Chapter 4: stratigraphic modelling

4.1 Stratigraphic overview of the study area

A preliminary model of stratigraphic development for the study area was created during the first phase of the project (Brown *et al* 2005: chp 9). This model was developed through a combination of data sources including BGS geology maps, airborne remote sensing, ground based remote sensing and invasive coring transects. One of the aims of the second phase of the project was to refine the phase 1 understanding of the stratigraphy of the study area through the analysis, integration and interpretation of: (1) borehole data supplied by Lafarge Aggregates Ltd; (2) Geoprobe cores drilled for OSL sampling of sediments and (3) further gouge cores used to investigate palaeochannels. The stratigraphic data from all of the various data sources was used to assess three-dimensional interpolation and modelling techniques for investigating subsurface stratigraphy and alluvial architecture. This chapter provides an overview of the stratigraphy of the study area established in phase 1, along with the results and assessment of the proposed three-dimensional modelling methodology. The stratigraphic understanding of the study area was supplemented considerably through access to record a series of exposed sediment faces within the Warren Farm Quarry (NGR SK4772330158) and so the results of this fieldwork are discussed. A final summary of the stratigraphic modelling of the study area is then provided, prior to the results of the refined chronostratigraphy and radiometric dating program being described in chapter 5.

4.1.1 Introduction to the study area

4.1.1.1 Geology

The geology of the study area has been mapped by the British Geological Survey (BGS) at 1:50,000 scale (sheet 141, 1974). Four main lithologies were identified within the study area: sand and gravel; silt and gravel; clay, silt and sand; and diamicton. The sands and gravels form the terrace deposits to the southwest and northwest of the study area, with the BGS identifying them as late Devensian (MIS 2) in age (Holme Pierrepoint Sands and Gravels). The silt and gravel deposits covering much of the central part of the study area have been mapped by the BGS as Hemington Terrace deposits. These silts and gravels were probably deposited by channel migration and braiding during the early to mid Holocene and are essentially the reworking of the Devensian sediments (Brown *et. al* 2005). The clay, silt and sand is concentrated along the modern channels of the Trent and Soar, as well as along the larger and topographically lower palaeochannels in the study area, and are mapped by the BGS as alluvium. These deposits are a result of overbank sedimentation in both abandoned channels and across the wider floodplain. Further to the west of the study area is an area of poorly consolidated material that has been classified by the BGS as Diamicton, a probable glacial deposit. In addition, the BGS also highlight an area of Syston Sand and Gravel on a low terrace of the River Soar to the southeast of the study area, probably resulting from an earlier Devensian aggradation (MIS 4).

4.1.1.2 Topography

The LiDAR LP DTM data provided an accurate model of the topographic variation present across the study area. In broad terms the LiDAR distinguished a general trend of decreasing elevation from north to south (i.e. towards the modern Trent channel). When compared to the stratigraphic model established in phase 1, it can be observed that this change in elevation corresponds with the tripartite division of the geomorphology of the study area into two river terraces and the modern floodplain. The Devensian terrace located to the south/southwest of the study area (Terrace 2) is evident as higher ground, with a notable decrease in elevation towards the Holocene terrace (Terrace 1) in the central part of the study area. To the north of the study area is the modern floodplain, surrounding the contemporary channel system. The elevations on the flood plain are generally significantly lower than those on the Holocene terrace to the south.

Although this general trend of decreasing elevation from south to north can be identified within the study area, there is also a considerable amount of micro-topographic variation present within each geomorphological component of the landscape. This topographic variation was clearly visible in a series of terrain profiles produced from the lidar elevation models (Brown *et. al* 2005: 7.2). The profiles were highly irregular, demonstrating significant decreases in topography where they crossed palaeochannels, as well as a tendency towards minor undulations and slopes across the terrace and floodplain surfaces themselves.

As stated in Phase 1, the LiDAR elevation profiles indicate a higher level of topographic irregularity than is generally assumed for alluvial environments. This irregular variation in height values is probably the result of the erosion of formerly flat floodplains by channels that have subsequently been abandoned, as well as reflecting the natural topographic variation of a former floodplain, which was dominated by what appear to be scroll-bars and braid-plan morphology.

4.1.1.3 Stratigraphy

The stratigraphy of the study area outlined in phase 1 was established through combined ground-penetrating radar (GPR) surveys and gouge coring transects. The transects were targeted on the various locations across the Devensian and Holocene terraces, and the modern floodplain.

4.1.1.4 Terrace 2 (Devensian) stratigraphy

The stratigraphy of the Devensian terrace was revealed most clearly through the T2T1 GPR and gouge core transect (Brown *et al* 2005:5.3). The thickness of alluvium overlying the gravel deposits on Terrace 2 was shallow, generally being between 0.3-0.4 m. The alluvium comprised a red brown clayey silt containing fine medium sand. A topographic depression partway along the survey line suggested the presence of a palaeochannel, an interpretation supported by the recognition of a yellow brown sandy clay identified during coring (this clay may represent the basal fill of an early channel). The sandy clay deposits were relatively shallow, however, and are considered to have a low palaeoenvironmental potential. The gravels beneath the alluvium demonstrated some limited internal variation, with the GPR survey isolating four sub units of lower reflectance within the main gravel body (Brown *et al* 2005:5.3). The bedrock was identified at a depth of c. 4 metres below the ground surface.

4.1.1.5 Terrace 1 (Holocene) stratigraphy

A series of GPR surveys and gouge core transects were carried out across the Holocene terrace during the phase 1 fieldwork, with the Terrace 1 transect 1 (T1T1) revealing the stratigraphy of the terrace with clarity. The depth of the red brown clayey silt alluvium across the terrace was found to be variable, although was generally quite shallow at c.0.40-0.50 m. The variation in the thickness in alluvium is partially due to the presence of numerous palaeochannels incised into the terrace, with some having accumulated significant quantities of alluvium onto the terrace surface. Transect T1T1 identified five palaeochannels within its 395m length. These channels were all incised into the gravel deposits of the terrace, with a relative stratigraphic relationship between the channels themselves being established where the features clearly cut across each other. The GPR surveys indicated that the gravels on Terrace 1 were heterogeneous in structure, with a broad division between stronger and weaker reflecting units (Brown *et al* 2005:5.2.1). It is unclear whether this variation is due to the weaker reflecting gravels representing earlier Devensian deposits lying beneath stronger reflecting Holocene gravels, or whether the reflectance values are showing two Holocene gravel units with differing sand and gravel ratios. It is worth noting that in the nearby Hemington gravel pit, Devensian gravels were exposed underlying the later Holocene gravels (Salisbury 1992:159). The depth to the bedrock beneath the gravels at Lockington was not established for Terrace 1.

4.1.1.6 Modern floodplain stratigraphy

The stratigraphy of the modern floodplain was found to vary considerably across the areas surveyed through GPR and gouge coring. The depth of the red brown clay alluvium ranged from shallow over gravel deposits, to much thicker within the numerous palaeochannels, which are incised into the gravel deposits underlying the modern floodplain. Considerable variation was also revealed within the gravel deposits. Distinct gravel units with higher and lower reflectance signatures were revealed by the GPR surveys, suggesting deposits with differing sediment architecture possibly suggesting different migration patterns. The depth of gravel deposits on the lower floodplain was considerable, reaching over 2 metres in places, with the contact to bedrock not determined.

4.2 Three-dimensional stratigraphic modelling of the study area using existing data sets

4.2.1 Outline

The gouge core transects and geophysical surveys conducted across the study area provided detailed information about the stratigraphic development of the particular sample locations. This information was supplemented by the provision of thirteen previously unpublished borehole logs for the study area by Lafarge Aggregates Ltd. In order to better understand the overall stratigraphy of the floodplain, these data sources were used to create a generalised model of the whole study area. It was hoped that this generalised stratigraphic model could be used as a guide to isolate areas of higher archaeological and palaeoecological potential.

4.2.2 Methodology of wider area 3D stratigraphic model

The data for constructing the three-dimensional stratigraphic model came from the interpretation of the borehole logs, the gouge core transects, the OSL sample cores and the core transects along the ground-penetrating radar (GPR) survey profiles (Fig. 4.1). Thirteen borehole logs were obtained for the project, courtesy of Lafarge Aggregates Ltd, providing detailed stratigraphic information for a series of locations across the study area. These logs provided National Grid coordinates for the borehole locations, as well as a classificatory breakdown of the main sediment units that were present. In total, there were also 248 gouge core records generated during the project, including cores taken along the GPR transects. 29 separate logs were also obtained from the cores taken to provide sedimentary samples for OSL dating. The sediment terminology was standardised across the various data sets and Excel tables were produced recording the surface elevation of each core, as well as the depth to the base of alluvium and, where possible, the depth to the base of the sands, which often form the supra bar sediments of the gravel bar cores.

An Excel table combining the stratigraphic information from all the different data sets was produced and put in to a format that was compatible with the Borehole Manager within Rockware's Rockworks software. The tabular data was imported in to the Borehole Manager in Rockworks and a series of two-dimensional logs and cross-sections, as well as three- dimensional fence diagrams and surfaces were constructed. The data was saved as Rockworks 2D ('.rkw') or 3D ('.xml') graphic image files. The stratigraphic fence diagrams were also exported from Rockworks as ESRI 3D shapefiles for integration into ArcGIS ArcScene for display in a pseudo three-dimensional environment along with other data from the project (Figs. 4.2-4.4).

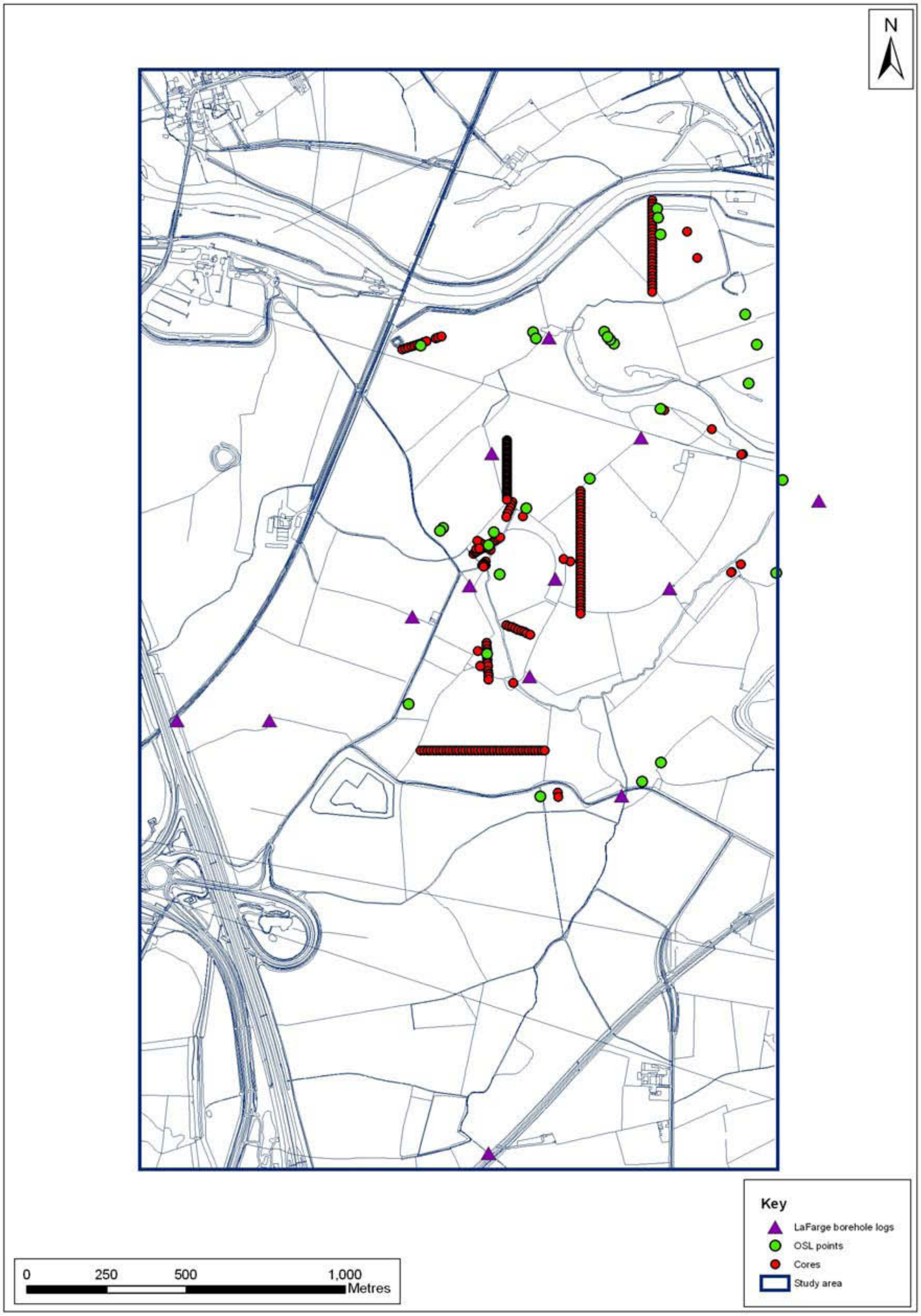

Fig 4.1: Location of data points for the 3D stratigraphic modelling (map by permission of OS).

4.3.3 Summary of modelling

The three-dimensional modelling of the wider area using the borehole and gouge core data provided mixed results in terms of resolution and interpretive information, largely due to the uneven distribution of sediment logs across the study area. In areas where a dense and regular arrangement of cores have been taken, for example where core transects followed the route of a GPR profile to allow depth calibration, an accurate and representative three-dimensional fence diagram can be produced. In these locations within the study area, the fence diagrams provide a detailed record of the depth and stratigraphic relationships of the key sediment units. However, attempting to produce fence diagrams between cores or boreholes that are widely spaced and with few intervening logs is problematic. To assess the methodology, fence diagrams were produced between widely spaced logs and then intervening cores were used to assess the validity of the interpolated profile. This process demonstrated that these fence diagrams showed little resemblance to the subsurface stratigraphy. In certain cases the surface topography had changed considerably, even between relatively closely spaced sediment logs, leading to the subsurface fence diagram displaying above the ground surface when viewed in a three-dimensional environment.

The attempt to use the borehole and core information to generate a subsurface Digital Elevation Model (DEM) representing the base of the alluvial deposits was equally problematic. The method was heavily dependent on the specific interpolation method employed and was only capable of creating a very coarse surface showing the general trend across the study area (Fig. 4.5). As with the fence diagrams produced from widely spaced cores, the uneven distribution and relatively small number of sample points from which the surface has been interpolated means that the model is of limited value for determining specific areas of high archaeological or palaeoenvironmental potential. Without a dense, carefully targeted and systematic distribution of sediment logs it is suggested that three-dimensional subsurface modelling be used with some degree of caution. Fence diagrams and surfaces produced from core transects or closely spaced logs were able to create accurate depictions of the stratigraphy. However, without a dense concentration of raw data, the interpolation methods required to produce three-dimensional models can result in false representations of subsurface stratigraphy.

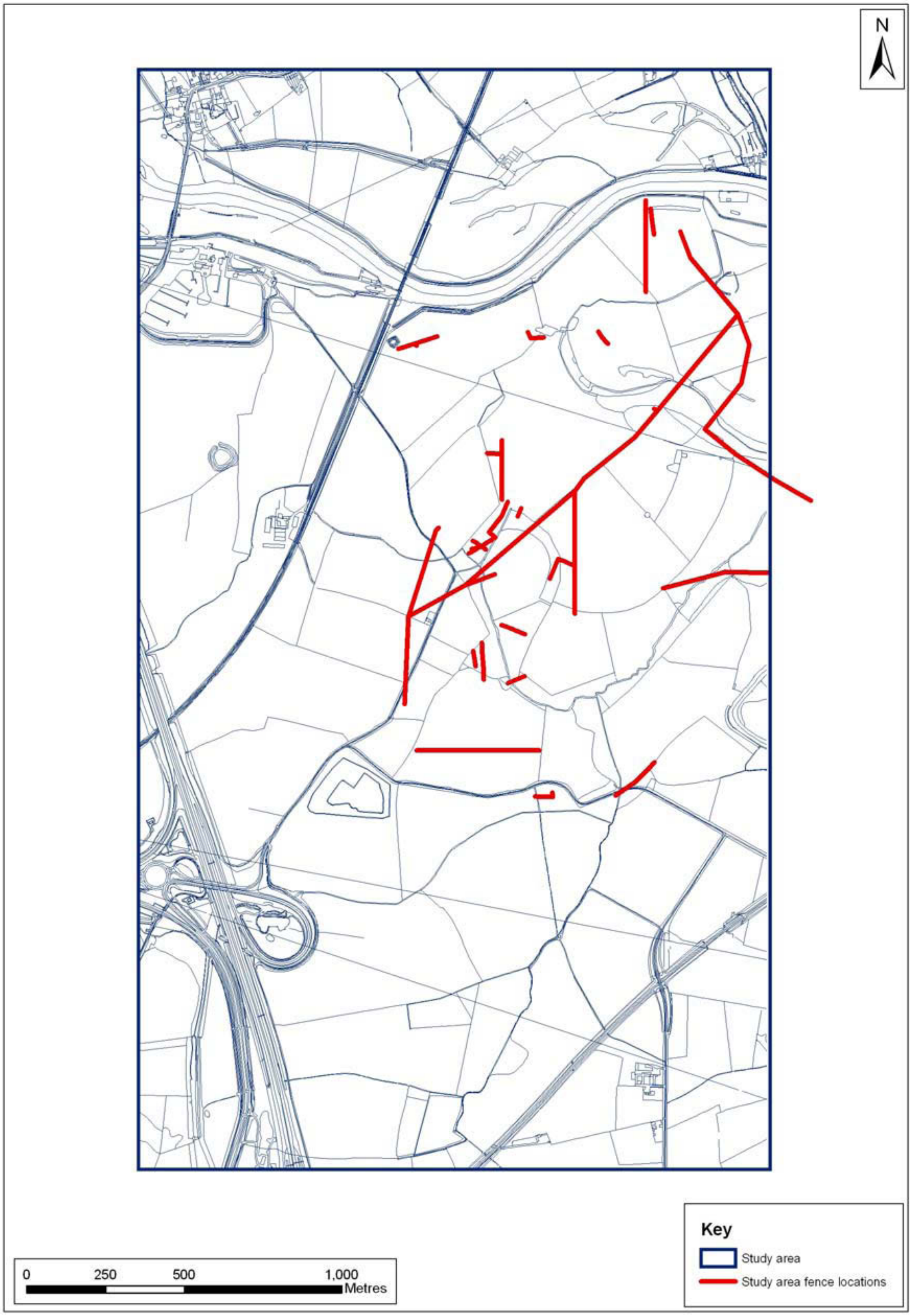

Fig 4.2: Location of stratigraphic fence diagrams (map by permission of OS).

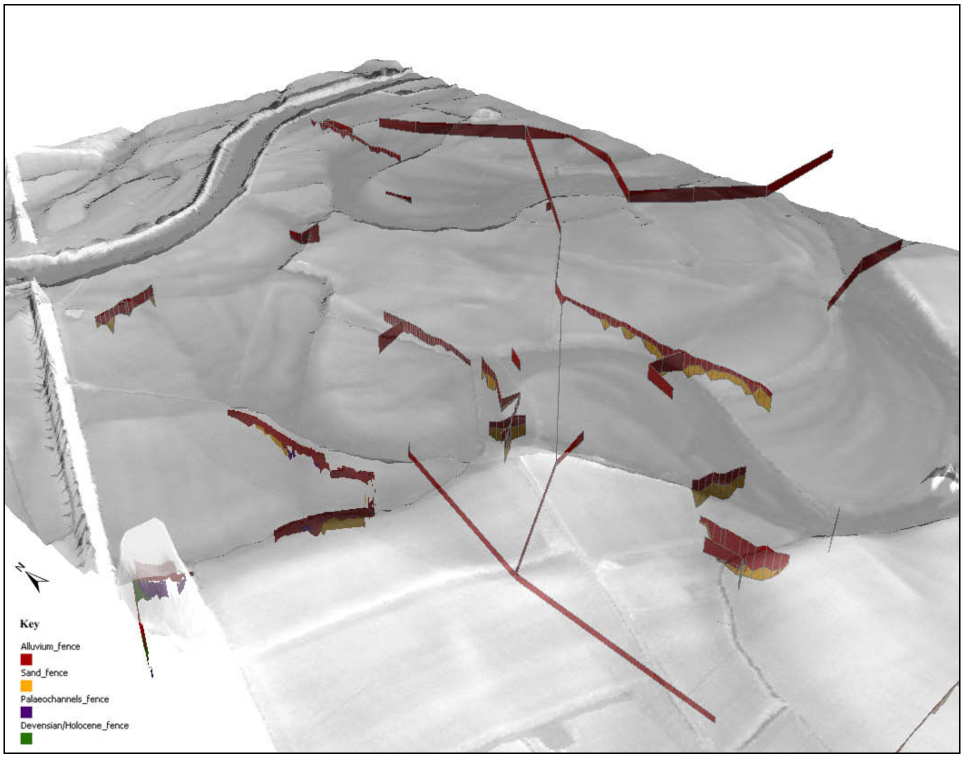

Fig 4.3: ArcScene visualisation of study area stratigraphic fence diagrams below lidar elevation model.

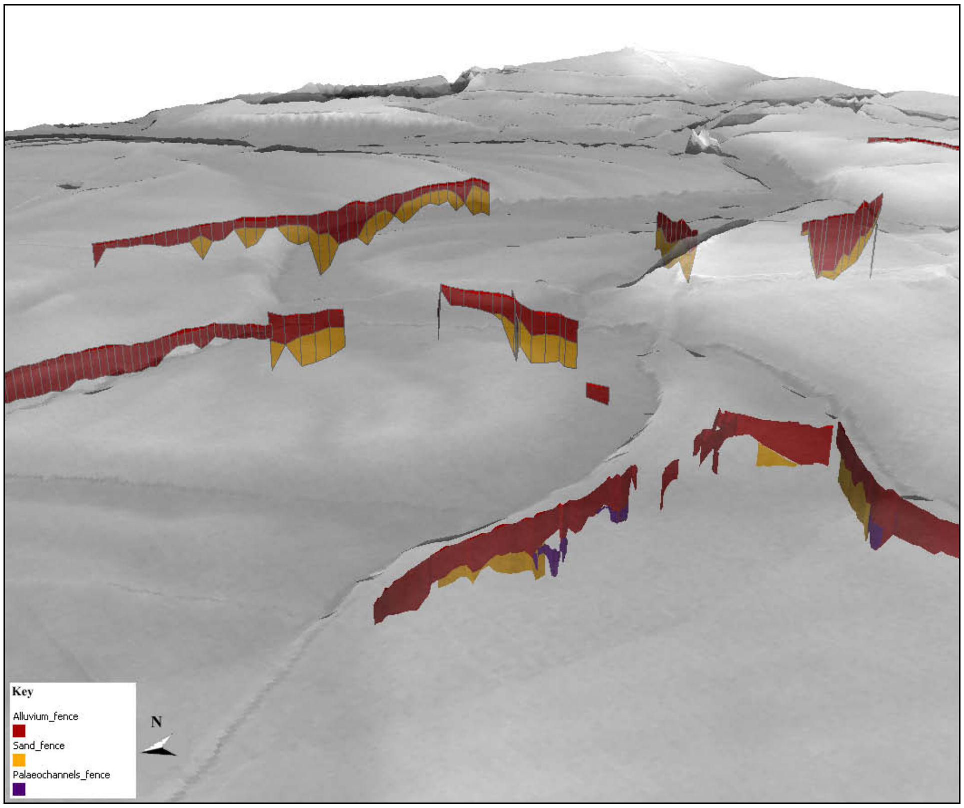

Fig 4.4: ArcScene visualisation of Terrace 1 stratigraphic fence diagrams below lidar elevation model.

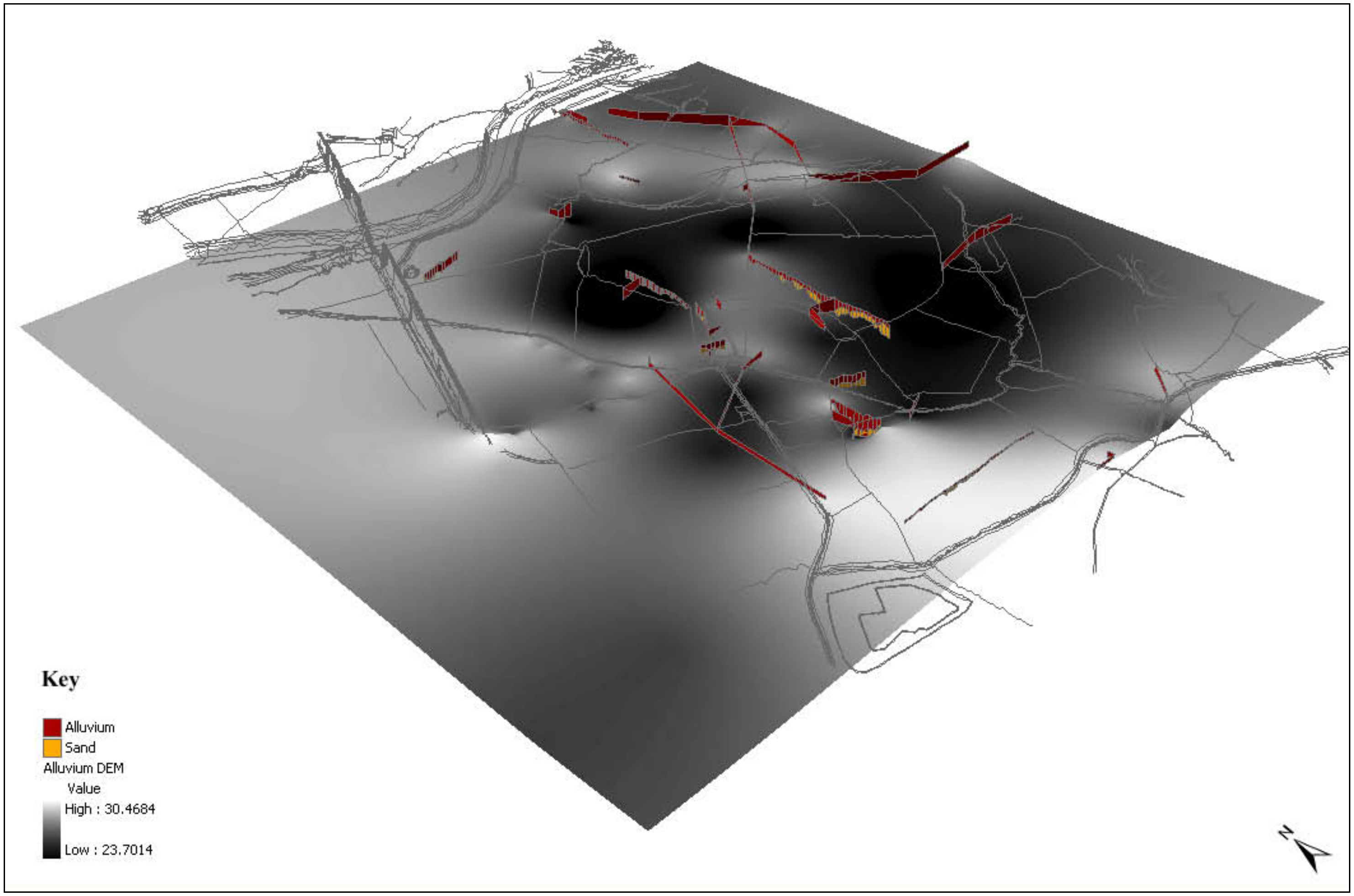

Fig 4.5: Interpolated surface showing base of alluvium across the study area (map by permission of OS).

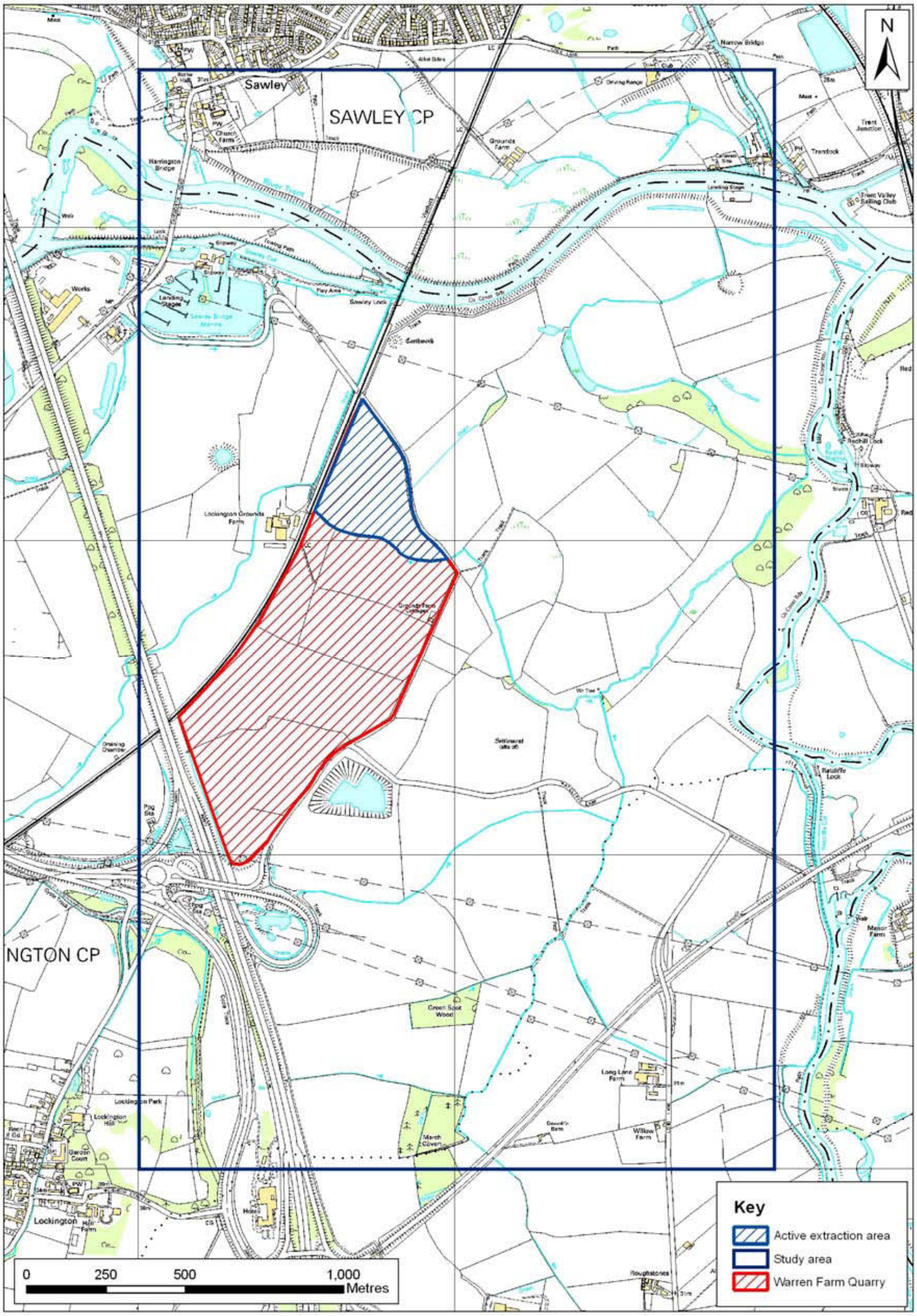

Fig 4.6: Location of Warren Farm Quarry and the active extraction area (map by permission of OS).