPS aimed to provide a detailed digital record of the stratigraphy of the quarry that could be used to create a three-dimensional subsurface model. The GPS recorded a series of XYZ points along the ground surface, the base of the section and any intervening stratigraphic boundaries (Fig. 4.8). The survey focused on the palaeochannels visible in the section faces and recorded the location and outline of the channels, the thickness of alluvium, sand and gravel deposits and where the boundary between the Devensian and Holocene terrace sediments was visible. The existing survey control network already established across the study area was used to fix the survey accurately.

Rockware's Rockworks software was again used for the subsurface modelling of the stratigraphic information obtained from the GPS recording of the quarry sections. The GPS points were entered into an Excel spreadsheet in the particular format required by the Rockworks program. The table was then imported into Rockworks Borehole Manager and used to create a series of two-dimensional logs and cross-sections, as well as three-dimensional fence diagrams and surfaces. The stratigraphic fence diagrams were exported as ESRI 3D shapefiles and opened in ArcGIS ArcScene, where they could be displayed in a pseudo three-dimensional environment and compared to other data from the project, such as the lidar surfaces and palaeochannel features mapped from airborne remote sensing (Figs. 4.9 - 4.11).

4.3.3 Stratigraphic description of Warren Farm Quarry palaeochannels

4.3.3.1 Palaeochannel 1

Palaeochannel 1 was located towards the centre of the extraction area and was recorded in a north facing section of the northernmost quarry pit (Fig. 4.12). The sediment stratigraphy indicates that it is a single channel oriented in a north-northeast direction (an interpretation supported by analysis of the elevation surface from the LiDAR survey flown prior to aggregate extraction). The channel was recorded as being approximately 37 metres wide, with a maximum depth below alluvium of 2.68 metres.

The palaeochannel was incised into the Holocene sands and gravels of Terrace 1. A grey-white sand with inter-bedded horizontal bands of darker grey sand is situated immediately below the channel. Below this, to the west of the channel where the section face was deeper, a series of thin bands of orange and grey sands were revealed, interspersed with bands of red and grey sandy clay.

Two distinct sedimentary units were distinguished within the palaeochannel itself. At the base of the channel was a dark grey-black silty clay containing visible organic remains. This deposit has a maximum depth towards the centre of the profile of c. 2 metres, thinning to 0.1 metres at the eastern edge of the feature. To the west the base rises more steeply, with the silty clay deposit terminating c. 9 metres before the western edge of the channel. The upper deposit of the channel is a light grey silty clay containing occasional small clasts c. 2cm diameter. This deposit is located to the west of the channel, terminating 8.9 metres before its eastern edge. The deposit is thickest towards the western side of the channel, with a maximum depth of 1.2 metres. The channel is sealed by a covering of red brown silty clay alluvium that extends up to the modern ground surface with a maximum depth of 3.2 metres.

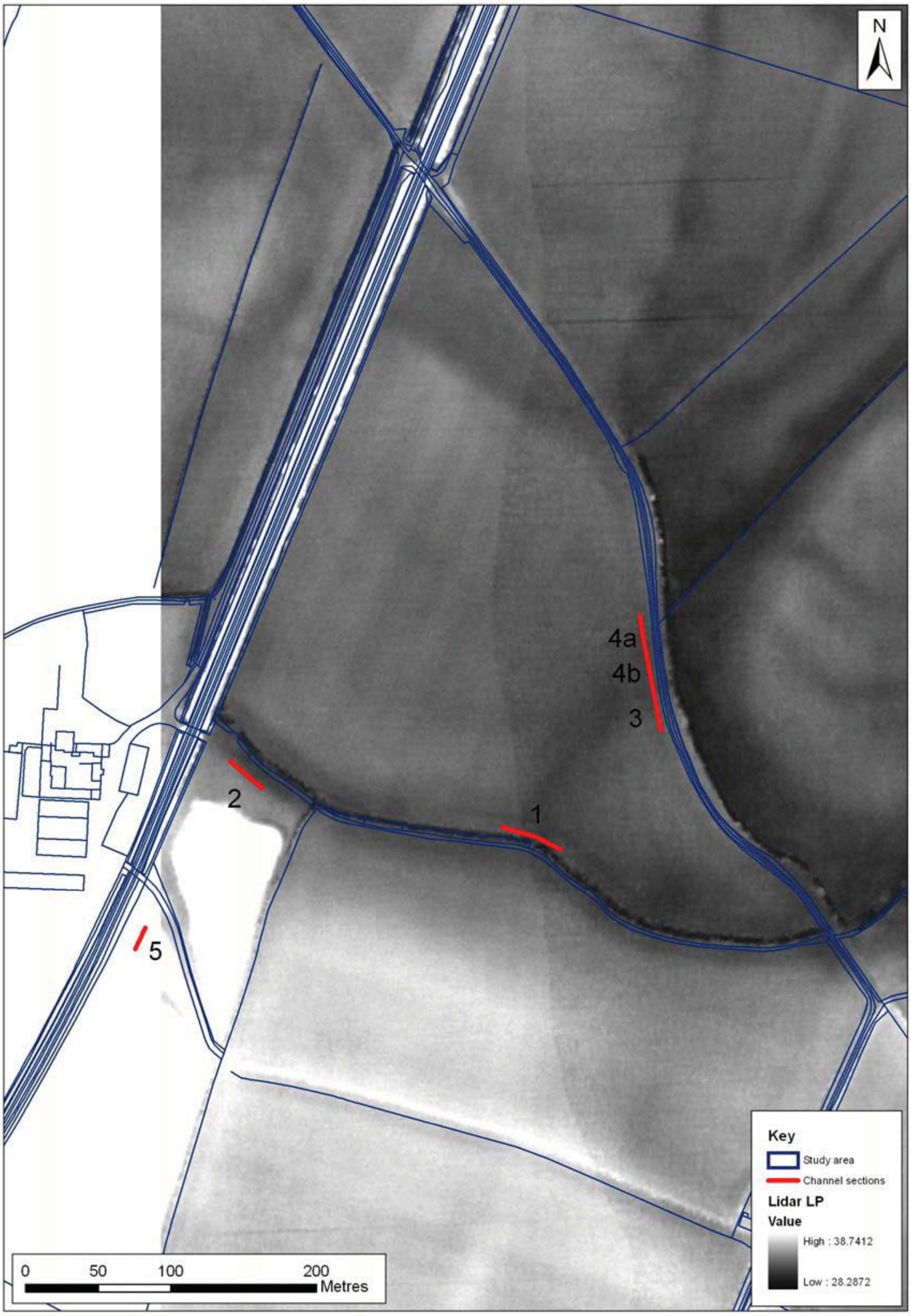


Fig 4.7: Location of sedimentary sections recorded in Warren Farm Quarry, overlain on lidar elevation model (map by permission of OS).

Fig 4.8: Location of GPS data points along visible stratigraphic boundaries in Warren Farm Quarry (map by permission of OS).

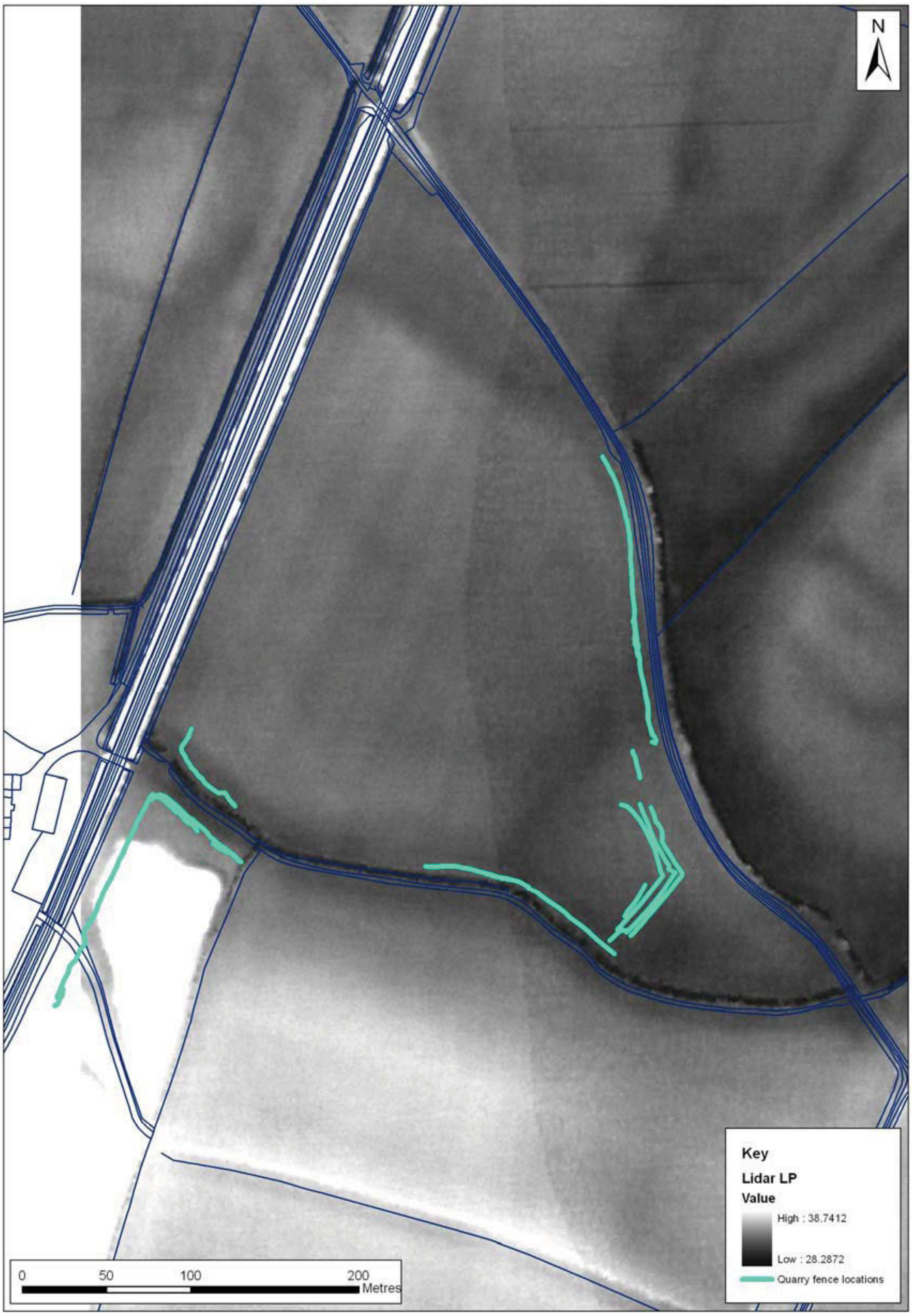


Fig 4.9: Location of stratigraphic fence diagrams within Warren Farm Quarry, overlain on lidar elevation model (map by permission of OS).

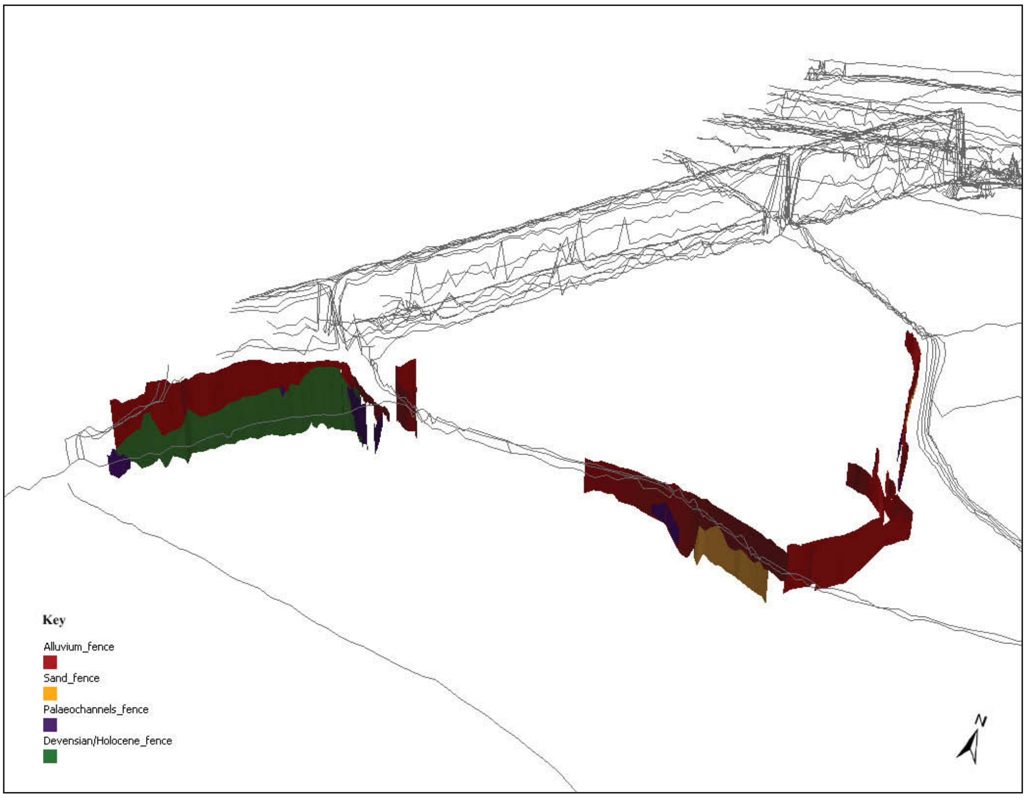


Fig 4.10: ArcScene visualisation of Warren Farm Quarry stratigraphic fence diagrams (map by permission of OS).

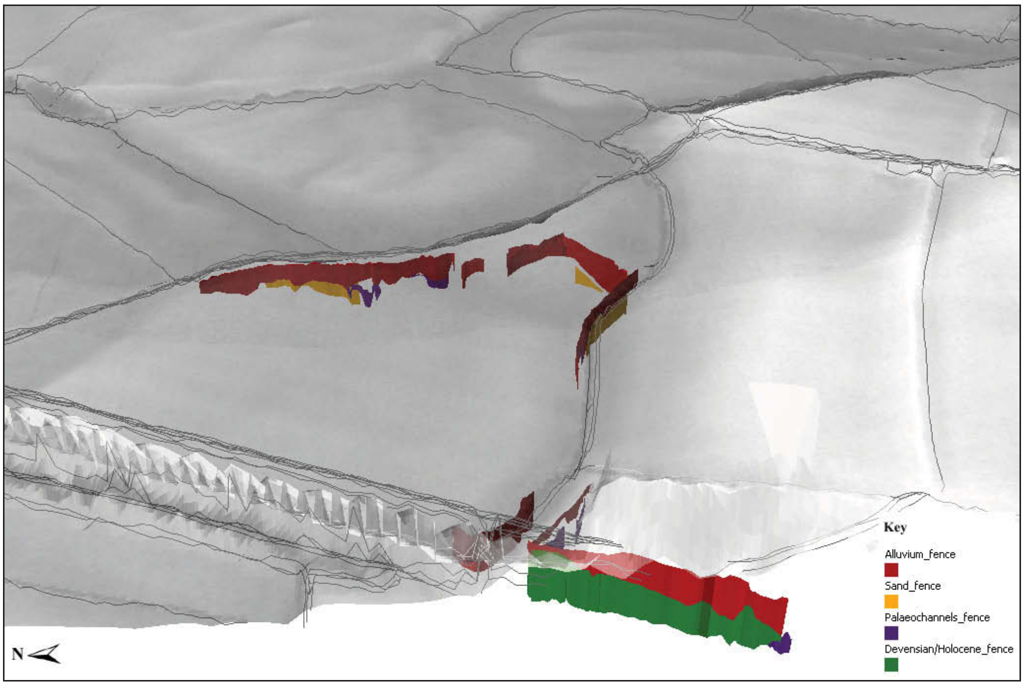
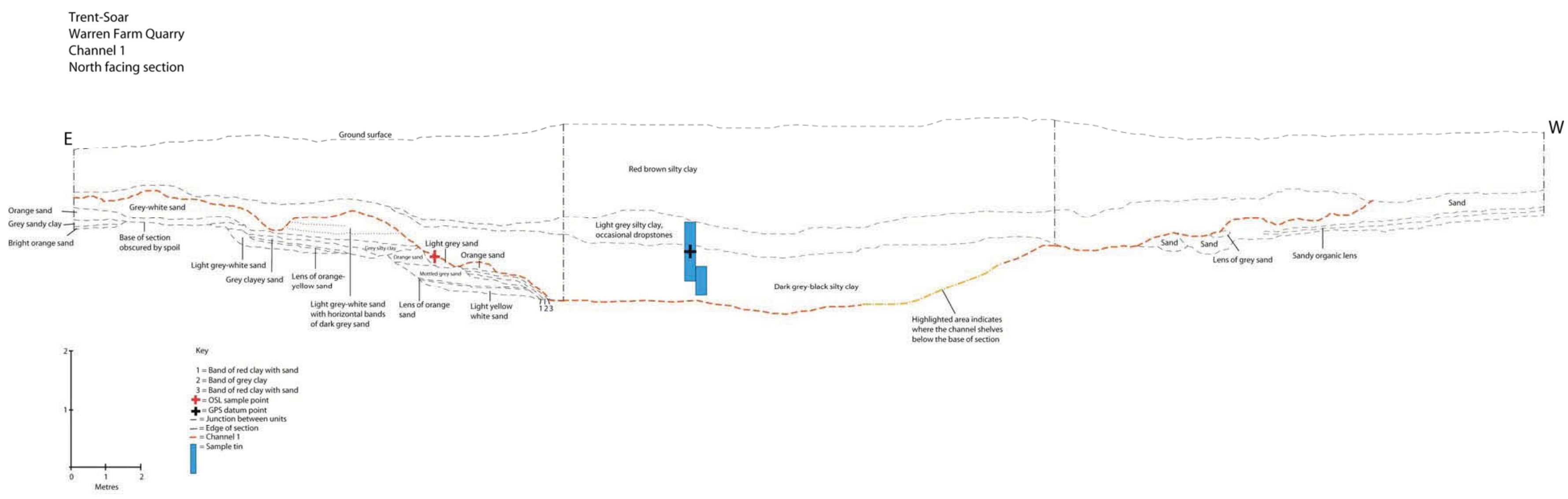


Fig 4.11: ArcScene visualisation of Warren Farm Quarry stratigraphic fence diagrams below lidar elevation model.



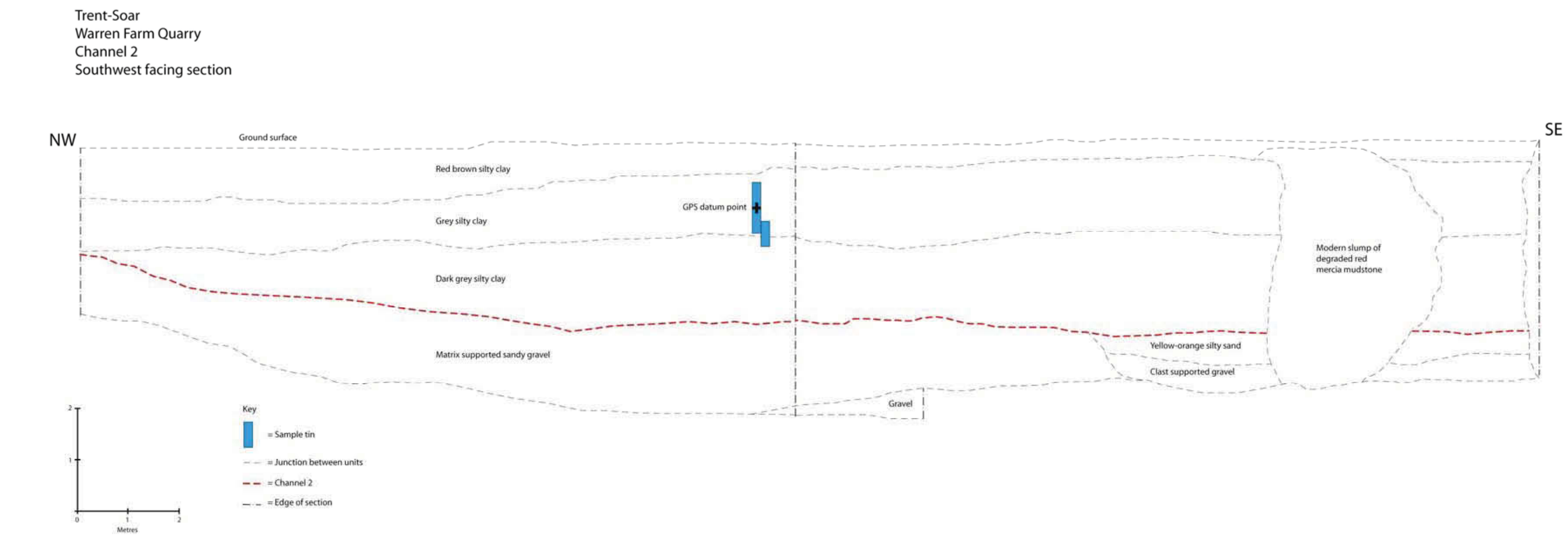


Fig 4.12 (top): Drawn stratigraphic sequence for channel 1 in Warren Farm Quarry.
Fig 4.13 (bottom): Drawn stratigraphic sequence for channel 2 in Warren Farm Quarry.

4.3.3.2 Palaeochannel 2

Palaeochannel 2 was located towards the western boundary of the quarry and was recorded in a southwest facing section (although the channel was also partially visible in a section face on the opposite northern side of a large access road baulk) (Fig. 4.13). The quarry face was cut obliquely across the channel, providing a section available for recording that measured c. 28.75 metres wide. The channel has a maximum depth below alluvium of 3.5 metres.

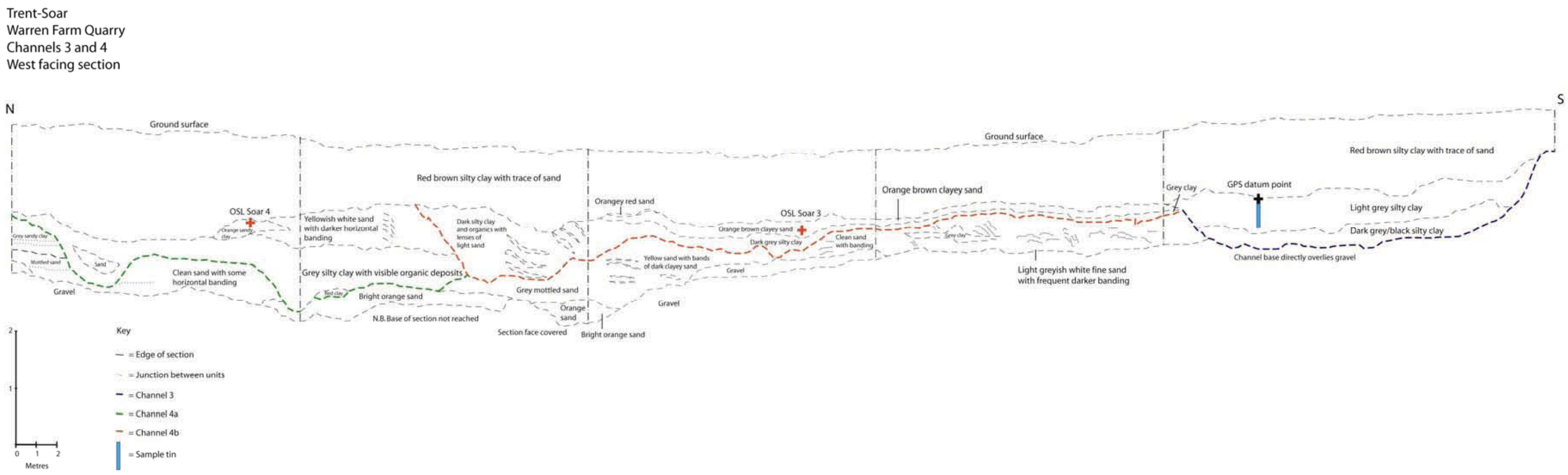
The palaeochannel was incised into the Holocene sands and gravels, with the channel extending broadly northwest-southeast trimming the boundary between the Holocene and Devensian terraces (Terraces 1 and 2 respectively). The channel has incised into a matrix supported sandy gravel along much of its profile, although with the southeastern side cutting into a yellow-orange silty sand that overlies a clast supported gravel. The matrix supported sandy gravel was exposed to a maximum thickness of 1.75 metres, but the steep slope of the section face at this point prevented the base of the deposit from being recorded.

Although the section face was obscured in several places, due to modern slumping during the extraction of the sands and gravels, a considerable portion of the channel was available for recording. Two discrete sedimentary units were identified within the palaeochannel itself, showing similar stratigraphy to channel 1. At the base of the channel was a dark grey silty clay, again containing visible organic remains. The deposit extended from the edge of the channel at the northwest, gradually increasing to a maximum thickness of c. 2.10 metres in the centre. Above this basal deposit lay a lighter grey silty clay with a maximum thickness of c. 1.60 metres. The palaeochannel was sealed by a relatively thin covering of red brown silty clay alluvium, which was deepest to the northwest of the channel at c. 1 metre thick, gradually reducing to a thickness of only 0.50 metres to the southeast.

4.3.3.3 Palaeochannel 3

Palaeochannel 3 is located towards the northeast corner of the quarry and was visible in the southwest facing section, which runs parallel to the line of Warren Lane (Fig. 4.14). The channel was recorded in a c. 78 metre long section that comprised of three complexly interrelated channel units (channels 3, 4a and 4b). Channel 3 is 19.6 metres wide and has a maximum depth below alluvium of c. 1.10 metres.

The palaeochannel extends broadly southwest-northeast and is incised into the Terrace 1 Holocene sands and gravels. The northern side of the profile indicates that the channel has truncated the southern extent of the deposits filling channel 4b, making channel 3 postdate channel 4b. Below this the channel has incised through a layer of light greyish white fine sand containing frequent banding of darker sand, before reaching a layer of Holocene gravel at its base.



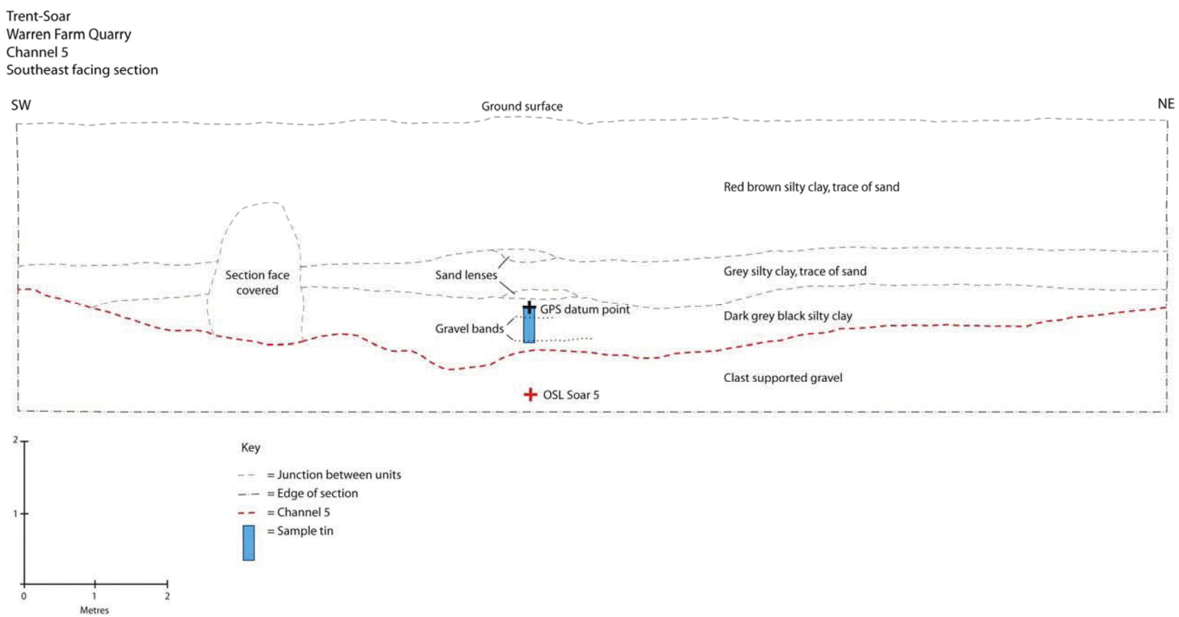


Fig 4.14 (top): Drawn stratigraphic sequence for channels 3, 4a and 4b in Warren Farm Quarry.
Fig 4.15 (bottom): Drawn stratigraphic sequence for channel 5 in Warren Farm Quarry.

Within the palaeochannel itself was a similar bipartite arrangement of sediment stratigraphy as in channels 1 and 2. A dark grey-black silty clay at the base of the channel was overlain by a lighter grey silty clay. The lower silty clay fill of the channel contained visible organics and was present to a maximum thickness of c. 0.5 metres. Above this, the grey silty clay was notably thicker, up to c. 0.8 metres towards the centre of the channel. A layer of red brown silty clay, slightly sandy in places, sealed the palaeochannel. Above channel 3 this alluvial deposit reached a maximum thickness from the ground surface to the channel fill of over 1.4 metres, although the deposit also overlay channels 4a and 4b.

4.3.3.4 Palaeochannel 4a

Palaeochannel 4a is located in the same southwest facing section running parallel to Warren Lane in which channels 3 and 4b were recorded (Fig. 4.14). The channel lies immediately north of channel 4b and extends for a length of c. 23 metres, although this is clearly only a partial width since the feature has been truncated to the south by channel 4b. The northern edge of the channel appears complete and displays a moderately steep sided channel with an undulating base. The channel has a maximum depth below the alluvial overburden of c. 1.8 metres. The channel has incised into the Holocene sand deposits of Terrace 1, with both a bright orange sand deposit and a light sand with darker banding being visible below the channel profile. To the north of the channel the Holocene gravels were visible at the base of the section.

The primary fill of the channel is a grey silty clay with visible organic deposits, which reaches a maximum thickness of c. 1.15 metres. Although this deposit is comparable to the lower fill of the other channels that have been recorded, the other deposits in channel 4a appear distinct from the in-channel sediments elsewhere in the quarry. A deposit of yellowish white sand containing darker horizontal banding is located above the grey silty clay. This deposit has a maximum depth of c. 0.8 metres and is overlain by a small pocket of orange sandy clay further to the north, measuring only c. 0.35 metres thick. To the south, deposits forming channel 4a have clearly been truncated by the incision of channel 4b, a stratigraphic relationship indicating that channel 4a predates channel 4b. Channel 4a has been sealed by the same alluvial deposit of red brown silty clay that also covers channels 3 and 4b. Above channel 4a this alluvial deposit reaches a thickness of c. 2 metres.

4.3.3.5 Palaeochannel 4b

Palaeochannel 4b is situated immediately north of channel 3 and was recorded in the same c.78 metre long section face located towards the northeast corner of the quarry (Fig. 4.14). The channel is 38.4 metres wide, with a steep sided profile to the north and a notably more gentle sloping edge to the south. The base of the channel undulates considerably at its northern end, although with a much flatter surface to the south as the slope of the profile decreases. The channel has a maximum depth below alluvium of c. 1.35 metres.

The channel is again incised into the Holocene sands and gravels of the Terrace 1 deposits. However, it is also clear that at its northern edge, the channel has incised into the deposits filling channel 4a, indicating that channel 4b postdates channel 4a. The base of channel 4b is cut into light greyish white fine sands containing frequent mottling and bands of darker sand. Approximately halfway across the channel profile the base dips slightly to also meet the Holocene gravels that are higher at this location than elsewhere in the section.

The lower fill of the palaeochannel is a dark grey-black silty clay with traces of visible organics and containing numerous lenses of light coloured sand. This deposit has a maximum thickness of c. 1.35 metres. Overlying was a relatively thin layer of orange-brown clayey sand up to c. 0.8 metres thick. This upper layer was only located to the south of the channel, with the dark silty clay fill being overlain directly by alluvium to the north. At its southern margin, the channel has been truncated by channel 3, as mentioned above. The channel is again sealed by the same unit of red brown silty clay that sealed channel 3, although at this location the deposit is thinner, with a maximum depth over channel 4b of c.1.4 metres.

4.3.3.6 Palaeochannel 5

Palaeochannel 5 is located along the western boundary of the quarry area, to the south of channel 2 (Fig. 4.15). The channel was visible in a southeast facing section of the quarry, suggesting a single channel oriented broadly northwest-southeast. The full extent of the channel profile was not visible, but a section measuring c. 16 metres was recorded. The recorded section indicated a relatively flat channel base with only minor undulations. Although the slope to the channel sides appears slight it should be noted that neither edge of the channel was recorded and therefore the actual profile form is not fully understood. The channel has a maximum depth below alluvium of c. 1.6 metres.

Channel 5 differs from the other palaeochannels in that it is incised into the Devensian sands and gravels of Terrace 2, suggesting a much earlier date. The recorded section indicates that the channel has cut into a deposit of clast supported gravel with a maximum recorded depth of 1.65 metres (although the base of the gravel was not reached). The internal stratigraphy of the channel was divided into a lower fill of dark grey-black silty clay, overlain by grey silty clay, sandy in places. The darker silty clay had a maximum thickness of c. 1 metre towards the centre of the section, with the upper fill being shallower and reaching a maximum thickness of c. 0.65 metres. Two narrow (c. 0.15m) sand lenses were also recorded, one immediately above the dark silty clay and the second between the lighter grey silty clay and the overlying alluvium. The alluvium covering the channel was a red brown silty clay containing a trace of sand and measuring a maximum of c. 2 metres in thickness.

4.3.4 Summary

Access to the exposed faces within the Warren Farm area of Lockington Quarry has allowed the detailed recording of the stratigraphy of this part of the study area. Of the six channels visible in the quarry sections, five were found to be incised into the Holocene sands and gravels of Terrace 1, with only one being located in the Devensian deposits of Terrace 2. Although channel 5 is not visible on the LiDAR elevation or intensity surfaces, its location at the top of the Devensian gravels is of importance in providing a maximum age for channel change in the reach. Channels 1 and 2 are cut into the Holocene sands and gravels of Terrace 1, but are located directly along the junction between this terrace and the earlier Terrace 2 formation. The LiDAR elevation surface reveals evidence of a slight depression extending along a broadly east-west orientation between channels 2 and 1, suggesting that both sections may actually be displaying the same palaeochannel.

Similarly, the LiDAR elevation model highlights another channel extending southwest-northeast between the sections covering channel 1 and channels 3, 4a and 4b. This feature suggests that a channel may have also connected the sediments of the sections drawn at these locations, although the resolution of the lidar does not allow the isolation of a single channel from the three visible in the west facing section along Warren Lane. The internal stratigraphy of channel 3 is most similar to that of channel 1, suggesting that the two may be linked to the same overall feature, but a direct relationship cannot be established. A further complication is that the channel feature visible on the LiDAR surface between channels 2 and 1 appears to continue further to the east of channel 1, with the sinuous field boundary visible on the modern OS mapping following the line of this feature. If channels 1 and 2 are part of the same feature, as well as channels 1 and 3/4a/4b being part of a connected feature, then the channel would have to divide at the location of the channel 1 section. Alternatively, these could relate to separate channels from differing periods, with the possibility that the channel 1 section was reactivated at a later date following its initial cut-off.

4.4 General study area stratigraphic summary

Based on the various data sources and methods of investigating the stratigraphy of the study area a number of general statements can be made:

- The stratigraphy of the study area can be broadly divided into four main sedimentary units:

    1. Devensian Holme Pierrepoint Sands and Gravels forming the terrace deposits to the southwest and northwest of the study area. These deposits generally have a low archaeological potential, but may contain intra-gravel palaeochannels of high palaeoecological importance.

    2. Holocene Hemington Terrace silt and gravel deposits covering much of the central part of the study area. These deposits are of demonstrably higher archaeological potential and post date the terrace 2 Holme Pierrepont sands and gravels.

    3. A series of palaeochannels, which generally contain a lower fill of organic silty clay, overlain by grey silty clay. The channels are of high potential for palaeoenvironmental reconstruction and all appear to have incised into earlier gravel deposits (see chapter 5).

    4. These sediment units are generally blanketed by a red brown alluvium of variable thickness.

The construction of the three-dimensional stratigraphic model of the study area provided variable results, primarily because of the uneven spatial distribution and resolution of the sediment logs. In areas where the distribution of cores was sparse, the resulting fence diagrams and surfaces did not accurately reflect the subsurface stratigraphy. However, the method does provide a useful first approximation of the stratigraphy of an alluvial environment, and where the cores were closely spaced the resolution and potential of the resulting models was much higher.