TOWARDS AN UNDERSTANDING OF THE ICE AGE AT WELTON-LE-WOLD, LINCOLNSHIRE

PROJECT REPORT FOR ENGLISH HERITAGE

MARCH 2004

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Supported by the Aggregate Levy Sustainability Fund

ACKNOWLEDGEMENTS

This project would not have been possible without Helen Gamble, AONB Officer of the Wolds Countryside Service and Elizabeth and Simon Brookes, the landowners. We are indebted to them all. English Nature kindly allowed us to work on the SSSI.

Thank you to all the project contributors, and especially to Jean-Luc Schwenniger for giving us so much of his time and expertise.

Thank you to Mark Goring and Paul Smith of Site Investigation Services, who carried out the coring with such flair and professionalism.

Many thanks to all who helped out for the Open Day: Thomas Cadbury, Anthony Lee (City and County Museum), Rachel Shaw (Lincolnshire Wildlife Trust), Sara Metcalf, Jane Cowgill, Bill Bee, Pete Wilson and Carol Aram. John Lord kindly provided the flint.

Thank you to Richard Roberts (CfBT) for his enthusiasm for the site and to the teachers for their feedback.

Thank you to Jeremy Dubber for processing all the environmental samples.

Thank you to Alan Straw for donating the fossils he collected from Welton-le-Wold for use in this project, and now permanently curated in the City and County Museum, Lincolnshire, and to David Robinson for copying some of the original photographs of the site.

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1 INTRODUCTION, BACKGROUND AND PROJECT PURPOSE

Two events were instrumental in the development of this project to further investigate and raise the profile of an important Palaeolithic site in the former sand and gravel quarry at Welton-le-Wold.

- A quarry 'Facelift' in 2001 funded by English Nature to clear undergrowth and slumped material from key exposures within the quarry in order that the research and educational potential of the geological resource in the quarry could be realised.
- The pilot Aggregate Levy Sustainability Fund (ALSF) which specifically supports projects to enhance a wider understanding of landscapes of aggregate extraction, and ameliorate the impact of the extraction industry on the natural and cultural environment.

Over the summer and early Autumn of 2003, the project fieldwork, coinciding with a programme of events and outreach, introduced hundreds of people to the Ice Age; to stone tool technology; to the excitement of scientific enquiry; and to the special quarry landscape on their doorstep. This has been transformed over the last 40 years, through careful management, from a vast open pit to a dramatic quarry landscape and haven for wildlife where orchids, grass snakes and buzzards are common.

Plate 1: General view of the western quarry face after a facelift. (Photo Helen Gamble)

Not all of the aims of the original project proposal could be achieved during the pilot period due to no funding being granted by English Nature. This has meant that one of the major elements of the project; to create a safe, permanent section through Pleistocene deposits in the Wildlife Trust Geological Reserve for education and research, was not possible. Hopefully, however, this element will be achieved in the future together with a strong outreach programme that will benefit from the increased knowledge gained from the work carried out so far.

This report describes the methodology and presents the results of all the project elements that did take place, supported by the ALSF distributed by English Heritage. These were:

- Project Area 1: the re-examination of the artefact and fossil material previously recovered from the quarry.
- Project Area 2: the further investigation and reassessment of the Welton gravels associated with the finds.

- Project Area 4: a programme of outreach and interpretation to enhance long-term intellectual access to the geological and archaeological resource at the quarry.

The discussion of the results will centre on the character of the sediments and finds in order to suggest a possible reconstruction of the environmental conditions and depositional processes that resulted in the concentration of this small assemblage of faunal remains and stone tools within the sands and gravels at Welton-le-Wold. The findings of this project will be related to those presented in the original publication (Alabaster and Straw 1976).

Finally, the report will discuss opportunities for further research, work and a continuing education and interpretation strategy for the quarry at Welton-le-Wold.

1. 1. SITE LOCATION AND DESCRIPTION

1.1.1. The village of Welton-le-Wold is located approximately 6 km west of Louth in the district of East Lindsey, Lincolnshire (Figure 1). The area is rural and the landscape is rolling chalk downland – designated an Area of Outstanding Natural Beauty (AONB) in 1973.

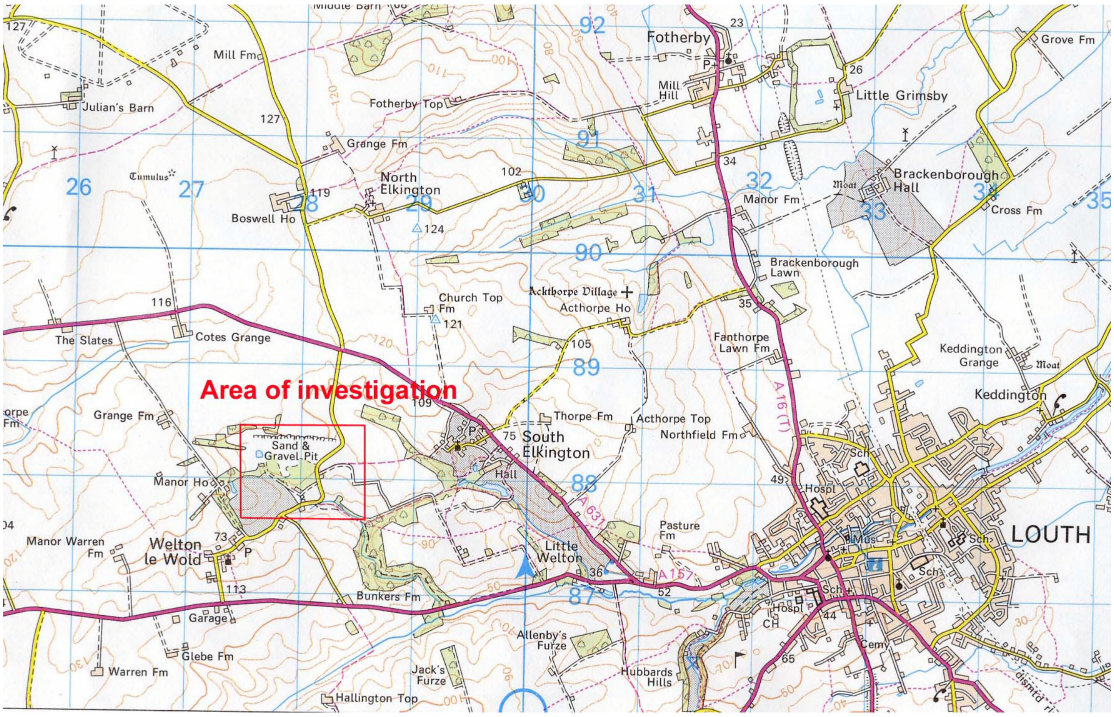

Figure 1: Site Location

1.1.2. In the late 19th century, sand and gravel extraction began in a valley on the northeastern limit of the village (TF 282 881 centre). Extraction intensified during the 1st and 2nd World Wars, primarily to provide materials to build runways. The valuable sands and gravels that fill the valley were deposited during the Pleistocene and are buried beneath glacial tills which are between 4m and 13m thick. The till was removed in a strip system and used to progressively backfill the areas already worked out. The quarry ceased to be economic in the mid 1970's, due to the necessity of removing this thick overburden of till. After nearly a century of excavations, operations ceased, leaving an area of extraction of approximately 50Ha, much of which has been partially backfilled and reinstated to pasture or planted with trees.

Plate 2: Working quarry in the 1960's (Photo by Alan Straw)

1.1.2. The quarry is a designated geological Site of Special Scientific Interest (SSSI) and a Regional Important Geological Site (RIGS) due to its important sequence of Ice Age deposits. Over the summer and autumn of 2001, the quarry received 'Facelift' funding from English Nature to re-create key exposures in the western and eastern limits of the former sand and gravel pit (Figure 2). The primary aim of the Facelift grant was to enable the significant educational and research potential of the quarry to be realised.

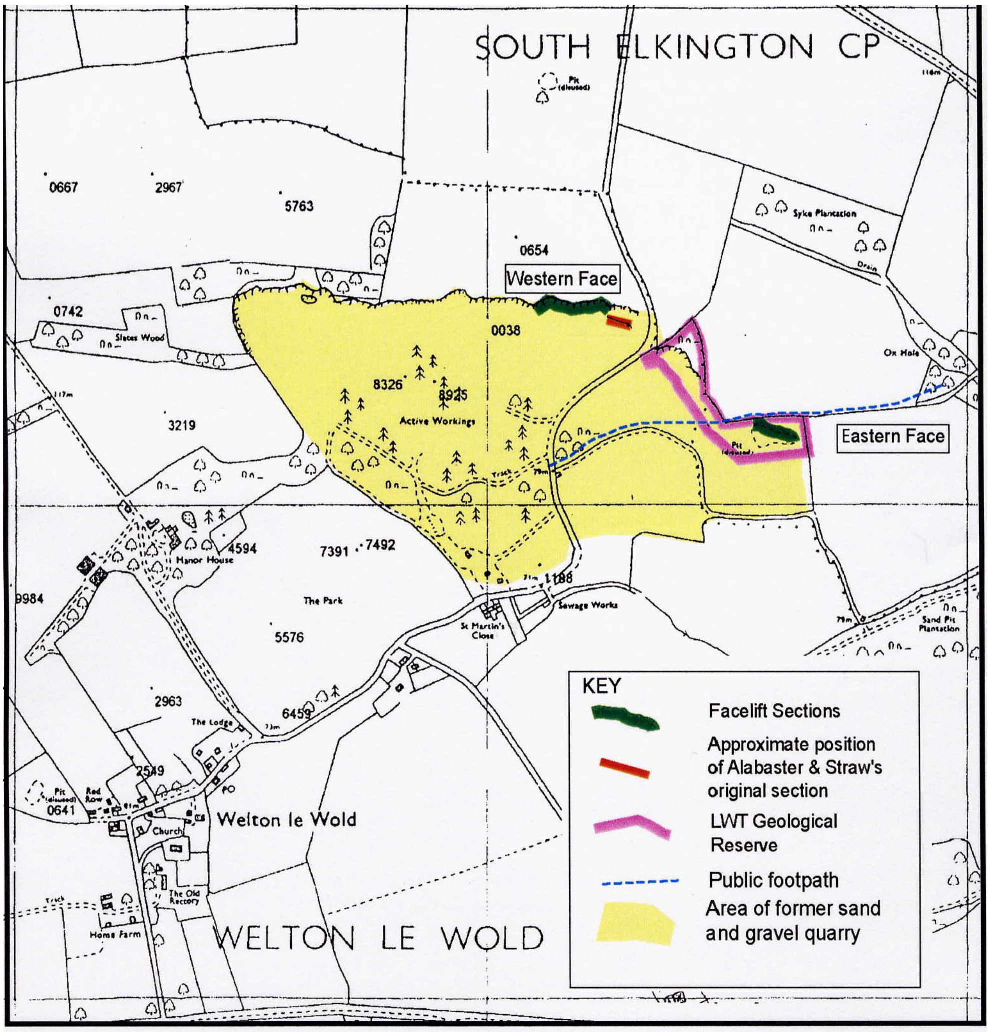

Figure 2: The quarry limits and Facelift sections

Plate 3: The western face prior to Facelift (Photo Helen Gamble)

Plate 4: The western face during Facelift work (Photo Helen Gamble)

Plate 5: The western face after Facelift (Photo Helen Gamble)

1.2. THE ARCHAEOLOGICAL AND GEOLOGICAL BACKGROUND AND CONTEXT

1.2.1 The original stratigraphic record

Between 1969 and 1972, Professor Alan Straw and the then schoolboy, Christopher Alabaster collected three hand axes, a retouched flake and the fossilised remains of elephant, red deer, probable Irish giant deer and horse (identified at the time by P.J. Boylan, former director of the Leicestershire Museums and Art Gallery). They came from a 1.5m to 2m vertical zone which was 3.25m to 4.25m below the base of the glacial till in upper Welton gravels, across approximately 30m of the active western quarry face in Welton-le-Wold (Alabaster & Straw 1976).

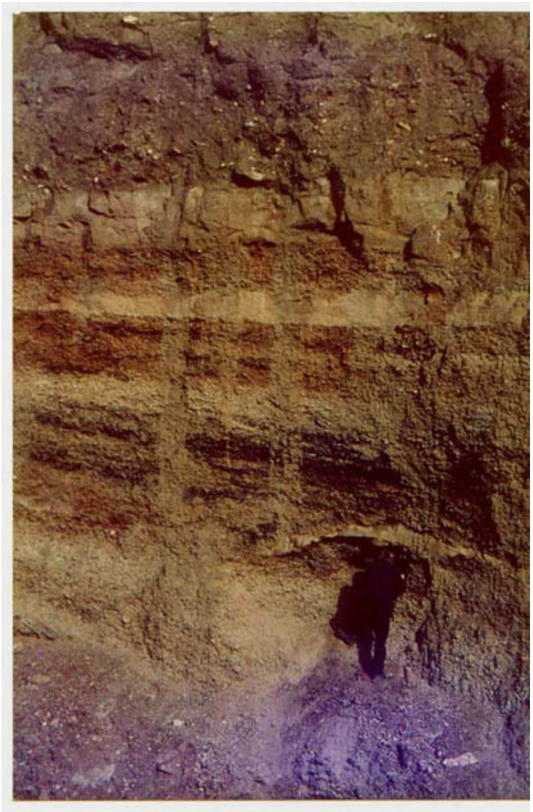

Plate 6: Excavating the elephant molar from the western quarry face in 1969 (Photo Alan Straw)

In order to record the location of the faunal remains and artefacts, the section was surveyed in 1969, and again in 1972 after it had been worked back a further 6m. Samples were also collected non-systematically for geological analysis.

It was, (and still is), so rare for Palaeolithic artefacts to be found unequivocally stratified beneath glacial till (Wymer and Straw 1977) that publication of the assemblage and its Pleistocene context, swiftly followed; in 1976 by Alabaster and Straw in *Proceedings of the Yorkshire Geological Society* and then in 1977 by Wymer and Straw in *Proceedings of the Prehistoric Society*.

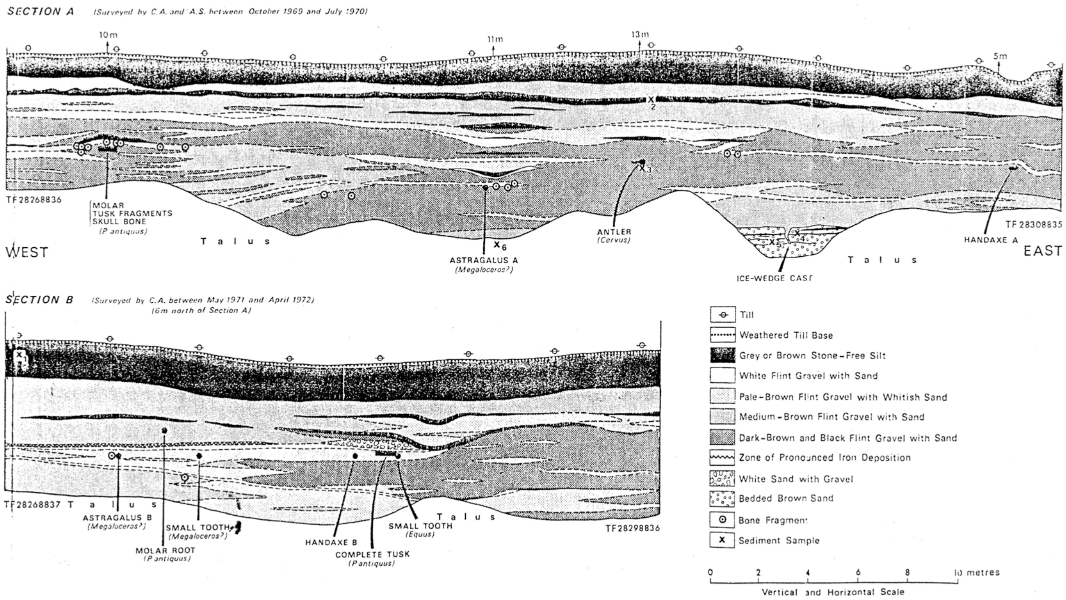

Figure 3: Alabaster and Straw's original recorded section
(From Proceedings of the Yorkshire Geological Society, Vol 41.)

In the published report Straw identified and described three separate tills overlying the Welton gravels, which themselves displayed two distinct divisions – the Upper and Lower Welton Gravel Members. The lowest till, hereafter called the 'Welton Till', is grey brown and does not yet have an agreed correlation with a specific glacial period. The upper red till or Marsh Till is identified by its erratic content to the Devensian tills of the Holderness coast of Yorkshire (Aram *pers. com.).* In the western face, the latest Devensian till is absent, yet there is a third creamy brown Calcethorpe Till present in the exposure here, also with no agreed date, that occurs stratigraphically between the lowest Welton Till and the latest Devensian deposit.

Plate 7: The Calcethorpe and Welton Tills in the western face (Photo Helen Gamble)

Plate 8: The Marsh and Welton Tills in the eastern face (Photo Helen Gamble)

1.2.2 The original chronological framework

In 1976/7 the characteristics of the faunal remains and their association with Acheulean hand axes suggested to the authors that the Hoxnian/middle Upper Swanscombe was the most likely date of the material, with an outside chance that it could be equivalent to a later interglacial somewhere between the Hoxnian and Ipswichian. Largely based on the assumed date of the fauna and archaeology, and working within a traditional Pleistocene framework of three glaciations and three interglacials (see Mitchell *et al*. 1973), it was concluded that both the Welton and Calcethorpe tills overlying the gravels belonged to the Wolstonian glaciation. The fabric and clast differences between the two tills were explained as reflections of variations in the precise direction of ice movement during this single glacial event. The Welton gravels were also considered to have been deposited during the Wolstonian or late Hoxnian in a pre-Wolstonian valley draining eastwards (Alabaster & Straw 1976).

1.2.3 The original interpretation of depositional context

The Upper Division of the Welton gravels were noted as being particularly flint rich and ice-wedge casts were observed at the interface of the Upper and Lower gravels. The Upper gravel member was considered to have been deposited by periglacial aeolian and niveofluvial processes, periodically affected by shallow cryoturbation, under increasingly cold climatic conditions as the Wolstonian ice sheet spread southwards. The conditions under which the gravels were deposited were thought to be too cold and hostile for the warm loving faunal remains and for human occupation. The archaeological and faunal material was, therefore, assumed to pre-date the deposits within which they were found. However, the concentration of remains within a 0.5m band, the size of the mammalian fossils and the freshness of the artefacts suggested to the authors that, although almost certainly derived, they had not travelled far, and could have originated within the Welton valley. The authors speculated whether the bedded sediments of the Lower Welton gravels, which were interpreted as water-lain possibly in a warm stage, were the original source of the material (Alabaster & Straw 1976), although no sediment was traced in the quarry which could have been a likely source.

1.2.4 The current debate

This section is best read with frequent reference to Figure 4, based on the time chart available on the AHOB website (www.nhm.ac.uk/hosted_sites/ahob). The chart is very much in progress, and there are still many uncertainties. Hoxne, for example, is dated to OIS 9, based on aminostratigraphic analyses of non-marine Mollusca, though faunally an OIS 11 correlation (as shown on the chart) is favoured (Schreve pers. comm and McNabb 2002).

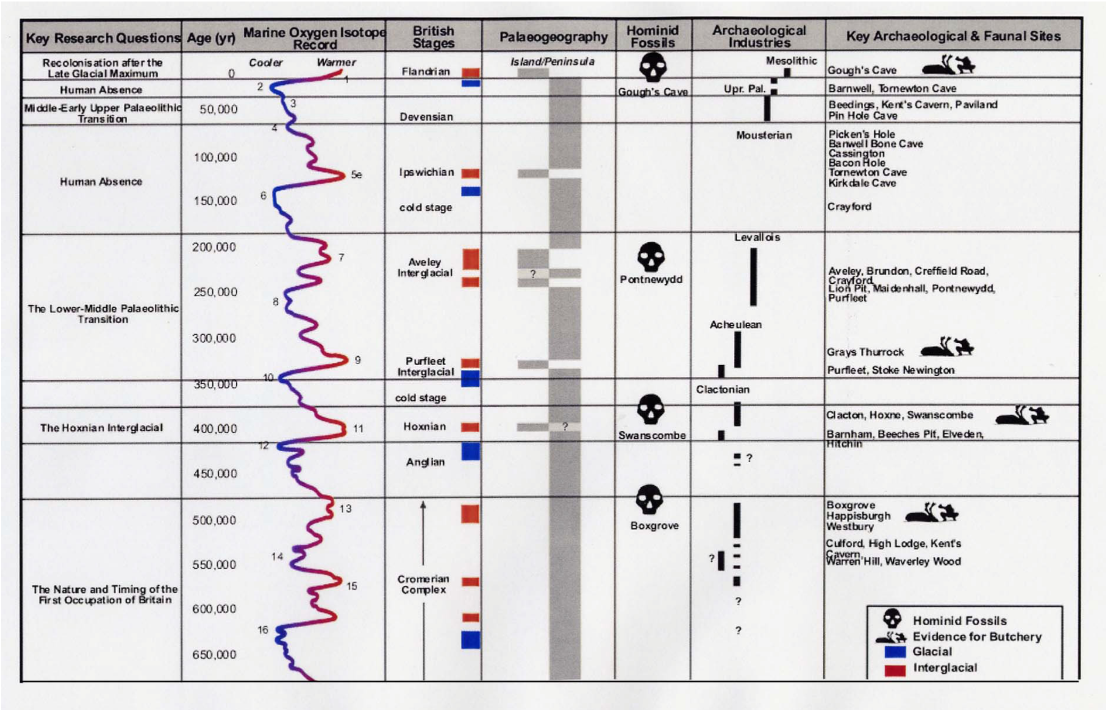

Figure 4: Overview of the Palaeolithic period in the Unite Kingdom
(From www.nhm.ac.uk/hosted_sites/ahob))

Since the 1970s publications, there has been much discussion over the dating of the Pleistocene sequence at Welton-le-Wold. Developments in Quaternary Science in recent years, specifically the remapping of deposits in the Midlands, has revealed that the glacial sequence at Wolston is in fact the westward continuation of Anglian deposits in East Anglia (Perrin *et al*. 1979; Sumbler 1983a, b; Rose 1987). The 'Wolstonian' is, therefore, redundant as a name for this cold stage (Rose, 1988). Until recently, it was widely accepted that the only Middle Pleistocene glaciation that could be recognised in Britain with any certainty was the Anglian. However, this has been challenged by Maddy *et al.* (1995) and Hamblin *et al*. (2000), the latter recognising glacial deposits in Britain which they correlate with OIS 16, 12, 10, 6 and 2.

1.2.5 The chronological problem

The implication for Welton-le-Wold is that the chronological framework is wide open and there are several dating options for the Welton gravels and the archaeological material within them:

- If the overlying Welton Till is OIS 6 or 10 (McNabb 2001/2002, Wymer 1996), the fauna and artefacts could be correlated with the interglacials of OIS 7, 9 or 11. (Although the original interpretation favoured a classic Hoxnian date, McNabb (2001) notes that a lack of Hoxnian age sediments in the region makes this unlikely.)
- If the overlying till is Anglian, i.e. OIS 12 (Lewis 1999), the fauna and artefacts would be over 100,000 years earlier and correlate with the Cromerian *senso lato*, anywhere between OIS 13 to OIS 16 (Straw 1982; Lewis 1999; comment by Bridgland in McNabb 2001/2002).
- There is even a remote possibility that the Welton and Calcethorpe tills represent an early Devensian (early OIS 2) glacial deposit, whilst the Marsh till is late Devensian (late OIS 2), giving a possible correlation for some of the faunal remains with OIS 5e (though the presence of horse makes this very unlikely).

1.3. THE SIGNIFICANCE OF THE SITE

The completeness of the glacial sequence, and the potential of the site to resolve critical questions of chronology in regional Pleistocene studies make Welton-le-Wold one of the most important quaternary geological sites in the East Midlands. In addition to this, the presence of stratified Middle/Lower Palaeolithic archaeological material is so rare (to date, not a single *in situ* archaeological site stratigraphically dated to the Middle or Lower Palaeolithic is known in the East Midlands (McNabb 2001/2002)), that Welton-le-Wold is recognised in regional and national research frameworks as being important for our understanding of the Middle/Lower Palaeolithic occupation in the region (McNabb 2001/2002, Wymer 1996).

In addition to the scientific value of the former quarry at Welton-le-Wold, the management of the geological SSSI's through Countryside Stewardship and as a Lincolnshire Wildlife Trust Geological Reserve means that improving wider public physical and intellectual access is a major element of the long-term management strategies.

2. THE PURPOSE OF THE PROJECT

2.2. AIMS AND OBJECTIVES

2.2.1. The fundamental aim of the project as a whole was to apply a multi-disciplinary approach to further understand and enhance the archaeological and geological resource at Welton-le-Wold former sand and gravel quarry.

To achieve this, the project was originally structured into four separate project areas, each of which had its own main aims. Project Area 3 was not funded. This meant that work to create a permanent and safe exposure across the Pleistocene deposits within the Wildlife Trust Reserve was not achieved, and parts of the outreach and interpretation programme were curtailed. The Project Areas' aims and objectives addressed in this project were:

2.2.2. **Project Area 1**: *A re-examination of the artefact and vertebrate fossil assemblages.*
AIM: To re-evaluate the artefactual and faunal assemblages to gather fresh information about the age, environment and context of the material
<u>Objective 1:</u> To re-evaluate, verify identification and further analyse vertebrate faunal remains
<u>Objective 2:</u> To re-analyse the stone tools
<u>Objective 3:</u> To re-analyse the stone tools for degree of abrasion to provide critical information on the (assumed) secondary depositional context of the Palaeolithic artefacts.

2.2.3. **Project Area 2**: *Geophysical and borehole investigation.*
AIM: To re-assess and further investigate the context of the finds previously recovered from Welton-le-Wold former sand and gravel quarry.
<u>Objective 1:</u> To locate the original 1970's gravel section, or the existing buried gravel face in the western quarry exposure
<u>Objective 2</u>: To core the sequence of gravel deposits in the western and eastern faces in order to:

- reconstruct a stratigraphic section of the sediments for comparison with those recorded by Straw between 1969 and 1972
- assess the potential for artefact and fossiliferous bearing deposits

<u>Objective 3</u>. To re-assess and re-examine the upper and lower sequence of the Welton Beck Member gravels with modern geological techniques.
<u>Objective 4:</u> To identify and assess deposits for Palaeoenvironmental, fossil and artefactual potential.
<u>Objective 5:</u> To identify and sample deposits suitable for OSL dating.

2.2.4. **Project Area 4**: *Outreach and dissemination*.
AIM: To complement and enhance immediate and long-term intellectual access to the geological and archaeological resource at Welton-le-Wold.

Objective 1: To raise awareness of the former quarry at Welton-le-Wold as an educational resource amongst schools.
Objective 2: To raise awareness of the former quarry by launching the newly accessible faces in a Welton-le-Wold day.
Objective 3: To disseminate information about the geological and archaeological resource at the former quarry at Welton-le-Wold in a clear and accessible form for use by other organisations developing long-term interpretation strategies, educational material and museum displays.

SECTION 2 A RE-ASSESSMENT OF THE ARTEFACT AND FOSSIL ASSEMBLAGES FROM WELTON-LE-WOLD (PROJECT AREA 1)

Main Aim: To re-evaluate the artefact and faunal assemblages collected in previous work, to gather fresh information about the age, environment and context of the material from Welton-le-Wold

2.1 THE BACKGROUND AND PURPOSE OF PROJECT AREA 1

The archaeological and faunal material from this site was identified and described by Boylan (in Alabaster & Straw 1976) and the archaeological material in more detail by Wymer and Straw (1977). The original analysis of the palaeontological material identified four species:

- Straight-tusked elephant (*Palaeoloxodon antiquus*)
- Red Deer (*Cervus* cf *elaphus*)
- Large Deer (*Megaloceros* sp.)
- Horse (*Equus* sp.)

The stone tools were identified as characteristic products of the Acheulean industry.

The characteristics of the assemblage and the association of the Acheulean hand axes indicated to Boylan (1976) that Hoxnian/middle upper Swanscombe was the most likely date of the material, although any date between the Hoxnian and Ipswichian interglacials was possible. Wymer and Straw (1977) also recognised similarities between the association of Acheulean hand-axes and specific fauna, elephant, horse, red and giant deer, from deposits at Welton-le-Wold, and from the Hoxnian stratotype at Hoxne, Suffolk.

Since the material was published, there have been major advances in our understanding of the complexities of climatic change in the Pleistocene. Of particular importance has been the cross-correlation of data from long fluvial sequences in the lower Thames Valley with the marine oxygen isotope record and biostratigraphical information from fossil mammalian assemblages (Bridgland 1994; Schreve 2001). Currently, four interglacial sediments are recognised, that are thought to correspond to four separate climatic cycles between the Anglian glaciation and the Holocene (Bridgland 1994).

Analysis of interglacial mammalian fossil faunas has identified a series of four distinctive mammal assemblage zones (MAZ) occurring between the Anglian and the Last Cold Stage (Devensian). This has enabled the differentiation of assemblages previously attributed to generalised ‘Hoxnian’ and ‘Ipswichian’ faunas into four separate interglacials, correlated with Marine Isotope Stages (MIS) to 11, 9, 7 and 5e of the oxygen isotope record (Schreve 2001). This correspondence is shown in the table below.

MAZ	MIS	Diagnostic fauna
Trafalgar Square	5e	Hippopotamus (*Hippopotamus amphibius*) Fallow deer (*Dama dama*) Absence of Horse (*Equus ferus*) and humans (*Homo* sp.)
Aveley	7	Mammoth (*Mammuthus primigenius*) Horse (*Equus ferus*) Large form of northern vole (*Microtus oeconomus*)
Purfleet	9	Brown bear (*Ursus arctos*) Water shrew (*Neomys browni*) Spotted hyena (*Crocuta crocuta*) Fallow deer (*Dama dama* ssp. indet)
Swanscombe	11	Cave bear (*Ursus spelaeus*) Large fallow deer (*Dama Dama clactoniana*) Small mole (*Talpa minor*) Giant beaver (*Trogontherium cuvieri*) Pine vole (*Microtus subterraneus*) Rabbit (*Oryctolagus cuniculus*)

Table 1: Correlation between marine oxygen isotope stages (MIS) and mammal assemblage zones (MAZ), with diagnostic faunas from each zone. Note that the Aveley MAZ can in fact be further divided into two discrete groups, the Ponds Farm MAZ, and a later Sandy Lane MAZ (after Schreve 2001).

In the light of the revised chronological framework and the possibilities offered by the MAZs, a reassessment of the faunal material from Welton-le-Wold was obviously necessary. The refinement of the original identification and the possible identification of some of the very fragmentary bone fragments might have enabled a closer correlation with a defined MAZ – or indeed find that the material belong to different interglacials – an interpretation not considered in the original reporting.

The derived nature of the faunal material and the artefacts was recognised in the original publications (Alabaster & Straw 1976; Wymer & Straw 1977), yet only generalised statements regarding the unlikelihood of the archaeology and the fossils being contemporary, or the fact that the stone tools were manufactured and the animals lived prior to the deposition of the gravels were made (*ibid*).

By the time of the original site investigation, Wymer (1968) was already using visual assessment of artefact abrasion to determine the extent of artefact transport, and recognised the need for more quantative experimentation (Wymer & Straw 1977). Shackley (1974 and

1975) was pioneering more objective observations based on the measurement of arête widths to calculate possible distances travelled by Palaeolithic artefacts.

This ‘artefact biography’ approach, pioneered by Shackley is being further developed by Chambers (*in prep*) who is carrying out experiments to study the detailed character of abrasion damage across the entire artefact according to specific modes of transport in high energy fluvial environments. In the light of this work, it was hoped that a study of the abrasion damage to the Welton-le-Wold artefacts would provide information about the nature and extent of their derivation.

Given the greatly increased number of independently dated Palaeolithic assemblages available now, it was also hoped that the re-examination of the ‘Acheulean’ hand axes for stylistic and manufacturing traits would possibly identify specific attributes that are of a particular period, and enable conclusions to be drawn concerning their contemporaneity.

An important aspect of all elements of the re-analysis was the resulting fresh and detailed information available to interpret the animal remains and stone tools at the City and County Museum where they will be displayed, and for ongoing educational and interpretation literature and activities centred on the quarry at Welton-le-Wold.

2.2 PROVENANCE OF THE MATERIAL

According to the recorded section drawings presented in Alabaster and Straw (1976) (Figure 3), faunal material from the section exposed in 1971/2 was collected predominantly from a single horizon, within a “pale brown flint gravel with whitish sand”, 0.2-0.3m thick and 3.25-4.25m below the till. This light-coloured gravel terminates against a silt seam towards the east and is considered by Alabaster and Straw to represent a period of quieter deposition. At the western end of the section, recorded in 1969/70, straight-tusked elephant molars, tusk and cranial fragments were present at a similar height but within a medium-brown flint gravel with sand. A red deer antler was reported from a dark brown gravel approximately 20m to the east of these remains, although again occurring at a similar height. The complete tusk was separated from the other tusk tip by approximately 12m and the two astragali by 14m.

Two of the hand axes were recorded *in situ* and recovered from the sections. Both were on the same general level as the faunal remains, one of them in the pale brown flint gravel with white sand very close to the complete tusk and the other in a dark brown and black flint gravel with sand just below a band of white flint gravel with sand (Figure 3). The other hand axe and the flake were recovered from a waste tip immediately south of the eastern end of the section. The staining indicated that they had undoubtedly come from the Welton gravels (Alabaster & Straw 1976).

2.3 A RE-EVALUATION OF THE WELTON-LE-WOLD MAMMALIAN ASSEMBLAGE

Danielle Schreve

2.3.1 Species List

Re-examination of the specimens collected in the 1970s has reassigned material attributed to the giant deer (*Megaloceros giganteus*) to a large bovid (*Bos*, or more probably *Bison*). The identification of the associated elephant molars has also been revised (see below). Minimum numbers (MNI) of individuals are given in brackets.

PROBOSCIDEA

Elephantidae

Palaeoloxodon antiquus (Falconer and Cautley, 1845), straight-tusked elephant (MNI = 2)

PERISSODACTLYA

Equidae *Equus* sp., horse (MNI = 1)

ARTIODACTLYA

Cervidae

Cervus elaphus Linné, 1758, red deer (MNI = 1)

Bovidae

Bovini sp., large bovid (*Bos* or *Bison*) (MNI = 2)

2.3.2 Description of the finds

The dentition of the straight-tusked elephant (*Palaeoloxodon antiquus*) is characterized by two large tusks (incisors) and high, narrow, lophodont molars. Both of these elements are present in the Welton-le-Wold assemblage. The cheek teeth are comprised of a series of enamel plates or “lamellae”, which are joined at the base and the enamel of the plates is coarsely wrinkled and usually thick (1.0-3.5mm, Maglio, 1973).

Plate 9 : Palaeoloxodon antiquus tusk (50cm scale)

Two associated molars of *Palaeoloxodon antiquus*, originally described by Boylan (in Alabaster and Straw, 1976) as the upper second and third molars, are in fact an upper first and second molar. The presence of associated teeth, apparently found in life position, strongly implies that further cranial material was originally also present at the time of deposition (a possibility hinted at by Alabaster and Straw [1976] on the basis of the presence of “many friable bone fragments” that were found around the teeth). A small fragment of maxillary bone is present on the buccal side of the M2, although no other cranial material is apparent in the existing collection. The M1 is well worn and comprises 10 plates, although the back part of the tooth is missing, as are the roots. The occlusal surface clearly shows the prominent median expansion of the plates that is characteristic of this species. The M2 is just coming into wear and comprises 13 plates and a posterior talon. As is typical in the early stages of wear, the enamel of the anterior plates has an elongated oval ring (*annulus*) flanked by smaller circular rings. This tooth was the most complete and was therefore the only one to be measured:

Overall length of the tooth, measured along the axis of growth and perpendicular to the lamellar plane): 254mm
Breadth of the tooth, measured at the widest part of the occlusal surface: 67.80mm
Height of the tooth: 213mm
Enamel thickness: 2.86mm
Lamellar frequency (number of plates over 100mm): 6

The relatively modest plate count and the size of the tooth conform most clearly with the upper second molar, based upon the observations of the author and the plate counts of 12-13 given by Falconer (1865) and Adams (1877-81), rather than the original identification of an upper third molar by Boylan (in Alabaster and Straw, 1976). Although plate counts vary enormously in the last upper molar, 15-20 is the norm. The anterior talon is only just visible and the roots are missing. Coarse sand and small gravel clasts are lodged in the exposed hollow ends of the molar plates.

Plate 10 : Palaeoloxodon antiquus molars (50cm scale)

A small molar fragment (2 plates), cf. *P. antiquus*, broken down the median line of the plate and across the centre of the plate, was found near the associated molars but cannot certainly be attributed to the same individual. A mid-posterior section of an upper molar (6 plates) of *P. antiquus* is also present in the assemblage. The roots are missing but the crown height and different degree of wear suggest that this is a separate individual to the one with the associated teeth. A minimum number of two elephants are therefore implied. The large, virtually complete adult tusk of *P. antiquus* is now in several large pieces with a number of smaller fragments. Measurements are given in Alabaster and Straw (1976). A 25cm straight section of tusk, including the tip, was found near the associated molars although it cannot certainly be attributed to the same animal. It is in a weathered and rolled condition. The surface has fine angular gravel clasts and coarse sand adhering to it.

A single small fragment of molar of horse (*Equus* sp.) is present in the assemblage. The tooth is broken transversally in the area of the lingual loop and is missing the lingual surface and roots. A small fragment of the posterior lingual edge is also present but the two do not conjoin. From the occlusal surface, the tooth is apparently in mid-wear but the absence of roots precludes a more precise estimation. On the basis of this small fragment, it cannot be determined whether the tooth is that of a 'true' caballine horse or one of the ass-like stenonid species.

An unshed antler base (?right) of *Cervus elaphus* is also present. The specimen is crushed, fragmentary and has undergone extensive consolidation and, therefore, could not be measured. The surface of the antler is blackened, probably due to manganese staining, and it has substantial amounts of coarse sand and small angular gravel clasts adhering. The antler belongs to an adult male individual and its unshed state indicates that the animal must have died between September and March, based upon present day antler growth cycles (Corbet and Harris, 1991).

Three finds originally attributed to giant deer (*Megaloceros giganteus*) have been reassigned to a large bovid (?*Bison* sp.), comprising a fragment of a lower molar and two right astragali, indicating a minimum number of two individuals. The molar is broken after the first cusp in the thinnest part of the tooth, immediately anterior to the mesostyle. It shows the characteristic selenodont cusp pattern of the large bovids and the tooth is both higher-crowned than in deer and with no sign of the basal narrowing of the buccal wall of the molar that should already be apparent were the tooth that of a large cervid. The postcranial material is extremely abraded and has been thickly coated in consolidant so any reinterpretation must be regarded as tentative. The less complete of the astragali has partial iron staining and small angular gravel chips adhering to the surface. The overall morphology of the two specimens is more consistent with Bovini than with giant deer, in particular, the two lobes of the caudal surface are more symmetrical than in *Megaloceros*. The astragali are of relatively small size, even taking into account the degree of erosion of the original bone surface, and are visually most comparable with smaller bison specimens (probably females) from early Devensian deposits in Britain. However, sexual dimorphism is extremely pronounced in bison, as are fluctuations in size in relation to climate change. In addition, two species are known from the British Pleistocene, *Bison schoetensacki* (Freudenberg) from the early Middle

Pleistocene and *Bison priscus* Bojanus, from the late Middle and Late Pleistocene. Any further identification is therefore not possible on the basis of such limited material.

Plate 11 : Astragali of large bovid (Bos or Bison) (50cm scale)

2.3.3 Taphonomy

Virtually all of the material has been treated with a thick consolidant ('Trycolac' according to a note in the collection) that has unfortunately obscured the original bone surface and with it any evidence of modification such as cut marks. Discolouration of the consolidant over the years is probably responsible for the brown, 'treacly' consistency currently observed. There is no visible evidence of carnivore modification on the limited amount of post cranial material present, although it is very abraded. Nevertheless, it is clear that different elements of the mammalian assemblage are very variable in its condition, the elephant molars being the best preserved material in the collection and the bovid astragali the least, suggesting different depositional histories. The red deer antler is too crushed and too heavily consolidated and the bovid and horse molar fragments too small to say much about their depositional history. However, since these teeth are naturally compact and robust, the presence of only fragmentary material is an indication of transport in a coarse substrate, trampling or other forms of breakage. With respect to the elephant molars, the occurrence of articulating teeth suggests that there has been only minimal disturbance of the material since deposition (resulting in the destruction of the maxilla and the removal of the fragile roots but leaving the specimens in life position). The presence of a fragile and relatively complete tusk also suggests that there has been little post-depositional movement. This contrasts markedly with the heavily abraded bovid astragali, which show clear evidence of transportation and have certainly been derived.

2.3.4 Evidence of local environment and climate from the vertebrate remains

The varying condition of the bones and teeth warns against consideration of the different elements as a unitary assemblage. Only the better-preserved elements, namely the elephant remains, are likely to give clues to an accurate reconstruction of contemporary climate and environment. The apparent period of quieter deposition inferred for the pale brown gravel also argues against long distance transportation of these elements. Straight-tusked elephant is restricted to interglacial or interstadial occurrences in Britain during the Pleistocene and is generally associated with local mixed or deciduous woodland habitats. In contrast, horse, red deer and bison are found in both cold-climate and temperate episodes. Horse is indicative of open grassland, whereas red deer and bison inhabit a wide range of environments at the present day, including both closed woodland and more open habitats. Local temperate forest is therefore certainly indicated but a mosaic of environments is possible, depending on the degree of reworking of the non-elephant material.

2.3.5 Biostratigraphy

The utility of mammalian assemblages as indicators of relative age for Pleistocene sediments has been repeatedly demonstrated (e.g. Currant and Jacobi, 2001; Schreve 2001; Stuart and Lister 2001) but the limited vertebrate assemblage from Welton-le-Wold is unfortunately not particularly age diagnostic. The two taxa identified to species level have some of the longest biostratigraphic ranges of any large Pleistocene mammals, thereby rendering age determination extremely difficult. The first occurrence of *P. antiquus* in Britain is in the Early Middle Pleistocene at Pakefield and Kessingland (Suffolk). This site is currently being reinvestigated by the Ancient Human Occupation of Britain (AHOB) project, but analysis of a new small vertebrate assemblage now suggests that it pre-dates the Cromerian stratotype of West Runton (*contra* Stuart and Lister, 2001) and that a place within the very earliest early Middle Pleistocene is more appropriate. Although *P. antiquus* is not known from West Runton and continental correlates such as Voigtstedt (Germany), it reappears in Britain during the latest part of the early Middle Pleistocene at sites such as Ostend (Norfolk) and is a common component of all four post-Anglian interglacials before becoming extinct prior to the Last Glacial Maximum. Red deer, which are still extant, have a similarly long stratigraphic range, appearing in NW Europe during the early Middle Pleistocene. Stenonid horses first occur during the Early Pleistocene but are present only sporadically throughout the Middle Pleistocene in Britain although they apparently survived into the Neolithic in southern Europe (Bökönyi, 1954). Caballine horses are present from the early Middle Pleistocene onwards and are known from every succeeding temperate episode with the exception of the Last (Ipswichian) Interglacial and the early part of the Devensian (Currant and Jacobi, 2001).

The mammalian assemblage from Welton-le-Wold could therefore fit within any Middle or Late Pleistocene interglacial or interstadial with the exception of the Last Interglacial.

2.4 ANALYSIS OF ARTEFACTS FROM WELTON-LE-WOLD *John McNabb*

Three bifaces and a flake from Welton-le-Wold were submitted for analysis. Such a small sample cannot be considered as an assemblage, nor can it be considered as a representative sample of one, since the size of the original assemblage is not known. Consequently, it is only possible to treat any observations made on these artefacts as 'isolated moments' in the broader continuum of both tool behaviour, and the pieces' depositional life history.

*Biface **39.76***

*Biface **40.76***

*Biface **56.70***

*Flake **41.76***

Plate 12: Welton-le-Wold bifaces and flake

A summary of the details of each artefact are presented in Table 2 below.

Description	**Artefact No.** **56.70**	**Artefact No.** **40.76**	**Artefact No.** **39.76**	**Artefact No.** **41.76**
Artefact type	Biface	Biface	Biface	Flake
Length in mm	84	99	119	Max L Axial L 99.5 81
Width in mm (Bordes 'm')	54	63.5	71	As rt. ang. to L 73 90
Thickness (Bordes 'e')	25	39	37	 31 31
Width @ 0.5 L (Bordes 'n')	51	62	63	/
Dist. From max W to base (Bordes 'a' Roe 'L1)	29	40	50	/
Roe B1	37	45	47	/
Roe B2	51.5	57	60	/
Roe Th1	17	20	18.5	/
Flint type	Fine grained with inclusions	Grainy with cherty inclusions	Grainy	Fine grained with inclusions
Blank	Probably flake	Indeterminate (possibly flake)	Flat elongated cortical pebble	/
Sides in profile	One straight, one sinuous	One sinuous, one v. sinuous	One straight, one too damaged	/
Sides in planform	Predominantly convex (tending to straight in lower third)	Predominantly convex	Probably straight but obscured by later damage scars	/
Butt	Thinned from one face to make flat butt	Almost all worked from one face	All worked	/
Cross section in long profile	Lenticular, irregular	Plano-convex	Lenticular, irregular	/
Stained	Extensive, very dark reddish/orange	Dark yellow to pale orange	Reddish orange	Pale brown
Patinated	Grey and over prints staining. Patchy	No	No	No

Bordes (1961) type	Thick; ovate/sub-cordiform	Thick; sub-cordiform	Thick lanceolate	/
Roe (1968) morphology	'ovate' type (only just), top left quadrat	'ovate' type, top left quadrat	'ovate' type, top left quadrat	/
Wymer type	Small handaxe	Sub-cordate	Pointed	/
Illustrated	Wymer and Straw 1977 fig 1.1. Alabaster and Straw 1976 not figured	Wymer and Straw 1977 figure 1.3. Alabaster and Straw 1976 Handaxe C	Wymer and Straw 1977 figure 1.2. Alabaster and Straw 1976 Handaxe B	Wymer and Straw 1977 not figured. Alabaster and Straw 1976 Handaxe D
Condition	Slightly worn. Some rounding of arêtes. Edges show nibbling and chattering but are still sharp in places. Arête on former ventral and on tip on opposite face appear slightly less rounded	Quite sharp. Arêtes only slightly rounded. Edges show only minimal sporadic chipping and not much rounding. Tiny promontories on edges still present in places.	Worn-rolled. Arêtes are rounded off. Extensive differentially patinated chipping along edges and tip. Where edges are undamaged they show rounding and chattering with tiny promontories on the edges removed.	Sharp. Arêtes are not rounded off or worn. Edges show very minute nibbling – Wymer interprets most extensive patch of edge damage as use wear.

Table 2: Summary of details of artefacts from Welton-le-Wold, Lincolnshire

2.4.1 Condition, surface appearance, raw material

All four artefacts are stained, showing various degrees of intensity and colour differentiation. Staining is here taken to be a particular form of discoloration of the surface of a flint artefact. The flint acquires a hue that varies from pale yellow/brown to a deep reddish or mahogany colour. It is generally assumed to be a reaction by the surface of the flint to ferrous oxides dissolved in ground water, but other substances such as manganese can also induce staining (Wymer, 1968). Staining may also have affected the artefacts differently depending on what kind of flint they are made out of. The two coarse-grained flint bifaces (39.76 and 40.76) appear to have acquired a similar staining, with 39.76 showing a darker orange colour, presumably reflecting a longer exposure to the staining agent. The staining on these two is quite different to that on the two fine-grained artefacts which also show differential exposure. Biface 56.70 is more deeply stained and is a darker reddish orange. Flake 41.76 shows a much paler discoloration. There is some link between condition and staining too. Biface 39.76 (the more deeply stained of the bifaces) is made from granular flint and the arêtes between its flake scars are visibly more worn (i.e. rounded) than biface 40.76. More recent differentially patinated damage scars are not present on 39.76's edges, which are also more rounded, suggesting a greater degree of rolling/transport abrasion. Similarly, 56.70, the more stained of the pieces made on fine grained flint, also has its arêtes more rounded than the flake 41.76.

A more detailed discussion on the evidence for rolling as a reflection of artefact transport is presented by Chambers in section 2.5 of this report.

Biface 56.70 is the only one of the four artefacts to show any evidence of patination on its surface. Patination is here taken to be the presence of another form of surface modification, in this case it appears as a discoloration that ultimately can turn a whole flint artefact white. In its earliest phases it is a bluish, or milky discoloration. It is associated with alkaline sediments (Wymer, 1968). Already stained artefacts can become patinated as the latter process overprints the staining, or the reverse may happen. In the case of 56.70 the patination visibly overprints the staining which is still visible as a dark stain beneath. The author has seen flints which have been recovered from dry sandy soils or cover sands, and which are fresh grey or black in colour patinate within a few minutes of exposure either to sunlight and/or air. The presence of the early stages of patination on 56.70 may possibly suggest a period of exposure after the initial burial of the piece in alkaline sediments.

In summary it is possible that the more deeply stained of the four artefacts were exposed to the staining agent longer, possibly indicating a slightly earlier burial, and that the patination on one artefact may imply a period of re-exposure at the surface, but this is largely speculative. It is possible that flint type has affected the staining process but the sample is too small to be certain. In terms of overall condition there is nothing to preclude these artefacts being broadly contemporary.

2.4.2 Typology, technology, and blanks

Typology is here taken to be what was made, and technology how it was made. Flake 41.76 is a medium sized, hard hammer, side struck flake. A portion of its distal and left lateral edges (proximal down and dorsal toward you) are made up of natural scars identified by non-conchoidal ripple marks and a dull surface appearance, contrasting with the normally shinier surface appearance of stained or patinated percussion generated flake scars. That the dorsal face has natural scars indicates this flake came from the surface of a nodule and so was located quite early on in the knapping sequence of that part of the nodule/core that it came from. One large proximal flake scar, and possibly the truncated scar to its left, represent shatter scars (type 1a platform break, Figure 5). The conchoidal ripple marks for the larger of the two scars originate from the point/cone of percussion on the ventral, indicating the missing fragment responsible for the scars actually removed the butt of the flake. This type of platform break is consistent with the spontaneous shatter that sometimes occurs during percussion. The right hand margin of the dorsal face has two percussion scars that cannot be explained by shatter, as they are too invasive and do not originate from the proximal end of the flake. These are remnants of genuine percussion scars. They are overprinted at the edge by smaller and less invasive scars which originate from the edge itself (as do the two larger ones). At this same place on the edge, ventrally, is a localised patch of small scars resembling retouch. This must be what Wymer (Wymer and Straw, 1977) described as edge damage resulting from use. If so the damage is unlike the shallow invasive damage known as *mâchures* (Ashton, *et al.,* 1992; Bordes, 1971) that results from chopping antler.

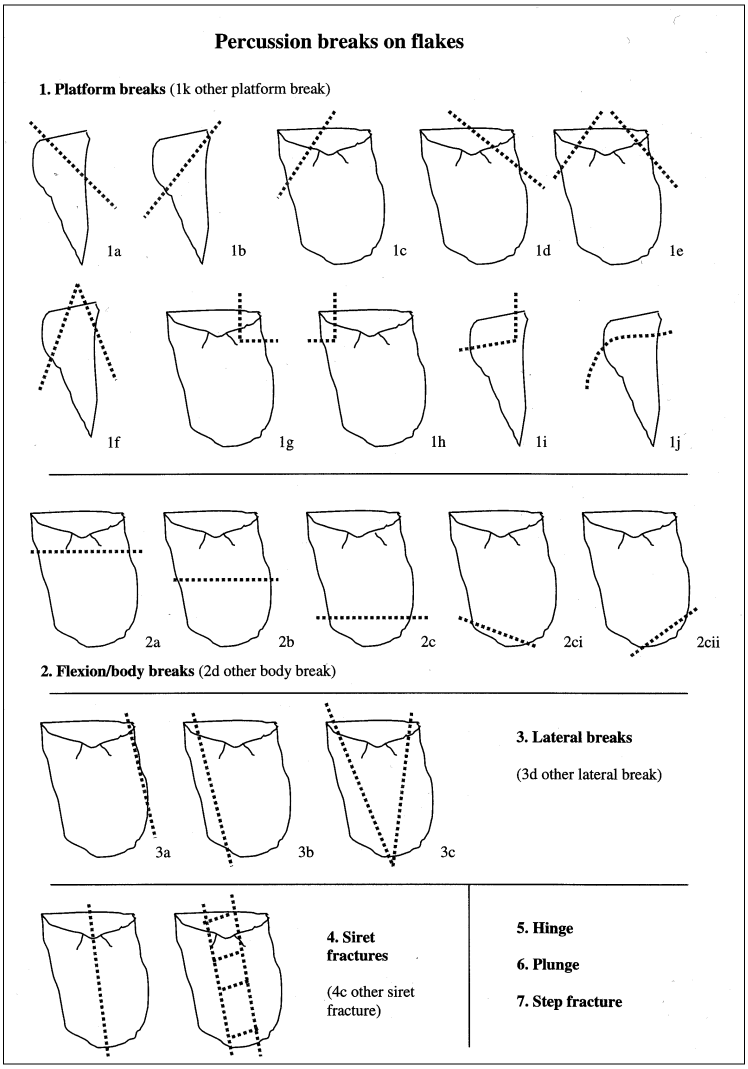

Figure 5: Break patterns noted on flakes after McNabb 1992. In plan, flakes are proximal, uppermost and ventral towards you. In profile, flakes are proximal, uppermost and ventral to the left. NB: hinges and plunges are not technically breaks – they are included for the sake of completeness

Typologically the bifaces represent a heterogeneous group of artefacts. The typological identifications are presented in Table 2. A simple comparison of outline shape is presented in Figure 6 below.

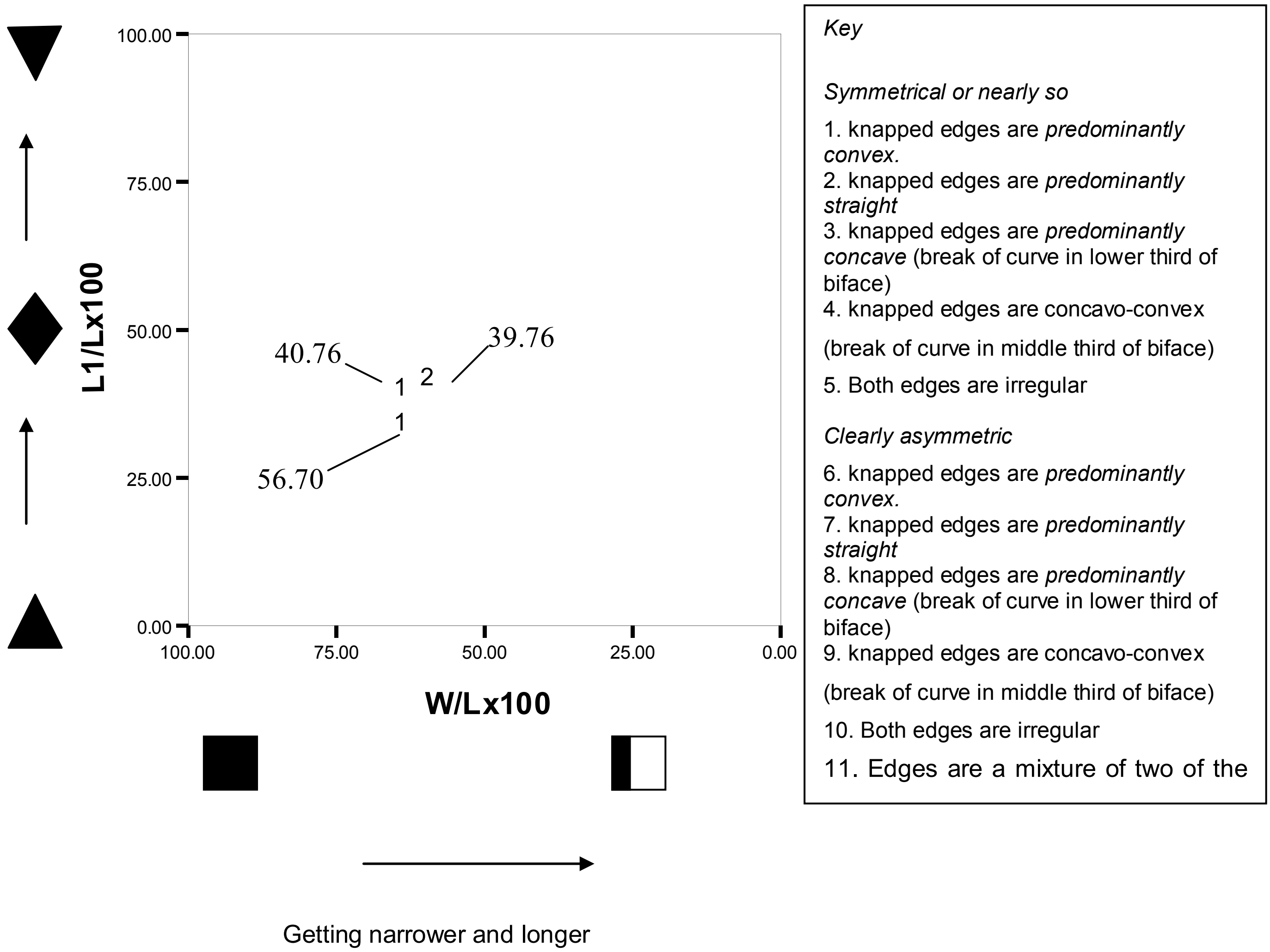

Figure 6. A simple diagram to show relationship between position of maximum width (Roe's L1/L) and length to width ratio (Roe's W/L), and the shape of the knapped portions of a biface's edge. A subjective measure of symmetry (edge types 1-5) is also incorporated into the diagram. For a site with a large number of bifaces no artefact labels would be present.

Strictly speaking only the blank for 39.76 can be identified with any confidence. This was a flat and elongated clast of grey flint. A thickish band of cortex is present, medially, on both faces, and continuing unbroken around the edges. Wymer and Straw (1977) suggest the cobble may have been taken directly from the chalk. The other two bifaces have no cortex. Biface 56.70 may well have been made on a smallish flake. On one face a small scar near the tip shows the flat positive characteristics of a ventral face as opposed to the negative concave appearance of a flake scar. 40.76 may also have been made on a flake although no evidence of a relict ventral can be seen. The identification is based on the marked plano-convex profile seen in the long cross section.

Tips, sides and butts present some intriguing features. All three of the bifaces are elongated (i.e. W/L =<0.5), but not markedly so (i.e. W/L =<0.25), and so have relatively long edges. Bifaces 40.76 and 56.70 have combinations of straight or sinuous edges when seen in profile, while 39.76, the most 'pointed' of the three has straight edges in profile above the cortex (where later damage does not obscure the character of the edge). In planform, Table 2 and Figure 6 indicate all three bifaces would have been symmetrical or nearly so. 56.70 and 40.76 have predominantly convex edges (the former only just). 39.76 has straight edges in planform above the cortex. All three have had their tips damaged, presumably by subsequent rolling or transport. The butts of the three bifaces are interesting as they are all worked. That of 39.76 raises a general question concerning the working of biface butts. This is the most elongated of the three, with thinning and shaping of the straight sides creating a markedly convergent tip/upper portion. As with most 'pointed' bifaces, the centre of balance is low down, located in the bottom third of the biface. This is the area where most of the cortex is located, i.e. the biface's margins in this lower third are mostly unworked. This part of the biface seems not to have been intended for use. So why then flake the butt itself, while leaving most of the margins of the lower third unworked? Not all bifaces, no matter how carefully shaped and extensively worked were used solely for cutting purposes. A small number of them have clusters of incipient percussion cones in the middle of their flat faces indicating use in a task very different from that which is normally associated with bifaces (Wymer, 1958). There appears no functional reason for flaking the butt on 39.76, it is not associated with a nest of percussion cones and there appears no evidence of battering on the butt itself. This may be a window on Middle Pleistocene psychology in regards to what counted as acceptable practice in hominin social technology in some population groups, although for the moment the glass in this particular window remains frosty and difficult to see through.

Bifaces 56.70 and 40.76 both show a similar pattern in terms of how their butts were worked. Tentatively it is suggested that this is a response to the idea expressed above, that both were made on flakes. In the case of 40.76 the working of the butt is almost all from the flat face (probably the ventral) onto the convex face (probably the dorsal). Consequently, the working is quite steep and accompanied by step fractures. The butt was finished off by turning the biface over and, in one corner of the butt, flaking back onto the planar surface. On biface 56.70 the opposite has been done. The butt is worked from the dorsal onto what is interpreted as the old ventral face of the flake. Again the working is steep but step fractures have not been produced this time. The working here is so intense it creates a flat, to slightly indented base. With the working of the edges described below, 56.70 resembles an attempt to make a small *bout coupé*, and in outline shape it resembles this kind of biface more than anything else. In terms of their bases both 40.76 and 56.70 show a strong similarity in approach to working, but this is probably occasioned by the need to trim the base of a thick flake blank, so similarity in this case would not be cultural/typological, but an artifice of technological necessity.

There are some interesting details concerning the overall approach to knapping and biface working present on two of the bifaces. Details of the knapping strategies applied to 39.76 are obscured by the damage on the edges incurred during transport, as well as the later differentially patinated damage scars which have removed portions of the biface's edges and tip. However knapping patterns are discernable on the remaining two bifaces. One edge of 40.76 has a series of long invasive and sub-parallel thinning and shaping scars whose flakes were detached from that edge. They are on the convex face (dorsal), and suggest, though it is difficult to be certain, that all or most of this edge was thinned and shaped from the former planar (ventral) face. On the opposite edge it is not possible to identify the strategy of thinning and shaping that was applied. In addition both faces of 40.76 show evidence of trimming and regularisation. These are short, non-invasive scars, whose flakes were taken from the edge in order to finalise shape and regularise edge outline. They visibly cut into the larger and more invasive thinning and shaping flakes. (Caution should always applied in distinguishing these from damage scars resulting from transport. In this case, these artefacts only show a very minimum degree of transport damage (see abrasion section) and so this explanation can be discounted from the interpretation of these particular scars.)

Although impossible to prove, this author has the strongest subjective impression that 56.70 was a slightly larger biface that has been re-flaked perhaps during manufacture, or re-sharpened into the shape it has now. It is this re-working that has given it the fortuitous appearance of a small, atypical *bout coupé*. On the left lateral edge (looking at it with the base down and the relict ventral face of the original flake blank facing you) there are a series of edge trimming and regularisation scars that bite deeply into a series of comparable but slightly longer flake scars previously taken from along the same edge. From the angle suggested by the plane of the older scars, the biface was originally wider than it is now, or at least there was more of this particular edge than is currently present. Given that the base has already been noted to have been intensively worked (also from the dorsal onto the ventral), this author would suggest that the flaking on the base of the biface is also a product of re-sharpening or re-flaking. From the appearance of the thinning and shaping flake scars at the tip and on the old dorsal face, the current shape of the tip of the biface may also be a result of the re-flaking. If so, then the re-flaking may have proceeded something like this. Someone picked up an already smallish biface made on a flake (alternatively they were correcting a manufacturing fault). They re-shaped the base and one side by inverse flaking from the dorsal onto the ventral. As they worked up the side they flipped the biface over and reshaped the tip from the same side by direct flaking from the ventral onto the dorsal. The staining and patination evidence on 56.70 indicates that both the fashioning of the biface to begin with, as well as the re-sharpening/re-working, if correctly interpreted, occurred before the long term burial of the artefact during which time it became stained, and possibly patinated in a later episode of exposure. It is also worth noting that the arête on this re-worked ventral face appear slightly less worn and rounded than do the arête on the opposite face.

In summary these artefacts show quite a lot of diversity in a number of important technological features. Their shapes appear to be a reaction to a path of least resistance approach taken to flaking the blanks. There is clearly some attempt to ‘tidy up’ the shape on at least one biface (39.76). The rather curious shape of another (56.70) may be a result of trying to prolong its useful life. The reaction to blank type demonstrated in the Welton-le-Wold bifaces is fully in line with ideas concerning the limitations that *sometimes* affect biface shape (Ashton and McNabb, 1994; White, 1998).

2.4.3 Age and chrono-stratigraphic interpretation

Wymer and Straw (1977) noted that the type of bifaces represented by the small Welton-le-Wold sample could have dated from the Hoxnian to the end of the Wolstonian as the Pleistocene stratigraphy of Britain was then understood. Bridgland (Bridgland, *in prep*) picks up this point but extends its lower limits further back in time. Ample evidence now exits for the occupation of Britain by hominins in pre-Anglian (MIS 12) times (McNabb, 2002). Disputing the identification of the Welton Till and Calcethorpe Till as being of a Saalian (MIS 10 – 6) equivalent age, Bridgland asserts that these two tills could easily be Anglian, making the cold climate gravels within which the artefacts and fauna were recovered pre-Anglian in age. This is an intriguing suggestion, and if ultimately proven to be true it renders the Welton-le-Wold artefacts the most northerly evidence of pre-Anglian occupation in Britain yet discovered. Additionally it would locate early occupation well away from the Bytham River Valley (Lewis, 1998) where much of the East Anglian and Midlands evidence for early occupation has so far been found. Like the valley of the Bytham, the valley occupied by the Welton Gravels in which the artefacts occurred was an east/west trending one, and it too was destroyed by subsequent glacial advance. Additionally the gravels contained an earlier temperate fauna reworked into later cold climate gravels. The Bytham also contains temperate sediments overlain by, in its latest phases, cold climate sediments (Collcutt, 1999). If Bridgland's suggestion is ultimately supported it could be argued that early occupation of eastern England was up the valleys of major eastward flowing rivers north of the pre-Anglian Thames, which is itself in pre-Anglian times strangely lacking in the evidence of human occupation (McNabb, 2002). But this remains speculative for the moment. For now it is merely important to reiterate Wymer and Straw's earlier caution about using the artefacts to date the deposits below the Welton Till, and to set them into the context of current research agendas. The age of the Welton-le-Wold artefacts must rest solely on the identification of the age of the Welton Till. This must be established by means other than archaeological evidence.

2.5 A STUDY OF ARTEFACT ABRASION ON THE WELTON-LE-WOLD STONE TOOL ASSEMBLAGE *Jenni Chambers*

It has long been noted that artefacts recovered from gravels display a range of physical modifications resulting from the high-energy depositional conditions they have been subjected to. Thus the *état physique* of such artefacts can be utilised as an indicator of how far from their original point of discard within the landscape they have been fluvially transported.

With regard to artefact abrasion, studies have focused on the degradation of biface arête (flake scar ridges). On freshly knapped bifaces arête arise thin and proud from the body of the artefact. As artefacts become incorporated within active fluvial systems they behave as clasts (Harding *et al.,* 1987); rolling, saltating, sliding and colliding with other clasts. These impacts reduce the height and increase the width of the arête.

Quantitative methods of measuring artefact abrasion have been developed by Shackley (1974 & 1975) and Hosfield (1999). These techniques have focused on the generation of an average abrasion value for the entirety of each artefact. However, this averaging masks the detail of the transport-related damage an artefact has sustained. It can be demonstrated (Chambers *in prep*) that once abrasion begins to develop, it does not do so in a uniform manner across the whole artefact, but in a way that different degrees of damage are sustained on both an intra and inter-face basis. This differential abrasion development has implications for the type and duration of transportation artefacts have been subjected to. It has been, therefore, necessary to develop a recording strategy that reflects the varying arête abrasion values that artefacts commonly display.

2.5.1 Methodology

This methodology was devised during the course of the author's PhD research (Chambers *in prep*, Hosfield *et al.,* 2000), based on the observed physical characteristics of Palaeolithic bifaces recovered from the gravels of the River Axe (Devon, UK) and the Solent River System (Hants, UK). In a manner reminiscent of Shackley's original methodology (1974 & 1975), each face of the artefact is divided into six equal zones (Figure 7), and two arête widths are recorded (using microscopic techniques) from each zone, in a systematic manner from zone one through to zone six on each face.

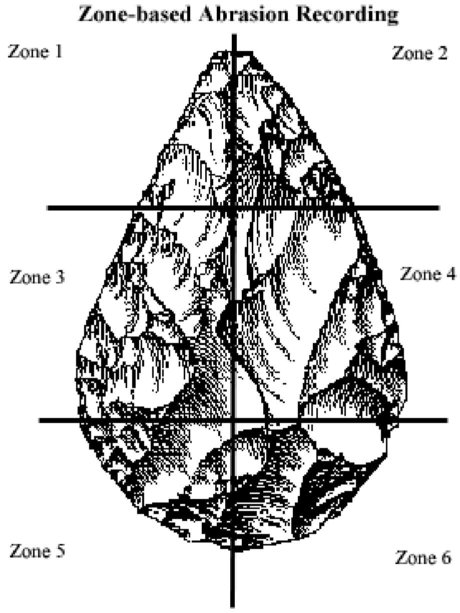

Figure 7: Zone based recording of artefact arête widths

This data can then be plotted graphically (Figure 8), allowing the identification of differential abrasion development within, and between, the faces of the artefact. This characterisation of damage can provide information about both the type and duration of transportation each artefact has been subjected to within fluvial environs. Analysis of the Welton-le-Wold artefacts will be based on data collected following this methodology (Chambers *in prep*).

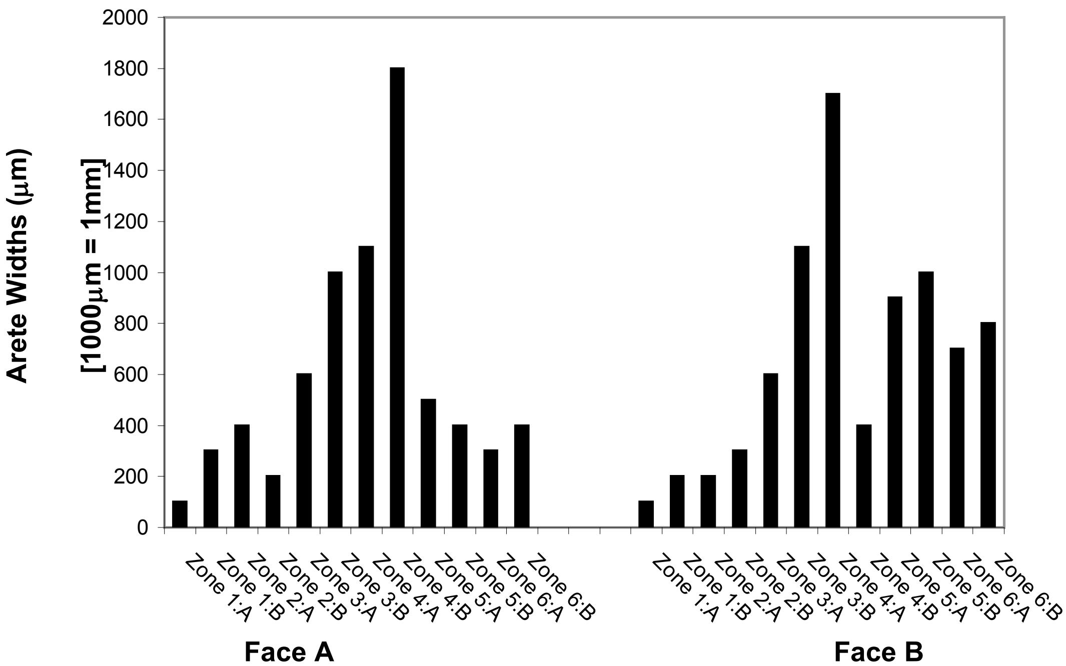

Figure 8: Plotting biface abrasion values recorded by zone

Flume experiments were conducted to evaluate the effect of different types of bed-load transportation, (e.g. sliding, rolling and saltation), and the resulting damage sustained by replica bifaces. These experiments showed that different transportation regimes produce different abrasion and edge damage signatures (*ibid*). Artefact morphology was also demonstrated to influence movement, as only plano-convex artefacts are likely to slide (on their planar face) for any significant distance. Therefore a consideration of the morphology of individual artefacts and comparisons with the appropriate experimental data allows the identification of the transportation regime and duration that individual (and populations of) artefacts are most likely to have been subjected. This process is described in Figure 9 below.

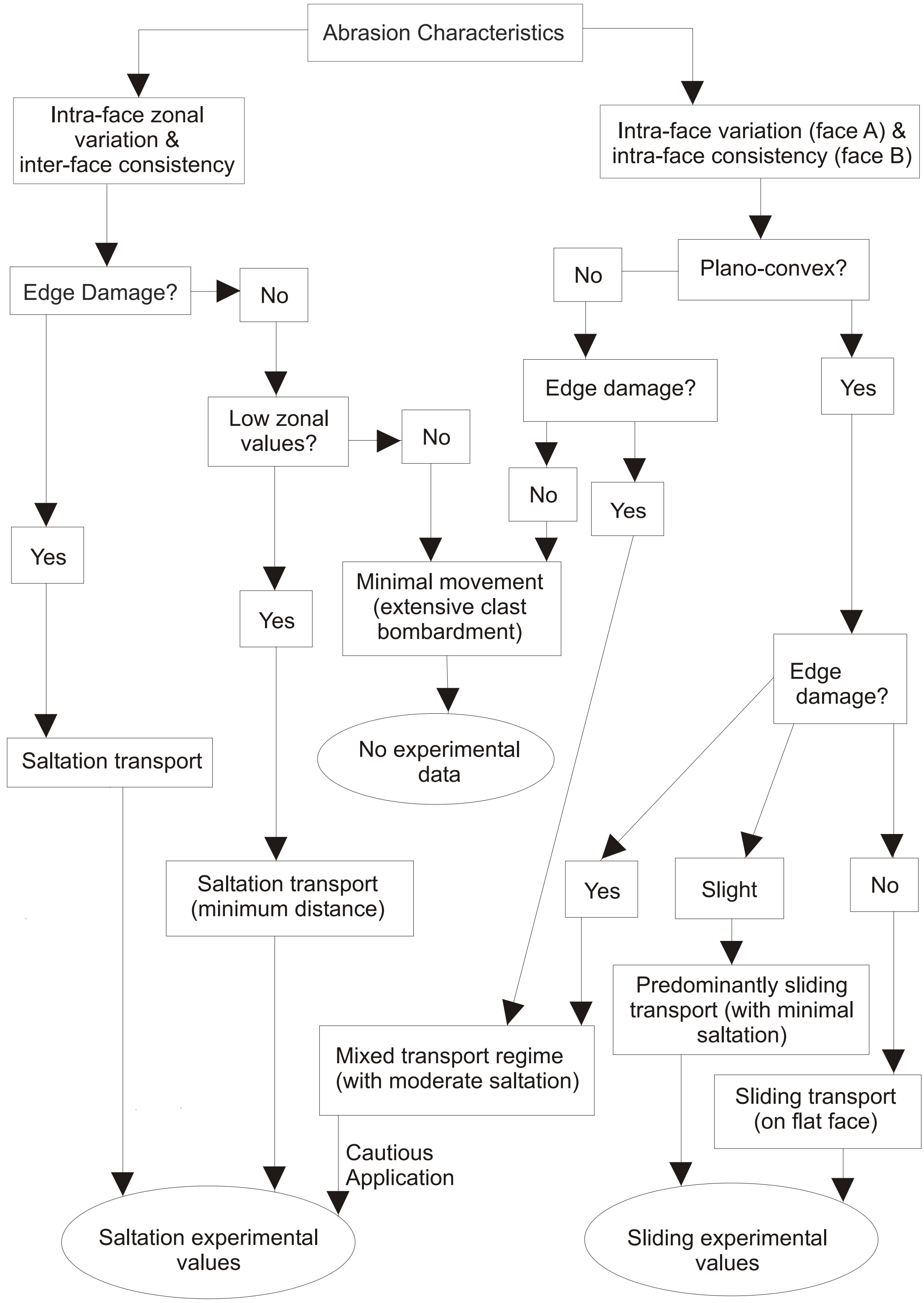

Figure 9: Flow chart of the correlation between experimental and archaeological abrasion data sets

2.5.2 The transport related damage of the Welton-le-Wold artefacts

The transportation-related damage of each of the Welton-le-Wold artefacts will be discussed individually, before a consideration of the assemblage as a whole is offered.

i. <u>Biface 39.76</u>

Biface 39.76 does not display marked plano-convexity. The edges of Biface 39.76 display moderate quantities of micro-flaking around the circumference of the artefact (Plate 13). Consideration of these morphological characteristics suggests that the artefact is most likely to have been transported primarily through saltation and/or rolling motion.

Plate 13: Profile of Biface 39.76; note absence of marked plano-convexity, retained cortex and micro-flaking to edge.

Plotting the arête widths of Biface 39.76 broadly indicate transportation via saltation, the arête widths of Face A are highly variable. Comparison with the saltation experimental data set would indicate that Biface 39.76 has been transported a minimum distance of 250m. This correlation is based on morphological grounds (the absence of pronounced plano-convexity and presence of micro-flaking indicates saltation motion). As can be seen in Figure 10 the arête of Face A correspond well to the experimental arête widths after 250m of movement.

Arête Widths (µm) for Biface 39.76			
FACE A		FACE B	
Zone 1:A	100	Zone 1:A	200
Zone 1: B	100	Zone 1: B	100
Zone 2: A	200	Zone 2: A	100
Zone 2: B	100	Zone 2: B	200
Zone 3: A	300	Zone 3: A	200
Zone 3: B	0	Zone 3: B	200
Zone 4: A	0	Zone 4: A	100
Zone 4: B	200	Zone 4: B	100
Zone 5: A	300	Zone 5: A	0
Zone 5: B	700	Zone 5: B	0
Zone 6: A	200	Zone 6: A	0
Zone 6: B	300	Zone 6: B	200

Table 3: Arête abrasion values for Biface 39.76

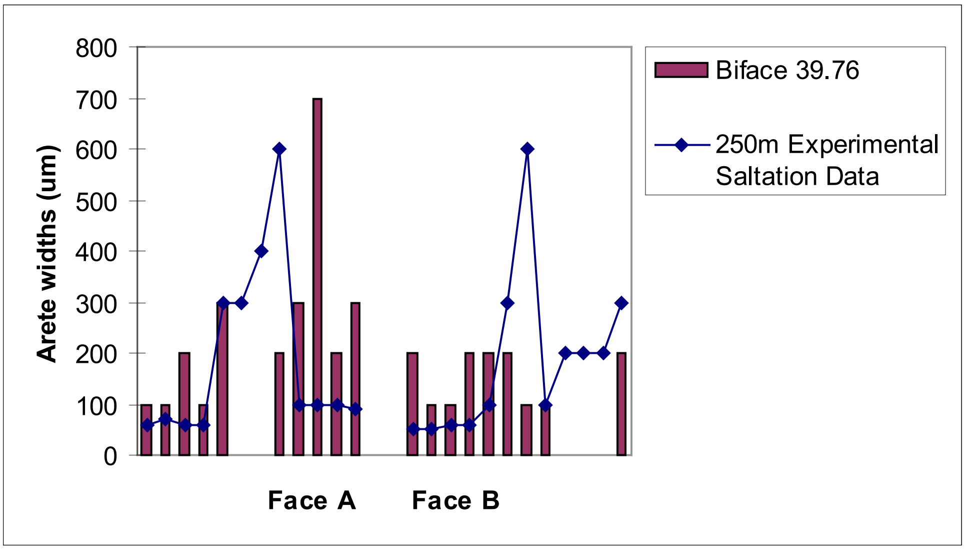

Figure 10: Arête correlation of experimental data and Biface 39.76

The different peak locations in the graph correspond to the thickest regions of the artefact, which are prone to greater abrasion damage. Correlation of the Face B data is rather weak. However, whilst highly variable within a single face, saltation abrasion damage usually produces very similar inter-face values. Biface 39.76 is not invasively flaked. Cortex is retained in the thickest portions of the artefact, most extensively on Face B. As these areas most commonly sustain the greatest abrasion damage transportation distance has been based on the correlation of the Face A arête values and the experimental data set. Due to the retention of cortex in diagnostic zones of the artefact, it is possible that Biface 39.75 has been transported substantially further than the modelled data suggest. The distance of 250m transportation via a primarily saltating motion is offered as a **minimum** transportation distance.

ii. Biface 40.76

Biface 40.76 displays plano-convexity (Face A = planar, Face B = convex), and shows only very slight evidence of edge damage in the form of micro-flaking (Plate 14). These morphological characteristics and the relative homogeneity of the arête widths on Face A, the planar face (Table 4), suggest that it is most likely to have been transported by sliding motion.

Plate 14: Profile of Biface 40.76; note plano-convexity and minimal edge damage

Arête Widths (µm) for Biface 40.76			
FACE A (PLANAR)		FACE B (CONVEX)	
Zone 1:A	200	Zone 1:A	100
Zone 1: B	300	Zone 1: B	200
Zone 2: A	200	Zone 2: A	200
Zone 2: B	200	Zone 2: B	100
Zone 3: A	200	Zone 3: A	200
Zone 3: B	200	Zone 3: B	200
Zone 4: A	100	Zone 4: A	300
Zone 4: B	000	Zone 4: B	200
Zone 5: A	300	Zone 5: A	400
Zone 5: B	400	Zone 5: B	1200
Zone 6: A	300	Zone 6: A	300
Zone 6: B	200	Zone 6: B	200

Table 4: Arête abrasion values for Biface 40.76

Comparison with the experimental abrasion development data showed a strong correlation with the sliding data set. Sliding is typified by more uniform abrasion damage to the planar face (Face A) combined with highly variable arête values for the convex face (Face B). The variable abrasion to the convex face is produced as exposed areas are bombarded by other mobile clasts. The abrasion sustained during sliding motion by plano-convex artefacts has only been modelled up to a distance of 250m (Chambers *in prep*). Correlation between archaeological and experimental sliding data sets focuses on the damage displayed by the planar face, as this directly relates to transportation rather than the more random effects of clast bombardment.

Exact correlation between the experimental and archaeological datasets cannot always be demonstrated, however the methodology provides a means of assessing the most likely mechanisms and duration of artefact transportation within hydraulic regimes.

The arête values for Biface 40.76 are slightly higher than those demonstrated by the experimental artefacts at the maximum sliding transportation distance modelled (Figure 11) This suggests that Biface 40.76 has been transported slightly greater than 250m. The more variable abrasion damage displayed by the convex face of Biface 40.76 is considered to relate to the bombardment of this face either during its exposure during sliding episodes, or during episodes of immobility and/or partial burial. The substantial ‘additional’ abrasion sustained to the thickest area of the artefact (Figure 11) and the absence of edge micro-flaking supports this interpretation.

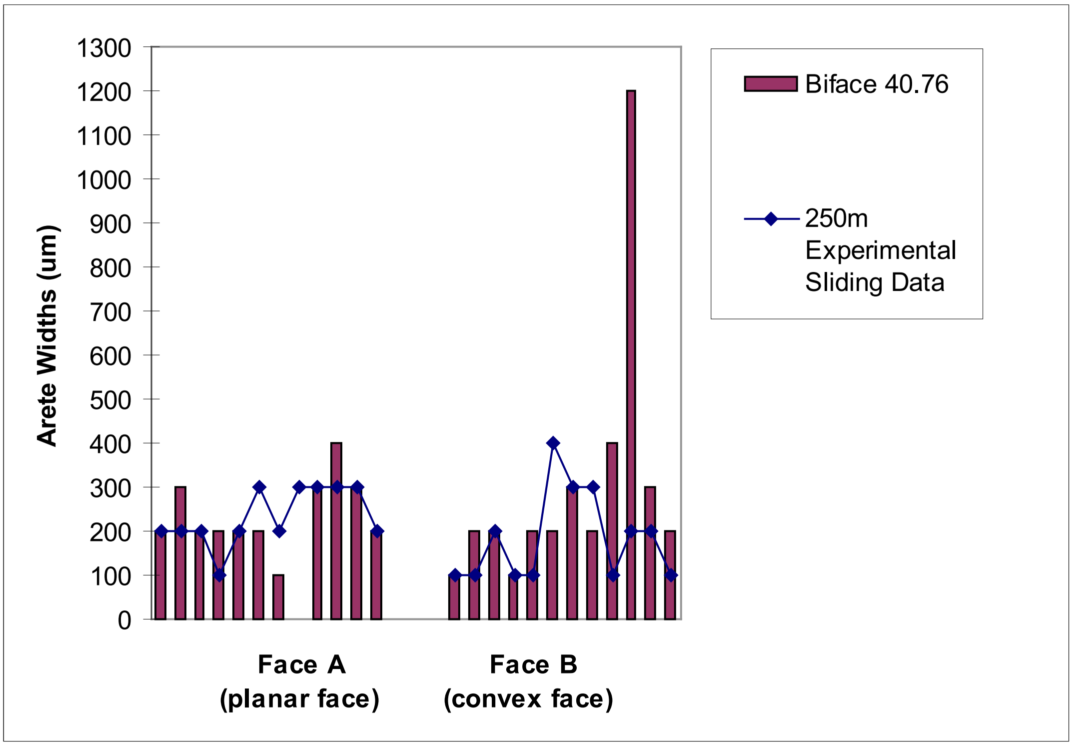

Figure 11: Arête correlation of experimental data and Biface 40.76

iii. Biface 56.70

Biface 56.70 does not display marked plano-convexity. The edges of Biface 56.70 display moderate quantities of micro-flaking around the circumference of the artefact (Plate 15). Consideration of these morphological characteristics suggests that the artefact is most likely to have been transported primarily through saltation and/or rolling motion.

Plate 1: Biface 56.70; note edge micro-flaking and the absence of plano-convexity

Arête Widths (µm) for Biface 56.70			
FACE A		FACE B	
Zone 1:A	100	Zone 1:A	100
Zone 1: B	100	Zone 1: B	200
Zone 2: A	200	Zone 2: A	0
Zone 2: B	100	Zone 2: B	100
Zone 3: A	100	Zone 3: A	300
Zone 3: B	300	Zone 3: B	500
Zone 4: A	300	Zone 4: A	600
Zone 4: B	500	Zone 4: B	200
Zone 5: A	200	Zone 5: A	400
Zone 5: B	700	Zone 5: B	200
Zone 6: A	200	Zone 6: A	200
Zone 6: B	400	Zone 6: B	100

Table 5: Arête abrasion values for Biface 56.70

Plotting the arête widths of Biface 56.70 confirms transportation via saltation; the arête widths of each face vary substantially, but inter-face comparisons show strong similarities (Table 5, Figure 12). Comparison with the saltation experimental data set would indicate that Biface 56.70 has been transported approximately 250m (Figure 12). Biface 56.70 shows slightly larger arête widths than the replica artefacts showed after 250m, but less than those shown after 300m of saltation transport. It is therefore suggested that Biface 56.70 had been transported c.275m.

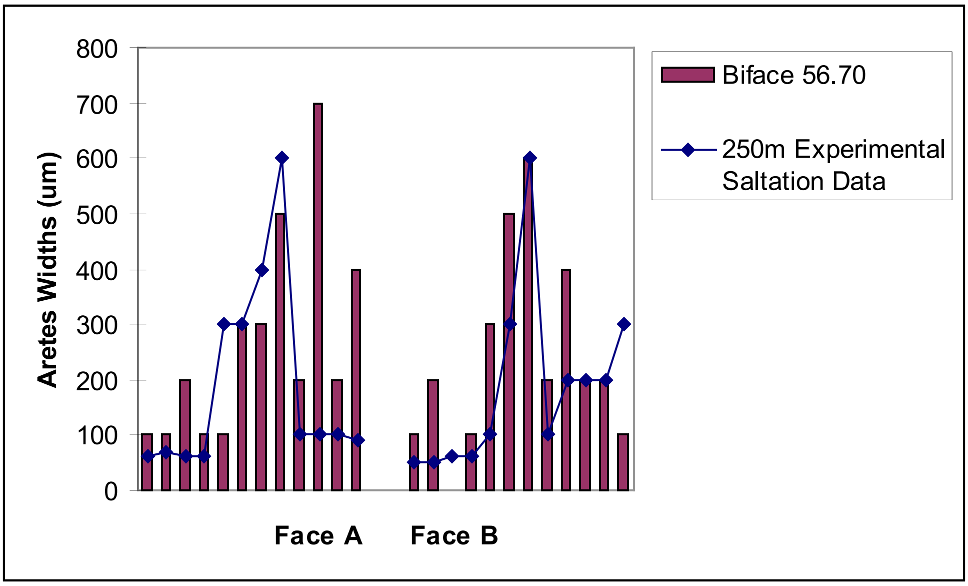

Figure 12: Arête correlation of experimental data and Biface 56.70

iv. <u>Artefact 41.76</u>

Artefact 41.76 is a hard hammer, side struck flake (McNabb, Section 2.4 this report).

Plate 16: Profile and dorsal face of flake 41.76. Note absence of plano-convexity, edge damage micro-flaking, technological flake scars and arêtes.

The abrasion recording and experimental data sets used in this analysis were generated primarily for application to bifacially flaked artefacts. However there are general trends within the experimental data set that can be applied to flake material recovered from secondary contexts. Flake 41.76 shows an extensive dorsal scar pattern. These arêtes can be recorded in the same manner as biface arête. Considerations of the most likely mode of transport can also be undertaken.

Flake 41.76 does not show pronounced plano-convexity, which has been experimentally demonstrated to preclude substantial sliding transportation. Consideration of the damage to the edges of Flake 41.76 indicates that substantial transportation via rolling or saltation also seems highly unlikely (Plate 16).

However, while the edges of Flake 41.76 show little sign of damage, the arête of the dorsal face show substantial damage (Plate 16, & Figure 13). Unfortunately, the ventral face provides little opportunity for assessing abrasion via arête widths, although measurements of the bulbar scar arête generated values in the region of 100-200 μm, much smaller than the dorsal arête.

If considered in isolation, the dorsal arête damage would be indicative of transportation for c.400m with additional damage sustained locally. However, the overall pattern of damage of Flake 41.76 (large dorsal arête widths, very little edge damage and little discernable ventral damage) suggests that much of the arête abrasion damage may have occurred *in situ*.

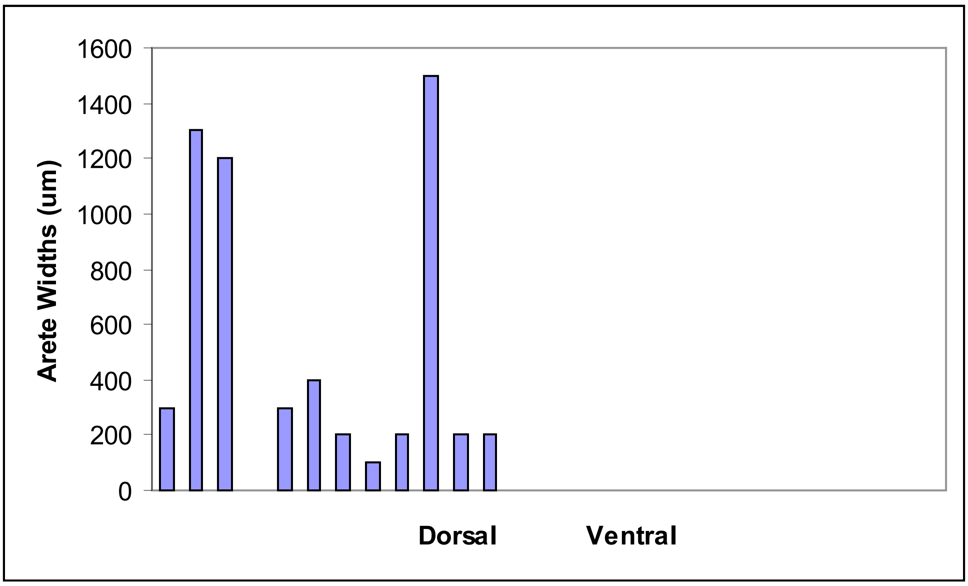

Figure 13: Arête widths of the dorsal face of Flake 41.76

The absence of an unambiguously planar face (on which sliding would have taken place) indicates that it is unlikely that Flake 41.76 moved any significant distance via sliding motion. Had substantial saltation or rolling movement taken place the edges of the flake would have become damaged through the removal of micro-flakes.

It therefore seems most probable that the dorsal arête abrasion damage primarily reflects the bombardment of Flake 41.76 by mobile clasts or sediment.

2.5.3 Summary and conclusions

The three bifaces from Welton-le-Wold can be demonstrated to be of relatively local origin. Comparison of the *état physique* data from the Welton-le-Wold bifaces and experimentally abraded replica artefacts (Chambers *in prep*) indicate that they have been transported via bed-load movement mechanisms approximately 250m. Modelling the transportation of Flake 41.76 has proved more problematic due to the absence of ventral arête, however its morphology suggests that much of the demonstrated damage relates to bombardment rather than transportation.

It should be emphasised that it is not currently possible to model suspended load transportation, and therefore the transportation distances presented here should be regarded as the **minimum** distances over which the observed damage could have developed.

2.6 CONCLUSIONS AND RECOMMENDATIONS

2.6.1 Conclusions

The re-analysis of the faunal remains and the archaeological material from Welton-le-Wold has largely confirmed their original identification, with the exception of the reassignment of the giant deer (*Megaloceros giganteus*) to a large bovid (*Bos* or more probably *Bison*) and the elephant (*Palaeoloxodon antiquus*) molars as being the upper first and second molars, rather than the upper second and third. The re-analysis of the stone tools has shown that they are a heterogeneous group that do not display any identifiable age specific characteristics, though as a group there is nothing to preclude them being broadly contemporary. All are stained due to long-term burial and one is patinated, indicating an interim period of exposure.

The application of abrasion analysis has provided new information about the likely nature and extent of derivation of the archaeological material. The three bifaces correlate with experimental profiles of artefacts that have been transported a distance of approximately 250m – 275m. In addition, the faunal material displays varying depositional histories. The bovid astagali are heavily abraded and the red deer antler and the horse teeth are fragmented and crushed. These attributes are consistent with being transported in a coarse gravel substrate. The articulated elephant teeth and tusk, however, have had minimal disturbance following deposition. (John's info here)

The re-analysis of the material has provided much more detailed information about each specimen. This information is a valuable enhancement to the archive. McNabb's description of the stone tools, which hypothesises the decisions and actions of the toolmaker when describing the resulting artefact, will be particularly useful for their future interpretation and display.

As a result of this project, the entire object archive is now reunited at Lincolnshire's City and County Museum, from where it will be displayed in Spring 2005.

2.6.2 Recommendations

The work carried out on the Welton-le-Wold assemblage as part of this project has extracted as much information as is possible from the material itself, working within the limitations of current techniques and within the current understanding of the Pleistocene. Revisiting the material will only be warranted in the future if it becomes feasible to apply new analytical techniques to it.

Chronological context will only be achieved through two means:

- the collection of a larger assemblage, particularly any microfauna that are more chronologically sensitive.
- the independent dating of the gravels and the tills.

The collection of new micro and macrofaunal material, and a refined dating programme are thus priorities for this important site.

If the finds can be provided with a securely dated context, the whole assemblage should be published, as it would be the only Middle/Lower Palaeolithic archaeological material in the region to be dated and stratified.

SECTION 3 A RE-ASSESSMENT OF THE STRATIGRAPHIC CONTEXT OF THE FINDS AT WELTON-LE-WOLD (PROJECT AREA 2)

Main aim: To re-assess and further investigate the context of the finds previously recovered from Welton-le-Wold former sand and gravel quarry.

3.1 BACKGROUND AND PURPOSE OF PROJECT AREA 2

The importance of the stratigraphy at Welton-le-Wold to resolve regional questions of Pleistocene chronology has been described above. Unfortunately neither the field work nor artefact and fossil assemblages recovered between 1969 and 1972 when the quarry was being worked are diagnostic as to stage and although the re-assessment of these assemblages has added to our knowledge it was not expected that they would clarify the chronology of the site. This project area was therefore proposed to locate intact gravel deposits that could be correlated with the fossiliferous horizons as close as possible to the original find spots and sample these deposits through coring, and assess their potential for further investigation.

In the original analysis of the deposits and stratigraphy at Welton-le-Wold the fossil and artefact assemblages were studied (Alabaster and Straw 1976; Wymer and Straw 1977) but no effort was made to investigate other palaeoenvironmental evidence. This area of the project was therefore designed to include an assessment of the palaeoenvironmental potential of the deposits recovered by the coring, particularly the survival of pollen and macrofossil and small vertebrate remains.

The dating of this site can be seen as the most important potential outcome of this project area and although a variety of dating techniques were considered (ESR, Palaeomagnetic dating, Stable isotope analysis) it was concluded that Optically Stimulated Luminescence (OSL) offered the greatest potential for dating the site within this project. The identification of sediments suitable for dating by OSL and their subsequent sampling and analysis was therefore one of the primary objectives of the project since this singly had the greatest chance of resolving the debate as to the age of the site. This technique was not available when the site was first investigated over thirty years ago.

The silts and sands interpreted as wind-blown or loessic deposits (Alabaster and Straw 1976) are present as widespread bands and lenses within the sands and gravels (Fig. 3) and these sediments, identified by Straw (op cit.) as being dominated by quartz sands, were considered to be potentially suitable for OSL dating. While these deposits could only give dates above or below the deposits actually containing the artefacts and fossils, it would provide extremely useful constraining dates for these deposits and the fixed chronological point which the site at present lacks.

3.1.1 Components of the Project Area

The primary intention of this project area was to obtain a series of intact cores through the fossiliferous gravels which, after lithological description, could be used to reconstruct a long section of the deposits for direct comparison with the sections published in 1976 (Fig. 3). These cores would additionally be sampled for geological, OSL and biological analysis.

The starting point for this investigation was the location of the last recorded gravel face prior to the closure of the quarry and the establishment of the present location of *in situ* gravel deposits and the line of this face. This was necessary because during the quarrying of the gravels the 10-13 metres of till overburden that were removed to expose the gravels were used to backfill the already quarried areas of the pit, and since the closure of the quarry the pit has been backfilled to a depth of over 14 18 metres, landscaped and planted and no areas of the original quarry floor remain, nor any visible gravels.

3.2 THE LOCATION OF THE QUARRY FACES RECORDED BETWEEN 1969 AND 1972

Alabaster and Straw made a number of visits to the quarry between October 1969 and July 1970 and again between May 1971 and April 1972. During these two periods they surveyed and drew the gravel face (Fig. 3) for a distance of approximately 41 metres and 31 metres respectively. Alabaster and Straw (1976) note that the later section was approximately six metres back from the line of the earlier section. The grid references would indicate that the later section was 7.5 metres at the east end and 10 metres at the west end behind the earlier section (Fig. 14) although the eight figure grid references mean that the end points of each section can only be known to the nearest 5 metres. A surveying team using the grid references published by Alabaster and Straw (1976) and a total station theodolite, laid out a line on the ground surface which corresponded with the line of the 1971/72 section. It was known that in 1972 the pit officially closed and the gravel company ARC moved their operation. This line was therefore taken as the maximum southward extent of any *in situ* gravel deposits that might have survived in the quarry. Anecdotal evidence suggested that the quarry face retreated only one strip, perhaps six metres wide each year, a suggestion reinforced by the fact that the sections that Straw and Alabaster drew in 1969/70 and 1971/72 were only six metres apart. This limited extraction, although the face was 800 metres long, was due to the necessity to remove an overburden of 10-13 metres of glacial till before the gravel could be quarried, and was the primary reason for the final cessation of work in the quarry.

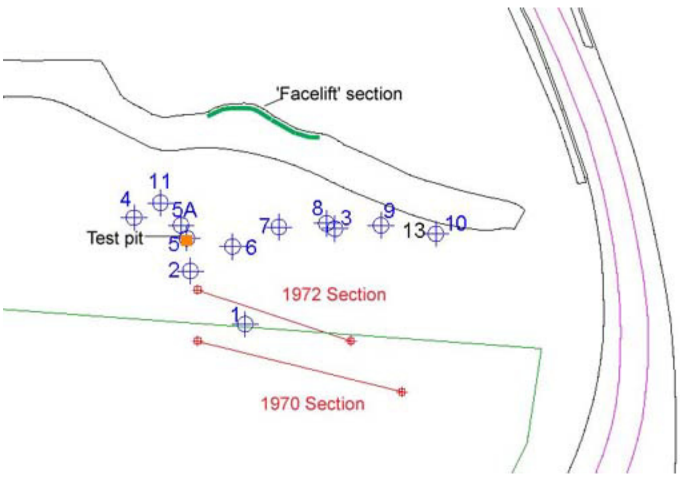

Fig. 14: Plan of project area showing 1969 and 1972 sections, 'Facelift' section and location of 2001 test pit.

The line of this section (Fig. 14) was used as the starting point for the investigations into how much of the gravel bench recorded in 1972 had survived after closure of the quarry. In 2001 John Aram, using funding granted by English Nature to carry out a 'facelift' or cleaning of the exposed cliff face immediately north (Plate 5) of the sections drawn in 1972, excavated a 2 x 2 metre pit at the base of the cliff (see Fig. 14 for location; Plate 17) to a depth of nearly 5 metres. This machine hole exposed an overburden of re-deposited and *in situ* glacial tills approximately 4 metres thick overlying the undisturbed gravels. Since the modern ground surface rose up another 1-2 metres to the south of this machine hole it was assumed that the overburden overlying any gravels between this pit and the line of the 1972 section was at least 4-5 metres of re-deposited clays. This depth of overburden indicated that there were significant practical problems associated with locating undisturbed gravels beneath the backfill.

Plate 17: Test pit through Welton Gravels, excavated in 2001 *(Photo Helen Gamble)*

3.3 GEOPHYSICAL SURVEY TO ESTABLISH THE PRESENT LOCATION OF THE GRAVEL BENCH

A number of non-intrusive geophysical techniques are available for locating a potential gravel bench beneath the later till and backfill deposits (Fig. 15). After discussion with various geophysics teams three techniques were suggested as having possibilities, Ground Penetrating Radar (GPR), Electrical Conductivity and Electrical Imaging. There is some debate as to which of the techniques would best identify a buried gravel bench of the sort illustrated in Fig. 15 beneath an overburden composed largely of re-deposited clays. GPR is relatively impenetrable and difficult to interpret through significant depths of clays but some specialists argue that penetration can be obtained to depths closer to 10 m in some clays when using a low frequency signal. Reducing the frequency results in a loss of resolution but the hypothesised gravel bench is such a major feature that its recognition and the plotting of its edge was considered to be within the capabilities of GPR. Electrical Conductivity should be able to identify a bench of gravel, if present within the predicted depth range, and map it. While Electrical Imaging using resistivity could produce a cross-sectional view of the deposits beneath each transect showing the edge of the bench in each transect and some of the structure of the gravel deposits. The most practical technique, but not necessarily the most cost effective, would be to sink a series of boreholes along transects at right angles to the present cliff and map the gravel bench in each transect to define its location.

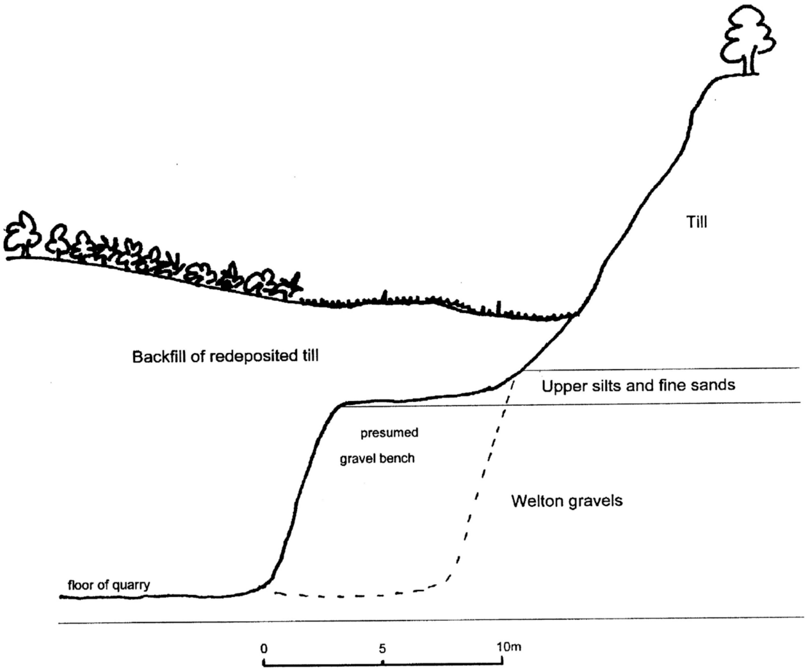

Figure 15: Sketch location of presumed target gravel bench for the geophysical surveys

Since this project was in the nature of an evaluation of the site and there was no consistent view as to which geophysical technique was most suitable all three techniques were commissioned. This would allow direct comparison of the results and interpretations and perhaps establish the most suitable technique for any further survey work of this type, for instance the recognition of terraces or deep palaeochannels in floodplain gravels beneath an alluvial overburden or the investigation of other old or backfilled quarries.

The three geophysical surveys were conducted by Peter Graham of Interkonsult ltd (GPR), Karl Taylor of Stratascan (Ground Conductivity) and Simon Dawson of IMC Geophysics Ltd (Electrical Imaging). Their detailed reports are attached in the appendices but their conclusions and results are summarised here. All were asked to try and locate a gravel bench beneath an overburden of 4-5 metres minimum of re-deposited and *in situ* clays, with the proviso that other material may have been dumped within this backfill.

Prior to the surveys, a grid (Fig. 16) was laid out by Archaeological Project Services across the area for prospection so that all three geophysical techniques could be directly related.

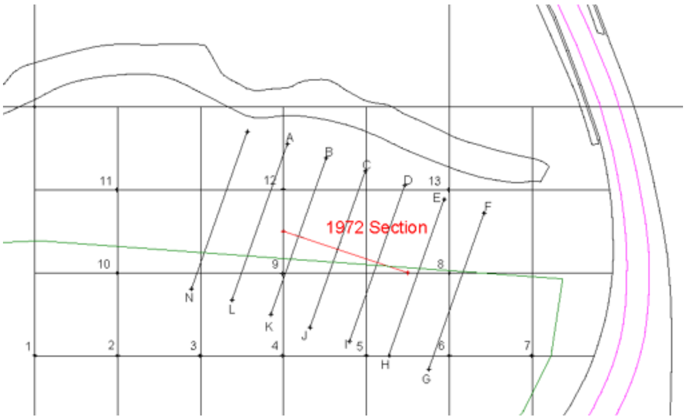

Figure 16: Plan of project area showing survey transects in relation to the location of the 1972 section

*3.3.1 **Ground Probing Radar** (Peter Graham)*

A standard RAMAC control unit manufactured by Mala Geoscience of Sweden with associated electronics was used and coupled to a shielded 250 MHz antenna which is pulled by an operator on known geographic lines (Plate 18). This configuration was considered to be a good compromise in terms of sufficient penetration to define the top of the quarry bench and resolution to identify different material compositions.

Plate 18: GPR survey

Seven parallel profiles were taken in a southeast to northwest orientation along the grid set out by Archaeological Project Services (Fig. 17). The profiles were taken in the same direction in each case at a spacing of 10m. In addition, three extra profiles (Fig. 17) were taken following the lines used for the electrical imaging survey. The extent of the profiles was limited towards the North by the steep inclination of the surface and a ditch.

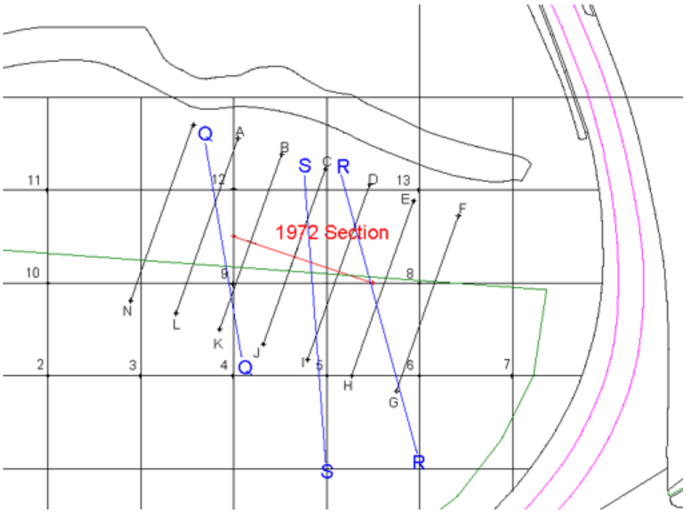

Figure 17: GPR profile overlay

In general terms, good rates of GPR penetration have been achieved over the site, indicating that the prevalent host material is of a course matrix associated with sandy conditions or course clay. The dielectric properties of such an overlying material would be very similar to that of underlying gravel beds and, as a result, distinguishing between the two materials is difficult.

Although good rates of penetration have been achieved, no marked horizons that can immediately be attributed to the bench geometry were detected as would be possible, for example, in the case of a clay/limestone interface. However, a number of characteristics were observed in the majority of the profiles that indirectly point to a major transition in material properties. These properties are probably more related to the permeability and porosity of the material (and therefore water content) than conductivity.

On profiles 2, 4, 5 and R (see Appendix IV) a clear transition can be seen from a material with low permitivity to a material of higher permitivity. This generally coincides with the surveyed position of the 1972 section (marked on Fig. 17). The effects shown by the GPR profiles are probably the influence of the bench on the overlying material in contrast with the undisturbed material where no extraction has taken place. In the area of the transition, (about 1.5m length) the ground appears to be more disturbed which could be representative of the interface/joint of one type of material with another. On the remaining profiles the transition effect is not so noticeable as the traces are generally weaker.

The three-dimensional composite of the profiles also confirms a more permitive area to the Northwest of the survey grid (Appendix IV, Fig. 3). The dark anomaly which coincides with the marked bench line extends towards the north-western part of the grid where the gravel beds are already known to be intact.

GPR Conclusions

Good rates of penetration up to 8m were achieved during the GPR survey indicating that the host material is generally of a course matrix with good permitive characteristics.

No definitive structural boundaries were encountered; if these are present then they are masked by similar dielectric properties. This is possible if the gravel beds and fill are of similar material and were intermixed at closure.

However, a marked change in permitivity was detected in most of the profiles occurring beyond a depth of approximately 2.5m. When plotted on the topographic grid, an area of ground with different characteristics is evident and coincides with the edge of the 1970s bench position although it is not intact for the entire length. This feature also seems to be evident on enhanced aerial images of the area. As a result, IKL believes that there is sufficient evidence to suggest that the 1970s bench may be intact and represent the final position of the quarry.

3.3.2 ***Ground Conductivity*** *(D.J.Sabin)*

Ground Conductivity was employed using the Geonics EM31 instrument which uses induced current to generate a response from the sub-surface (Plate 19) and the data recorded in a DL600 data logger. This survey method was considered the most effective technique when considering the probable depth of the gravel bench. The conductivity of the gravel is significantly lower than that of clay and is likely to produce good definition if a bench or edge exists.

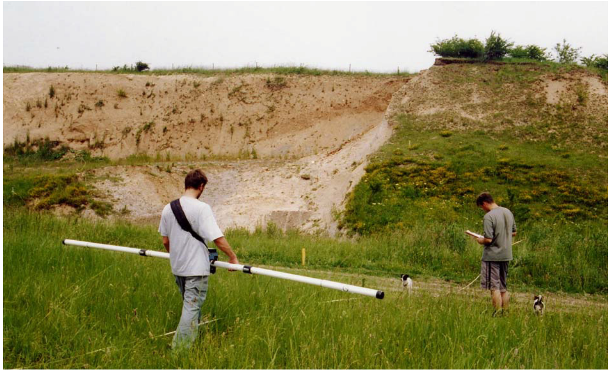

Plate 19: Ground Conductivity survey

Readings were taken at 2m stations at centres along lines 2m apart with the boom of the instrument across the survey line. Vertical dipole readings were taken at each station together with inphase ("metal detecting or susceptibility mode") and quadrature ("conductivity mode"). The depth of the scan for the vertical dipole is approximately 6m. The resolution is approximately a fifth of the coil separation thus giving 0.7m.

The analysis of the results is focused on the quadrature component. Areas of low conductivity occur towards the northern and eastern sides of the survey area (Fig. 18). The contrast between areas of high and low conductivity appears well defined along the northern edge of the survey area suggesting an anomaly having approximate dimensions of 45m by 9m. The low conductivity towards the eastern side of the area is less well defined.

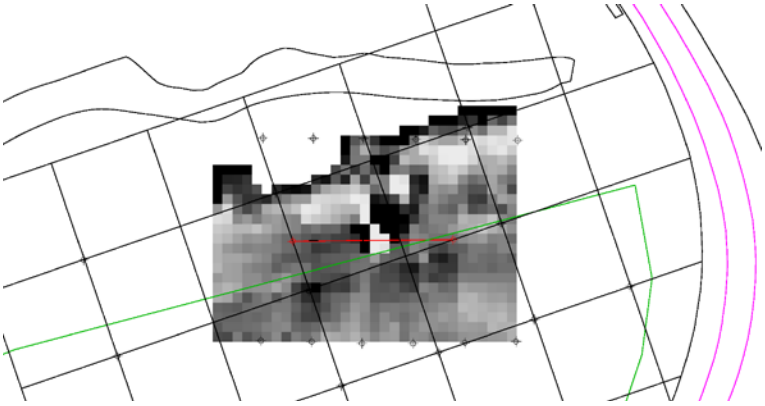

Figure 18: Plot of quadrature processed conductivity data

A small area of high contrast conductivity measured centrally within the survey area probably relates to material used in the backfill of the quarry.

Ground conductivity conclusions

The low conductivity anomalies towards the northern boundary of the survey area represent the likely target for the location of the gravel bench.

3.3.3 ***Electrical Imaging*** *(Simon Dawson)*

Four lines of electrodes were laid out across the site. Three broadly parallel lines Q, R and S, nominally 46.5, 62 and 62 m long, and a fourth T eastwards at an angle of 60 degrees to line Q with a nominal length of 46.5 m (Fig. 19).

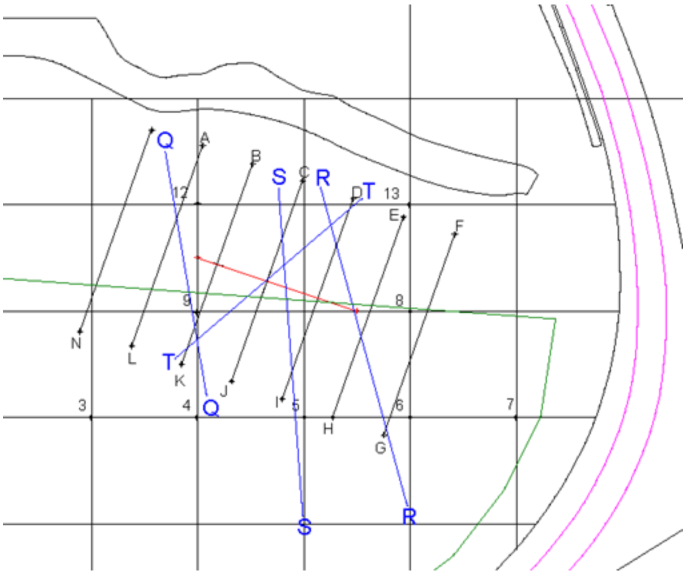

Figure 19: Location of Electrical Imaging transects Q, S, R and T within survey area

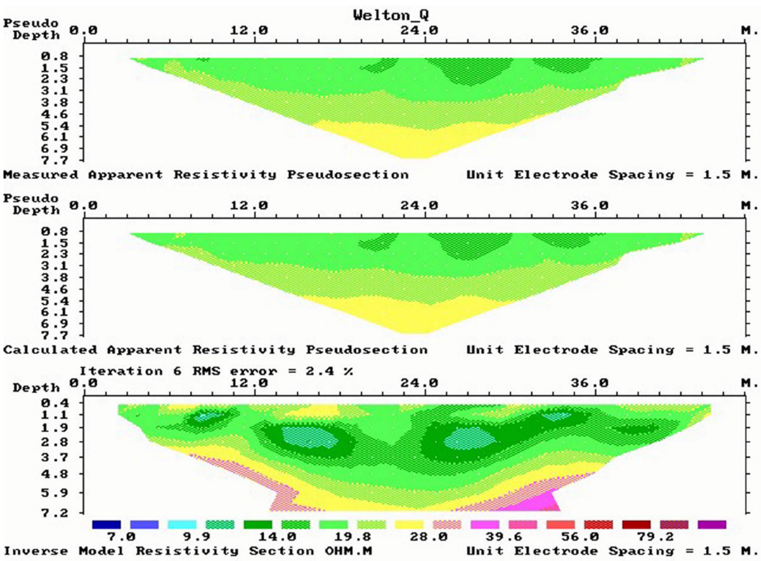

Figure 20: Electrical Imaging along transect Q

The range of values is quite wide, indicating the significant differences between the backfill (typically green/blue) and the strata underneath (reds, Figs. 20 and 21). If this is chalk, then it is reasonable for it to have a higher resistivity than the clay-rich fill.

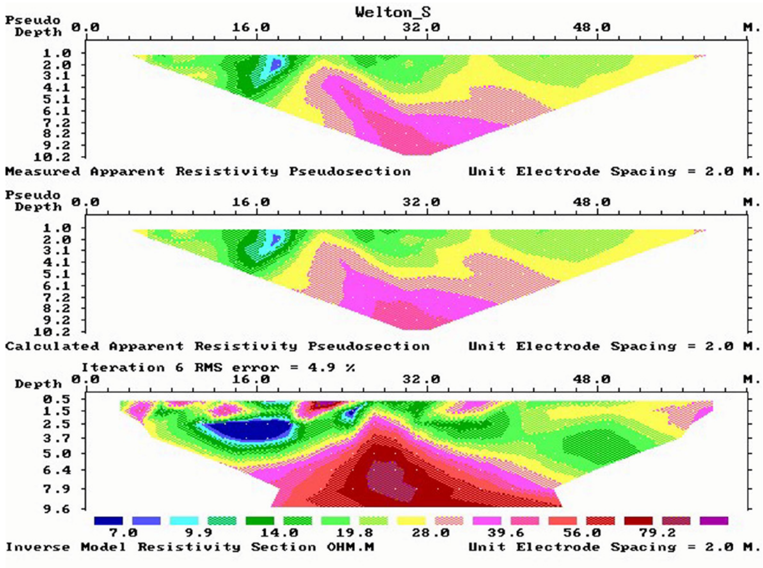

Figure 21: Electrical imaging along transect S

The colour scale of electrical resistivity has been adjusted to be the same on each section (Figs. 20 and 21 and Appendix VI, Figs 1-4). There appears to be a ridge of high resistivity material under the middle of lines S and R, which is interpreted as either the underlying chalk or possibly drained gravel. The simplest interpretation of the material to the north, left on the sections, is that it is fill, which is possibly wetter in places causing localised conductive (blue) anomalies.

Electrical Imaging conclusions

The overall impression from these results is that any remnant gravel bench is closer to the quarry face than we were able to image except possibly on line Q, where there is some weak evidence of such a bench at the north end. The deepest parts of the fill imaged otherwise appear to be at some 5-6 metres depth.

3.3.4 General conclusions on the geophysical surveys

Perhaps disconcertingly the results of the three geophysical techniques were neither comparable nor at all conclusive. The GPR suggested that the gravel bench might still lie approximately along the line of the 1972 section, while the Ground Conductivity suggested that the face had been cut back further but a bench of gravel might be surviving for a few metres out from the base of the cliff, at least along the eastern two thirds of the area surveyed. The Ground Conductivity survey area extended beyond that targeted using GPR and Electrical Imaging in the northeast corner and picked up this possible gravel bench in an area the other techniques did not survey. In contrast to both of these techniques the electrical imaging suggested that any gravel bench probably lay outside the area covered by the survey. With this technique, as the illustrations show, only the deposits within a triangle between the two outer points and the maximum depth permitted by the distance apart of these points can be surveyed. So if the gravel bench occurred beneath the survey lines but at a depth below that indicated by the triangular data it would not be seen. For example in Fig. 21 a gravel bench could occur 12m in from the end of the survey line at a depth of below 5 metres and not be recorded.

Only in Line Q of the Electrical Imaging survey was there any suggestion that there may be a gravel bench at the extreme northern end of the line (Fig. 11). The Electrical Imaging line S (Fig. 21) across the centre of the surveyed area produced an anomaly in the centre of the site which was also present in line R (Appendix VI, Fig. 3). This ridge was interpreted by Simon Dawson as either chalk or drained gravel a result which seemingly contrasts with the high conductivity recordings obtained during the Ground Conductivity survey for this same area which are interpreted as probably deriving from backfilled material. These two techniques work in opposition and a high reading for one would be expected to produce a low reading from the other. However it is possible that the techniques are measuring two different elements in the anomaly since the two techniques have a different depth profile. The GPR profile along the same line as the electrical imaging shows no similar anomalies. A reassessment of the Ground Conductivity results in the light of the cores and the Electrical Imaging does raise the possibility that the high conductivity readings along the northern margin of the survey area are recording the gravel bench. A high iron content in the upper silts and gravels might be sufficient to produce a high conductivity reading since metal content in the sediments is a factor (Simon Stowe, Stratascan, pers comm.). The upper gravels revealed in the 2001 test pit and some of the cores were rich in iron and partially concreted which could account for these high readings. Nevertheless at the time of the surveys it was not at all clear what the different techniques were recording and none produced a clear positive result and it was necessary to undertake a small series of trial boreholes to establish the presence of gravels before the sample coring was undertaken.

3.3.5 Recommendations

Of the geophysical techniques used all were ultimately constrained by the fact that the target bench they were supposed to locate was not present in the survey area (see below). The Ground Conductivity and Electrical Imaging surveys showed some consistency in their results and although neither technique appears suitable for further work at Welton-le-Wold, both appear to have picked up features beneath the thick overburden of clay. If the gravel bench had been present it is probable that these techniques would have located it, and the Ground Conductivity may have in fact recorded it. The

GPR results are more problematic and it is not clear that this technique produced any indication of the deeper deposits.

Ground Conductivity and Electrical Imaging would probably be suitable for picking up palaeochannels or terrace deposits under deep alluvial cover in areas of proposed quarrying within a depth range of 6-10 metres but the GPR system used at Welton-le-Wold may not be so effective.

3.4 THE CORING OF THE WELTON GRAVELS

The sequence of gravels were cored in order to collect material to:

- reconstruct a stratigraphic section of the gravels for comparison with those recorded by Straw between 1969 and 1972
- assess the potential for artefact and fossiliferous bearing deposits
- obtain samples for OSL dating

3.4.1 Proving the gravels

The failure of the geophysical surveys to locate the gravels with any confidence added the need to using the coring as a technique to locate the gravels.

The coring was undertaken by Mark Goring of Site Investigation Services using a top drive hydraulic rotary rig mounted on a Mercedes Unimog (Plate 20) and an independent air compressor. During the initial exercise to prove the presence of gravels the rig was fitted with a rotary drill of approximately 120mm diameter and the compressed air was used to clear the borehole during drilling allowing the sediment being cored at the base of the borehole to be recognised by the debris the compressed air brought up out of the borehole. Of the three proving boreholes sunk the first, Borehole 1 (Fig. 22), was located a few metres south of the line of the 1972 section specifically to core the backfill of the quarry and ascertain its depth. Boreholes 2 and 3 were placed to test for *in situ* gravels (Fig. 22).

Plate 20: the Unimog rig

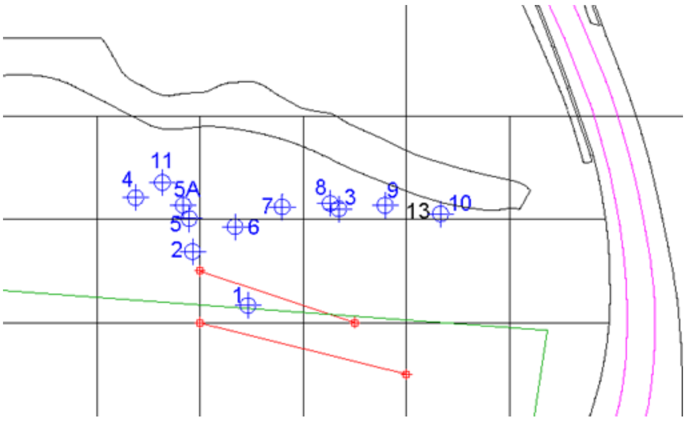

Fig. 22: Plan of project area showing all borehole locations

Borehole 1 was sunk through a backfill of clays to a depth of 14.5 metres. Between 14.5 and 18 metres the borehole cored through *in situ* compacted iron coated and limonite rich sands and finally hit chalk between 18 and 18.5 metres depth. On the basis of this core it was assumed that the quarry floor at this location lay at between 14.5 and 15 metres depth since the underlying sands had not been quarried, and were clearly not suitable for commercial extraction.

Having established the depth to which the boreholes might have to go to bottom the gravels the next borehole was located four metres north of the grid reference for the western end of the 1972 section and approximately 8 metres from the base of the cliff. This location was chosen to test if the 1972 bench was still intact having allowed for up to four metres of collapse at the face. The trial pit conducted in 2001 had established that gravel should be recorded by a depth of about 5-6 metres if the bench was intact. The borehole was sunk using the rotary drill to a depth of 10 metres. The deposits were clays for the whole of this depth and it was concluded that the gravels at this point had been removed and the borehole was aborted. The position of borehole 3 (Fig. 22) was located as close to the present day cliff face as could be reasonably accessed by the Unimog and still give a safe working area around the drill head. This put it two metres from the base of the cliff face. The borehole augered clay with flints and hit gravel at about 3 metres depth. This core and the test pit from 2001 indicated that the gravels were undisturbed at the base of the cliff but borehole 2 clearly indicated that they had been removed from the area within 8 metres of the cliff base. To avoid the expense of further boreholes to identify precisely where the gravels survived *in situ* a line of seven boreholes (Fig. 23) was laid out along the base of the cliff for the sampling cores. Since the primary objective was to obtain core samples for study the establishment of the precise edge of the gravel bench was not considered a priority. Owing to the presence of a machine dug ditch along the base of the cliff access could not be obtained for the Unimog right up to the base in places and the borehole location had to be placed at the nearest convenient point. For the placement of borehole 10 it was necessary to bring in a mini-digger and use this to backfill the ditch at the base of the cliff and create a working platform for the Unimog. These seven boreholes were laid out at approximately 10 metre intervals giving the potential for the reconstruction of a 60 metre section.

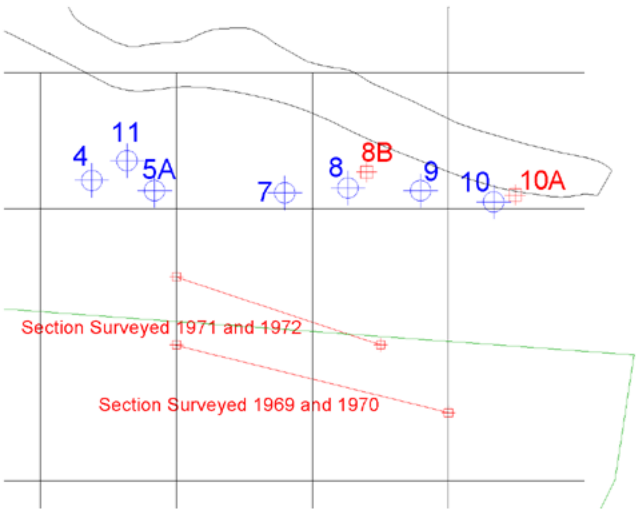

Figure 23: Plan of project area showing locations of extracted cores

Interestingly during the open day held at the site, after most of the field work had been carried out, two retired workers from the quarry attended and informed us that although the pit had been closed to major construction industries the quarry continued to sell gravel on a small scale for some time after its closure and the whole of the gravel bench left at the time of closure was removed piecemeal by local clients. The poor geophysical results can therefore be put down to the absence of the gravel bench they were searching for and in no way reflect the suitability or otherwise of these techniques for the task they were allotted. The correctness of the quarry workers memories was confirmed by boreholes 5 and 6 (Fig. 22), the latter of which could not be placed up against the cliff face because of the cutting of a recent drainage ditch. These both produced a clay fill to 7 and 6.8 metres depth respectively confirming the absence of gravel less than four metres from the cliff face. Borehole 5A was set back behind the southern most extension of the cliff face to replace borehole 5, but borehole 6 was not replaced.

3.4.2 Taking the sample cores

For the sample cores the rotary drill was used to core the clay backfill and undisturbed till until the sandy silts overlying the gravels were reached. At this point sampling was commenced in each borehole. The sample tube was a 1.1 metre long steel tube into which a plastic sleeve of 80mm diameter and 1m length could be inserted (Plate 21). The plastic sleeve was held in place by a steel shoe (Plate 22) for which special catchers were made that were designed to hold cores of loose material such as gravel. Unfortunately, although these worked some of the time, large flint clasts that were broken by the coring during sampling had a tendency to rip off the sprung steel leaves and destroy the catchers. Several were destroyed in this manner during sampling. On one or two occasions the basal part of a core was lost due to the failure of these catchers (see Appendix 00 – field logs). Two methods were used for driving in the sample tube. A redundant compressed air hammerhead drill bit was used as a compressed air hammer to drive the sample tube in using a ‘workshop’ made sleeve fitted to the upper end of the sampler tube and rods (Plate 23) being driven into the borehole. The air pressure was such that this functioned as a vibro-corer as well as a percussion corer and had some impact on the quality of the cores that we recovered (see 3.5.1 below). The second method, used occasionally, particularly on the finer grained sediments, was the hydraulic system on the rig which merely pushed the sampler in. This as noted below also had an impact on the cores that were recovered.

Plate 21: Plastic sleeve being extracted from the sampler

Plate 22: Driving the sampler in

To prevent contamination from material falling in after extraction of the sampler the boreholes were cased. This was accomplished using a drill bit that opened out the borehole and carried down a steel outer tube to case the hole (Plate 24). The borehole was cleared and sleeved down to the bottom of the last sample before the next sampler was driven in. As the depth of the borehole increased, additional sleeves were added at the top and the whole tube of multiple sleeves taken down as the lowest metre was reamed out. This process was carried out using the compressor which cleared any contaminants from the base of the borehole. The sample cores are therefore continuous with minimal, perhaps 2-4 centimetres maximum, of loss between consecutive cores and even less contamination of the upper centimetres of each sample core. After the sampler was lifted the shoe was unscrewed and the portion of the core retained in the shoe placed in a plastic bag and labelled. The plastic sleeve was then extracted (Plate 21), capped at both ends and labelled as to borehole number, sleeve number and depth below ground surface, with particular attention to which was the top and bottom of the core (Plate 25). The sampler was re-sleeved with a new plastic sleeve and the next sample taken after the bottom metre of the borehole had been cased with the steel pipe. The resultant series of cores representing the whole sampled sequence in any one borehole is illustrated by Borehole 10 in Plate 26. While this illustration shows that the coring was successful there were some problems.

Plate 23: The casing being inserted

Plate 24: The complete series of cores for borehole 10

3.4.3 Problems with the coring

Large flint clasts impacted in three ways on the cores. On occasion they cut and split the plastic sleeve, causing considerable problems with their extraction and subsequently requiring binding with tape to maintain the integrity of the sample core. Sometimes the flints gripped the sleeve and instead of the core sliding up inside the sleeve it pushed the sleeve up creating a concertina effect (Plate 25). This also caused problems with extraction and also the retention of the lower few centimetres of the core. Thirdly on several occasions the coring made very little or no progress. As a rule the sampler could be driven in, in about 15 minutes or less but if a large flint was hit, progress could be held up for between 15-30 minutes. This produced considerable vibration in the core and the coring was generally stopped and a short sample taken, before recommencing. The vibrating effect of using the compressed air hammerhead drill caused vibration in the coarser flint gravels, which particularly impacted on the upper 10-20cms of the gravel rich cores causing shakedown and sorting of the finer sand fraction in the gravels. This is particularly obvious in the upper 20cm of the three right hand cores of Borehole 7 (Plate 26) which also show considerable compression of the sleeve. This vibration impact was most severe in gravels where the coring was slowed or stopped by large flint clasts and we persevered for longer than we should have. One aspect of the cores that was not anticipated but is not unusual when coring to depths was expansion of the sediment. The fine-grained sediments, particularly, expanded during and after coring. This had two impacts, the one metre long core expanded out of the ends of the sleeve causing problems for retention but more importantly the last few centimetres of several cores took a very long time to drive in, even using the compressed air hammer. This was found not to result from a hard substrate that the sampler was having trouble penetrating, but rather that the sampler was full before travelling the full metre as a result of sediment expansion, and the whole sampler was acting as a hammer being driven into the sediments below rather than through them. It is a major recommendation of this study that when coring sediments of this sort a 1 metre sampler tube should be used for taking unit cores only 0.8m long. This allows for a 20% expansion, speeds up the coring and reduces the level of deformation in the cores. The coarser sediments had the reverse tendency and were subject to compression. Part of this compression is likely to have been the result of the vibration generated by the compressed air hammerhead causing settling in the sample sleeve. Several of the sleeves produced compression or settling levels up to 10%. A very marked deformation of the fine grained sediments was noted in several cores (Plate 27). The friction of the fine grained sediments against the plastic sleeve holds down the sediment against the walls of the sleeve while that in the middle is pushed up the sleeve, and expansion of the sediment body during and after coring may have had some impact. This produces a characteristic deformation of horizontally laminated sediments completely disrupting their integrity. It was noted that this pattern of deformation was more severe on cores that had been pushed in by the hydraulic system rather than those knocked in using the compressed air hammer (Plate 28). Occasionally the sleeved cores were difficult to extract owing to the expansion of the sediments. In these cases the cores were 'blown' out in a controlled manner using compressed air which caused some mechanical damage, such as splitting and partial shattering of the plastic sleeves or partially extruding the cores from the sleeves, but did not appear to prejudice the cores themselves. On occasions when the coring was making no progress even though only a portion of the sampler was filled the core would be stopped and a short sample collected and the sampler re-introduced for the next sample. This seems generally to have been when a large flint clast larger than the mouth of the sampler was encountered and the sampler had to smash it to make progress. This generally accounts for the short cores in each series (see below).

Plate 25: Core 10/4 showing concertina effect on the plastic sleeve

Plate 26: Core 7/3 showing shakedown of fine material in the upper 20 cm of the three right hand cores

Plate 27: Core 4/2 showing drag effect of the fine grained sediments at the edge of the sleeve

Plate 28: Cores 7/6 and 7/4 showing un-deformed and deformed laminates, the latter due to hydraulic power rather than the hammerhead action

At one point in Borehole 10 the sampler ‘fell’ through a void.

3.4.4 The depth of coring

Prior to the sample coring a decision was made as to the depth of core that would be sampled. Since the project's primary aim was focussed on the fossiliferous and artefact bearing deposits it was decided that each borehole should be sampled to a depth below this horizon. This level was estimated from the 1972 section drawing which indicates that the base of the drawn section lies at a maximum of 8.8 metres beneath the base of the till. All boreholes were therefore taken down to a depth of 11 or more metres except when circumstances prevented it.

It is useful to briefly consider the coring of each borehole and the details of each is summarised in an Appendix 00.

3.4.5 Conclusions

Despite the problems outlined above the photographs of the core sequences (Plate 24 and Appendix 00) show that the coring was successful and, except for one or two small areas where drilling was used to clear obstructions, the cores were continuous. The resultant intact cores were more than adequate for the lithological comparison with the earlier work (see section 3.5 below) and were suitable for the geological studies and biological and OSL assessments. The time allocations to this part of the project were correct and coring using this equipment managed approximately six to seven metres of sample core a day allowing for problems such as the irretrievable loss of the sampler down one borehole, breakage to the 'workshop' made sleeve that held the hammerhead drill, and the occasional large flints that slowed down the coring and other minor headaches. The casing of the boreholes was an absolute necessity both to prevent contamination and retain their integrity.

The recovered sample cores were generally good. The sampler unit lifted good cores and despite problems with the catchers these were rarely essential to the retention of the core sample within the sampler. The limits on the progress of the sampling was largely due to the need to case and clean out the borehole after each metre core was sampled. The sequence of setting up the sampler, fitting it to the rig, lowering it with the necessary extension rods to the sampling level, sampling, extraction, removal of the core sample, capping and labelling the sample, changing the drill head, cleaning out the lowest metre of the bore hole, casing the borehole to the level of the next sample, fitting and lowering the sampler for the next core rarely took less than an hour.

Of the two techniques used to drive in the sampler the hydraulic system was only used on fine sediments and this method appears to have resulted in the greatest deformation to the recovered sediments. The compressed air hammerhead drill created too much vibration in deposits that were resistant to penetration but this impact would have been much less if the coring had been stopped more quickly when penetration was very slow. While a simple percussion auger would probably have resulted in less disturbance to the coarse sediments in the cores it could have taken at least twice as long to sink one borehole. With care, the disturbance to the cores could be minimised when using the compressed air hammerhead by insuring that coring was stopped when the penetration rate dropped below about 10cm every five minutes. In the sediments at Welton-le-Wold the sample coring should progress at a rate no slower than 20-25 minutes a metre.

Coring at Welton-le-Wold was assisted by the lack of water in the deposits. If is difficult to assess what the impact of water-bearing deposits would have been since only one core produced water, but retention of the cores within the sampler during extraction would have been much more problematic if the conditions had been wet.

3.4.6 Recommendations

The field work and resulting study of the cores suggest the following recommendations for similar exercises:

The coring should use a 1 metre sample sleeve but only drive the core 80cm. This allows for an expansion of up to 20% for fine grained sediments.

The coring should be driven by either cable percussion or air compressed hammerhead to minimise deformation of fine grained sediments.

The compressed air driven hammerhead is likely to be much more efficient than cable percussion but as soon as the penetration rate drops appreciably coring should stop even if the target depth has not been reached. The sample core should be removed and a new sampler put on. This should result in a considerable reduction in the disturbance through vibration to the upper part of the core sample.

Serious obstructions are probably best drilled out with the consequent loss of information from this small part of the core since persistent driving to break through such obstructions causes disturbance to the deposits in the sample sleeve.

Good recovery of relatively intact and uncontaminated cores can only be guaranteed if the borehole is cased.

3.5 THE RE-ASSESSMENT OF THE SEDIMENTS OF THE UPPER AND LOWER SEQUENCE OF THE WELTON BECK MEMBER

3.5.1 Methodology

Following geophysical survey, a combination of augering and coring was used to define the extent of the sand and gravel deposits between the sections observed and measured by Alabaster and Straw in 1969 and 1972, and the surviving quarry face in the overlying till.

Based upon this work a series of boreholes were drilled close to the edge of the back-filled area of the former quarry. A rotary auger bit was used until the borehole approached the silt and fine sand deposit at the base of the till, when percussion drilling was used for coring the sands and gravels, whilst hydraulic pressure was used when fine sands and silts were encountered.

As sleeved cores were removed from the drill barrel they were closed with a plastic cap taped onto the sleeve at both ends. The sleeves were numbered from the top down-wards, with the borehole number, sleeve number and depth, recorded both on the sleeve and in a site notebook. The top and bottom of each sleeve was also clearly labelled on the tape used to seal the caps to each end. Any additional material extruded from the sleeve or collected from the drill shoe was collected and sealed in a clearly labelled plastic bag. This bagged material was kept with the appropriate sleeve, and transported to the site cabin. Successive cores were stored in the site cabin where the sleeves from each borehole were laid out in numerical order from the left to the right, with the tops of the cores to the same end and any material extruded from the sleeve or from the drill 'shoe' placed at the foot of the appropriate sleeve (Plate 24).

Using an electric angle-grinder, approximately one third of the plastic sleeve was cut away along its full length to reveal the core. This was then trimmed flat across, using a trowel for the coarser gravel and sands and a knife for the finer sand, silts and clays.

A difficulty encountered at this stage was the recording of material extruded from the sleeve as a result of the change in pressure within the sleeve once it had been removed from the borehole. This was particularly characteristic of the fine sand and silt materials. Laminated beds of these materials also showed a strong drag effect to the sides of the core; attributed to the rate of penetration of the coring tool when under hydraulic pressure. Also related to the use of hydraulic pressure and rotation was the presence of spiral compressions in the plastic sleeves and resultant gaps in the continuity of the core contents (see previous section 3.4.3 and Plates 25 and 27). Despite the use of casing down the borehole the tops of some of the cores seemed to show contamination from material that had either been lost from the previous core length, or had fallen in to the open borehole during extraction and re-entry of the drill-string. A more serious consequence of the drilling process was the presence of 'open', clast supported, flint gravels, where vibrations resulting from the percussion drilling process had shaken the sand and finer content down into the lower part of the unit and possibly into the underlying materials (Plate 26). This was particularly characteristic of those units where there appeared to be a higher proportion of medium to coarse sand and less finer sand and silt sizes in the matrix. It also appeared to be more developed in units that had low moisture content.

Each core was photographed, measured and the positions of changes in the sediments were marked on the adjacent sleeve. The nature of each section of the core was recorded using colour (Munsell), grain/clast size, grain/clast composition, shape, sorting and other observations as appropriate. Similarly the contents of the associated materials in the plastic bags were also described and recorded.
Subsequently samples were taken from selected cores for pollen and micro-fossil content, before samples were taken for macro-fossil study (see previous sections 3.6.1 and 3.6.2). Samples for more detailed sediment analysis were also taken at this stage.

Due to the limited vertical thickness of the coarse gravel sediments valid sample sizes of more than 5kg for grain size analysis could not be obtained from core materials (Jones et. al. 1999). Larger bulk samples from the Welton Gravels obtained from work prior to 2003 were laboratory dried and sieved, using standard sieves and methods, with results that compared generally with sample 3 illustrated in Fig. 3 of Alabaster and Straw (1976) The flint gravels having mean diameters of 5 to 12mm with less than 5% fine sand, silts or clay, and a coarsest fraction size that ranged from 20 to over 40mm. The largest 20 clasts were extracted from selected core samples of the coarser units and each clast was measured using a micrometer, in order to get an idea of the coarsest sediment being moved by the current in individual beds. Their roundness and sphericity were visually compared with the Krumbein and Powers standard images (Jones et al. 1999), as a guide to duration of transport and energy of the transporting medium. At the same time the lithologies of the selected clasts was identified and their surface colour recorded, as a guide to the environment and duration of exposure prior to burial.

The smaller sample sizes required to obtain a valid result for finer grained sediments were available from the selected core samples. Standard dry sieve analysis of the silts and sands from the Lower Gravel division confirmed the well sorted silts and very fine sands comparable to those illustrated as samples 4 and 5 in the previously mentioned figure, whilst the fine sands and silts from the Upper Gravel division were similar to those of samples 1 and 2. A binocular x20 microscope was used to study the finer granule and sand sized grains extracted from selected core samples. Grain morphology was measured by visual comparison of a number of grains with the Krumbein and Powers standard images, whilst different lithologies were identified, and the proportion of grains of distinctive type was estimated by comparison with a series of standard grain percentage illustrations. A microscope study of groups of laminated beds confirmed the repeated gradations in grain sizes in from fine sand sizes at the base to silts and possibly clays at the top of each individual lamination.

3.5.2 Summary description and interpretation and conclusions of the stratigraphy and sedimentary environment

A total of seven cores were extracted and described in full. A detailed description of each core is presented in Appendix VIII.

The deposits investigated by a series of boreholes at Welton-le-Wold can be divided into a number of distinct categories for purposes of interpretation (Tucker 1986).

i. Backfill: This is the overburden of Welton Till removed during the extraction of the sands and gravel deposits and used to fill the void left behind the advancing quarry face. Close to the former quarry face this material may also include some slumped and down-washed Welton Till materials.

ii. Welton Till: A diamicton consisting of glacially derived clasts of flint, chalk and other rock types from more distant areas of Britain, in a matrix of blue to grey clay. In this case the striation and rounding of the softer chalk clasts and the presence of similar but rare clasts of Jurassic and Carboniferous sandstones and limestones derived from Yorkshire and the North of England prove the glacial origin of this diamicton.

iii. Very Fine Sands and Silts: Defined in terms of dominant grain sizes (between 0.125 and 0.0625mm. for very fine sand, and between 0.0625 and 0.0020 for silt). This continuous bed occurs between the overlying Elton till ad the underlying Welton gravel. The bed was described as a silt in Alabaster and Straw (1976). The very well sorted nature of these fine sizes and presence of low angle bedding structures indicate that they were probably of aeolian origin but may have been re-worked in shallow bodies of water. A wind transported fine loess deposit settling into shallow, ponded waters might produce this type of deposit, but it could also be produced by a loess blanket of fine material being re-worked in situ by subsequent sheets of water. In the former case the individual beds should show micro scale graded-bedding, whilst if the latter explanation is correct small-scale ripple structures and other evidence of re-working might be expected. The geometry of the deposit would also help to differentiate these possible origins, but the current evidence of extent, height and thickness variations is not adequate to differentiate between a large shallow body of standing water and sheet processes operating over a large area. The difficulty of sustaining a lake above the series of Welton Gravels requires a very high water-table at this site. This could be due to a local perched water-table due to impermeable deposits beneath it, or possibly permafrost, or seasonally frozen ground.

iv. Welton Gravels: Alabaster and Straw (1976) divided these into an Upper Division and a Lower Division, the main differentiation being a weak unconformity with an ice-wedge cast that occurred at the top of bedded brown sands that formed the top of the Lower series. The mammal remains and the hand-axes were all recovered from the Upper series of sands and gravels at a depth of between 3 and 5 metres below the bottom of the Welton Till.

<u>Upper Gravels</u>*:* Analysis of the records of the boreholes and the sampled materials from the Upper Gravels shows them to have a thickness of between 5 and 7 metres, with their top at between 81.5

and 82.5m OD. Their composition of angular to sub-angular shaped predominantly brown flints, the largest ranging between 5 and 60mm. in maximum dimensions, suggests variable energy flows in a fluvial environment. The size range and the shape of the clasts indicate that they were transported for relatively short distances, and not in high energy turbulent flows. The absence of chalk clasts in a sedimentary sequence confined within a steep sided chalk valley is unusual and requires explanation. Possibly the highly soluble chalk material was dissolved prior to any deposition, either on vegetation covered valley slopes that may also have restricted the supply of larger chalk clasts, or they were rapidly dissolved in the relatively acid river water during fluvial transport. There is no evidence in these deposits for the solution of chalk clasts that had been incorporated in the gravels. Testing with dilute Hydrochloric acid confirmed that not only were there no large chalk clasts present in these gravels, but that the matrix was also largely free of calcareous materials (Jones & Keen, 1993).

A fluctuating fluvial interpretation for the environment is supported by the matrix content, ranging from fine sands deposited under very low flow energy conditions, to granules deposited under higher energy conditions. Almost all the flint had a brown colour that is typical of fluvial deposits where humic acids have acted upon the surfaces of the clasts. In Borehole 10, sleeve 3 passed through a bed of white flint gravel indicative of a considerable period of surface exposure to weathering processes. Both above and below this material the flints appeared to be very dark coloured, due to a coating of iron and manganese oxides and hydroxides. This staining process is considered to be secondary in age, due to salts of these metals being carried in solution through the higher porosity flint beds after deposition.

The effects of vibration during drilling are likely to have destroyed any bedding structures that might have been present in the original deposits. Similarly the size of the cores did not allow any such structures to be preserved in relatively coarse sediments. Variations in the lithologies encountered at the same depth from adjacent boreholes demonstrate the extreme lateral variability of this series of deposits. A sequence of relatively active and switching braided river channels is suggested, but could only be confirmed if channels and cut and fill structures could be seen in extensive faces in these deposits. On this evidence a cool temperate climate could be suggested for the time during the deposition of the main part of the Upper Gravels (Benn & Evans, 1998).

Lower Gravels: Possibly a misnomer, since the part cored proved to be a continuation of the brown sands recorded by Alabaster and Straw (1976). During this investigation only approximately the top 5 metres were cored, but Borehole 1 penetrated more than 3 metres of gravels below 72m OD. and above the chalk bedrock. The upper part of this series commenced with heavily stained sand beds but was dominated by very fine sand and silts in laminated beds that continued for more than 3 metres in several of the cores. The laminated sequences, with a few, thin coarser beds between them, and the rare flint clast, were deposited under very low energy conditions. The vertical and lateral extent of these beds suggests a lake or large standing body of water with annual or seasonal variations in the supply of exclusively fine sediments. A lacustrine environment is also supported by the presence of possible organic traces in some of these beds, whilst the coarser deposits could have their origins in small streams feeding into the margin of a lake. No definite drop-stones were observed in these deposits, but the isolated white flint in sleeve 8 of Borehole 7 could possibly have this origin. Drop-stones form either by stones falling onto ice over a body of water, where they fall into the sediments at the bed when the ice melts; or, less likely in this case, they are carried by blocks of glacial ice onto the body of water, where subsequent melting allows them to drop to the bed. The coarser beds in this sequence are almost all free of calcareous material and show secondary staining by iron and manganese salts. Movement of water through the sediment after deposition requires that the water-table is sufficiently high in the adjacent valley sides to restrict downwards movement of water in the valley floor. The restriction of the downward movement of ground-water is less of a problem in the Upper Gravels since the much less permeable finer sands, silts and clays of the Lower Gravels, underlie them. Evidence from Borehole 1 indicates gravels beneath the laminated beds, suggesting that downward movement of water into a very porous chalk floor to the valley would not be so restricted. In order to initiate lake formation above these lowest gravels the water-table would have had to be very high. Possible reasons for this might be a pluvial period when high precipitation raises the water-table, or permafrost; when ground-water in the chalk and lower gravels would have been frozen, preventing free downward movement of precipitation and any surface water produced by seasonal thawing. On balance the latter explanation is considered more likely; although no clear evidence was seen for cryoturbation in the borehole cores, some de-lamination occurred that might be attributed to this cause. Alabaster and Straw (1976) indicated an ice-wedge cast at the top of the Lower Gravels, strongly indicative of a severe tundra climate. The evidence supports an interpretation of a prevailing cold phase/periglacial environment during the period of deposition of the Lower Gravel Division.

3.6 THE ASSESSMENT OF SEDIMENTS FOR PALAEOENVIRONMENTAL, FOSSIL AND ARTEFACTUAL POTENTIAL.

The mammal fossils and artefacts recovered from the site in the late 1960s and early 1970s make this one of the most important early Palaeolithic sites in Northern England and their exceptional stratification below the later tills (Wymer and Straw 1977) means that they can with complete confidence be assigned to the Ipswichian or earlier. Nevertheless none of these finds is diagnostic chronologically (Alabaster and Straw 1976; Wymer and Straw 1977; McNabb this report; Schreve this report) and the recovery of further faunal, artefactual or palaeoenvironmental material might considerably improve our ability to date the sequence.

There is of course virtually no possibility that the coring exercise conducted at the site could retrieve either artefactual material or large mammal bones but the exercise was designed to establish whether the gravel sequence could be correlated with that recorded by Alabaster and Straw and therefore might contain such remains. It was considered possible, however, that the recovered cores could be studied for microfaunal and other palaeoenvironmental evidence such as pollen and to this end samples were taken from the cores for palynological analysis and whole sections of two cores were processed for macrofossil remains, primarily small vertebrates.

The pollen sampling was restricted to fined grained sediments and samples from Boreholes 5A and 8 (Appendix VIII - borehole illustrations for location of samples) were submitted for study. For the macrofossil evidence sections of core through both fine grained and coarse sediments were processed from Boreholes 8 and 9.

3.6.1 Pollen assessment Analysis (Dr. Rob Scaife)

Pollen samples taken from two of the five boreholes were examined for their sub-fossil pollen and spore content. The principal aim of the study was to ascertain if pollen and spores were present in these middle Pleistocene sediments. If present, to examine the potential for establishing the past vegetation of the site and the possibility of placing the site within the Pleistocene chronological framework of glacial and interglacial stratigraphy. A total of eight samples from Borehole 8 and two samples from Borehole 5a (Appendix VIII) have been examined. Unfortunately, Pleistocene pollen was absent in all of the samples. This is attributed to the minerogenic and possibly oxidised nature of the sediments which was not conducive to pollen preservation. Only small numbers of highly resilient pre-Quaternary, geological palynomorphs were recovered and these clearly do not allow the aims of the study to be met.

Pollen Method

Samples from Borehole 5a (at 72 and 35cm) and Borehole 8 (at 0.05, 0.08, 0.19, 0.45, 0.58, 0.67, 0.74 and 0.86m) were examined. Because of the mineral character of the sediments, samples of 5ml were processed. Standard techniques for the extraction of the sub-fossil pollen and spores (Moore and Webb 1978; Moore *et al.* 1991) were used. This included disaggregation with Na.OH, micromesh sieving (10u) to aid with removal of the clay fraction in the mineral sediments and digestion of coarser silicates with boiling Hydrofluoric acid. Acetolysis was also used to expand any pollen after HF treatment. Residues were mounted in glycerol jelly and examined using an Olympus biological research microscope. These procedures were carried out in the Palaeoecology Laboratory of the Department of Geography, University of Southampton.

3.6.2 Macrofossil Analysis

A series of samples from boreholes 8 and 9 (Appendix 00 - Figs. 00 and 00) were selected for processing. The thirty three samples were weighed and left to disaggregate in water. After disaggregation the samples were washed over a 1mm mesh sieve in a bowl and where anything floated this was collected in a 300 micron mesh flot sieve. The fraction of the sample that passed through the 1mm mesh sieve was retained and subsequently washed on a 300 micron sieve. The material that passed through this 300 micron sieve was discarded. The residues (the >1mm and >300 micron residues) were air dried and subsequently sieved dry through sieves of mesh 2mm and 6.65mm. The greater than 6.65 and 2mm residues were sorted for all the samples processed. The <1mm residue was scanned by eye by an experienced sorter used to dealing with small vertebrate remains, but not meticulously sorted in the manner of the larger fractions. The dried residues after sorting were passed to John Aram for more detailed description.

Unfortunately no vertebrate or organic finds were made in any of the samples. Several samples included some hard chalk clasts indicating that decalcification was not universal in the deposits (see Aram above) and very small flakes of chalk washed over in one of the flots. While these are disappointing results they represent a tiny proportion of the sediment body and the presence of some calcareous material is encouraging for the survival of fossil bones since the sediment analysis has shown that almost all of the deposits are decalcified and therefore unsuited to bone survival.

3.7 THE ASSESSMENT AND SAMPLING OF DEPOSITS SUITABLE FOR OSL DATING.

OSL dating was identified during the preparation of this project as having the greatest potential for producing a result. Since the dating of the horizon that produced the fossils and artefacts is the single most important aspect of the study, attention was given as to how this could be accomplished. Since the suitability of the deposits in the sequence is variable it was necessary to establish where in the core sequences suitable deposits occurred. Further more the core samples being collected in transparent sleeves were unsuitable for sampling for OSL and opaque samples sleeves were needed.

3.7.1 Sampling for OSL

After the sample coring had been completed two cores (Boreholes 8 and 10) were opened (Plate 29) and the deposits considered for suitability for OSL dating. Jean-Luc Schwenniger of the Luminescence Dating Laboratory of the Research Laboratory for Archaeology at Oxford University attended on site and deposits of fine-grained sands and silts and coarser grained sands were identified as having OSL dating potential. The depths of these sediments in the boreholes was noted and new boreholes immediately adjacent to those studied (boreholes 8A and 10A) were opened and cored down to a level 30-40 centimetres above the selected sample location. Specially prepared opaque sleeves painted black on the outside were used in the sampler and the sampler driven in and lifted. The 1 metre sleeve was removed, capped, labelled and wrapped in black plastic cling film to ensure the exclusion of all light and returned to the Oxford Laboratory. The borehole was then drilled down to the next sample location and the exercise repeated. OSL sample cores were taken from two boreholes and on the second site visit when the sampling of the second borehole was undertaken Jean-Luc took gamma spectrometer readings by lowering the equipment down inside the boreholes (Plate 30) after the casings had been removed and taking measurements at the depths from which the samples were taken. This was possible for all sample locations except the base of borehole 8A where collapse of the borehole walls prevented the equipment being lowered to the bottom sample location. In all OSL sample cores from seven locations were taken in the two boreholes.

Plate 29: Assessing core 8 for OSL potential

Plate 30: Jean-Luc measuring gamma spec. potential in Borehole 10A

3.7.2 Summary of the deposits sampled

Borehole 10 was selected for the fine grained sediments. One metre long sleeved cores were taken from:

- the upper slightly fine sandy silts immediately below the chalky boulder clay
- from a sediment unit sandwiched by gravels
- from the upper part of the fine sediments immediately underlying the gravels
- from the base of the fine grained sediments near the base of the sequence, and overlying chalk deposits

This series had the potential to yield dates for the onset of the fine sedimentation, a date for the sediments immediately predating the fossiliferous gravels, a date within the gravel member, and a date for the fine sediments immediately post-dating the fossiliferous gravels. The latter date also gives an 'after which' for the chalky boulder clay deposited over the cored sequence.

In Borehole 8 much coarser sand sediments were chosen for the dating programme to cover any differences in success between the sediment types. A one metre sleeve was taken to include:

- a sandy lens within the upper part of the gravels
- sandy gravels at the base of the main gravel member
- sand deposits at the base of the sequence and underlying all the gravels and fine-grained sediments.

This sequence would allow the dating of the earliest recorded sandy sediments in any of the cores, the basal part of the gravel formation and the upper part of the gravel formation, these latter two bracketing the fossiliferous gravels that produced the hand axes.

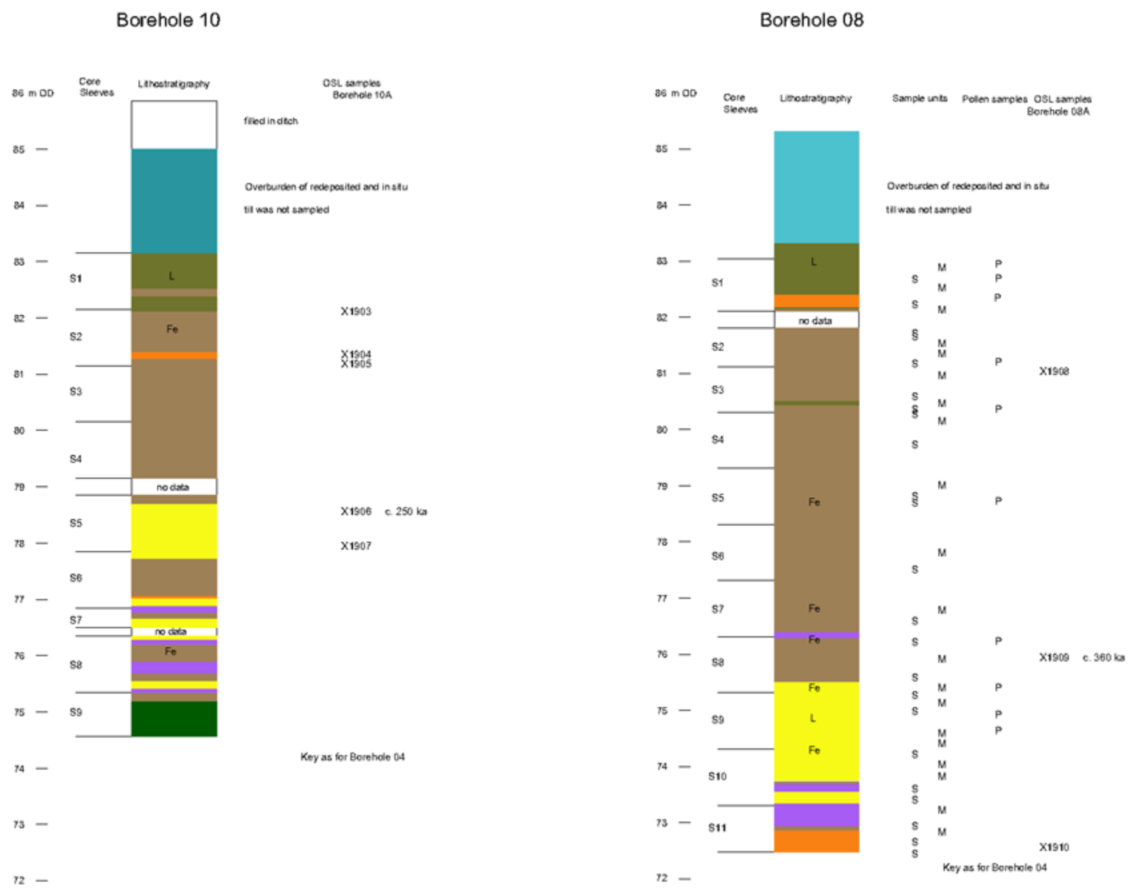

Figure 24: The location of the OSL samples from cores 8A and 10A (also see Appendix VIII, illustrations)

3.7.3 The potential of the deposits *(Jean-Luc Schwenniger)*

Sedimentary units suitable for OSL dating were identified in Boreholes 8B and 10A during fieldwork carried out on the 20th of August and 15th of September 2003. They consist of sand and sandy silt sediments which occur at varying depths throughout the sequence. Three promising sample locations are available in borehole 8B (±4.5m, ±9.7m, ±12.7m) and four in borehole 10A (±3.7m, ±4.5m, ±4.70 & ±7.0m). Two of these are overlapping at a depth of circa 4.5m. A series of six of these samples would enable the dating to span the entire sequence including the basal units.

In the case of Welton-le-Wold, it seems preferable to target sandy sediments as opposed to silt or clay deposits because they generally have much lower concentrations of radioactive isotopes. Due to the presumed old age of the deposits and potential problems of OSL signal saturation, it is recommended to initially attempt the dating of sedimentary units characterized by low environmental dose rates. A further advantage of focusing on coarse grains (90-300 microns) as opposed to polymineral fine grains (4-11 microns) is that OSL measurements may be made on aliquots of pure quartz, thereby minimizing signal contributions from potential feldspar contaminants. Coarse grains also offer the possibility of dating single grains in the case of partial bleaching.

Depending on the outcome of this pilot study, further luminescence dating may be carried out on the silty deposits in the future. From a dating point of view, this is an exciting prospect. The special way in which the samples were obtained in lightproof sleeves, offers the possibility to date the complete sequence of this very special site.

The environmental dose rate at suitable sample locations was also measured in a novel way, by attaching the detector of the gamma-ray spectrometer to a climbing rope and lowering it into the borehole (Plate 30). Special coaxial cable was bought in order to extend the standard cable of the instrument. The readings indicate that the external gamma-dose varies between 0.2 and 1.0 Gy/ka. This is on the low side and further minimizes the risks of encountering problems associated with signal saturation.

Preliminary test measurements completed on two samples collected from sandy units overlying the boreholes suggest that sufficient quantities of suitably sized quartz grains should be obtainable. Stimulation with infrared light confirmed the presence of feldspar either as single grains or mineral inclusions and some samples may have to undergo additional and extended treatment in H_2SiF_6 acid.

3.7.4 The OSL dating

English Heritage approved dating of all seven of the selected horizons, with the overlapping samples in each Borehole offering an opportunity to internally test the results and the stratigraphic correlations. In the event eight samples were taken for OSL from the seven cores, five from Borehole 10A and three from Borehole 8A. Each sample comprised a four to six centimetre section of the cores and their precise location in the boreholes is indicated on Fig. 25. In addition to this sample series two samples were collected from deposits within the tills overlying the gravels, one from the Welton tills above the borehole transect and one from the Devensian till in the Eastern quarry.

After analysis it was found that in six of the samples the OSL signal is saturated. This means that only a minimum age can at best be calculated. The sample that 'worked' best was X1909 taken from the basal sediments in borehole 8A (Fig. 25 at a depth of 9.34-9.38m]. The age estimate comes out at *c.* 360 ka. This sample is currently being remeasured in another machine to improve the counting statistics on the error. The results are expected shortly but not in time for this report.

A second sample (X1906) from Borehole 10A at a depth of 7.26-7.31m (Fig. 25) also produced an age estimate of c. 250ka. One other sample (X1907) collected just below X1906 (at 7.87-7.93m – Fig. 25) is also currently being measured and it is due to be finished shortly but not in time for this report, but it may not produce a result.

The two samples collected from the exposed sections, in order to bracket the sequence and make up for the difficulties in dating the upper sediments from the boreholes, have also been processed. The results are very interesting in that the dates turn out to be much older than expected. Sample X1785 collected from sands within the tills near the drilling site gives an age estimate of c. 200ka. Sample X1786 collected from the Devensian tills in the eastern quarry is c. 150ka. However no gamma-spectrometer measurements were taken for this sample and the date is based purely on the results of the neutron activation analysis.

The final interpretation of these results will have to await the completion of the full series of measurements that have been undertaken, but these results clearly indicate that the deposits at Welton Le Wold do have potential for OSL dating and have yielded preliminary results that can be used to re-interpret the site (see below).

3.7.5 Conclusions

Unfortunately most of the samples studied showed the OSL signal to be saturated and a minimum age at best obtainable. However after repeated measurement two OSL dates have been obtained from the core samples in Boreholes 8A and 10A and two preliminary dates have been obtained from deposits overlying the cored sediments. These preliminary results have given dates that correspond with Marine oxygen Isotope stages (MIS/OIS) 10/11 and 8, with the two samples from the tills above corresponding with MIS 6/7 and 6.

3.7.6 Recommendations

The suitability of the deposits for OSL dating was unknown prior to this project. The results of this work have shown that although most of the samples measured for OSL were saturated four samples have produced a sufficiently good signal to give preliminary dates.

The technique therefore has further potential at Welton-le-Wold and future work, for instance on the eastern part of the quarry, should ensure that OSL is undertaken to try and obtain further and confirmatory dates for the site. The positive results from the till samples are particularly important for our understanding of the glacial sequence at the site.

In the initial consideration of the dating programme for this project, Stable Isotope Analysis of the Straight tusked elephant and possible giant deer were considered an option for assessing their potential to show particular evidence for the climate at the time of death and initial deposition. The giant deer specimens have been re-identified and assigned to bovid, probably bison, but this does not diminish their potential for this study. The stable isotope potential was deemed to be low due to the (possible) great age of the material (definitely if pre-Anglian) and the fact that the material is derived (Schreve pers.com). In the light of the preliminary OSL dating these fossils may be much younger than Anglian and their potential for Stable Isotope Analysis can be reconsidered.

4 DISCUSSION

4.1 A REVISED INTERPRETATION OF THE DEPOSITIONAL ENVIRONMENT OF THE UPPER AND LOWER WELTON GRAVEL DIVISIONS

The programme of boreholes confirmed the general stratigraphic sequence of sediments illustrated by Alabaster and Straw (1976) and Figure 3 this report, with the Welton Till, overlying a 'silt' bed approximately one metre thick that separated the till from the underlying Welton Gravels. The gravels were divided into Upper and Lower divisions in the original publication; the Upper, approximately 6 metres thick, consisting of sandy angular flint gravel with seams of sandy or clayey silt, and the Lower division showing 2 metres of bedded sands, silts and gravels.

The boreholes were located as close as possible to the most northerly of these sections (Figure 23) in order to keep the projection of any correlations to the minimum distance. It is likely that borehole 10 penetrated a lateral extension of the same distinctive white gravels and flints recorded by Alabaster and Straw in the Upper division on their 1969-70 Section A, (Figure 3 this report, Alabaster & Straw 1976).

Upper Gravels

Laboratory analysis of selected samples from the borehole cores in the Upper division generally agreed with the previous findings in terms of particle size distributions and sorting. The largest flints recovered were over 60mm in maximum dimension, but limited by the diameter of the sleeve used to recover the core samples. Larger flints were probably encountered on a few occasions during coring. No clasts of chalk were found in the coarser gravels and only very rare small chalk pebbles occurred in the medium to fine gravels. No clasts of the types of erratic rocks that might have been derived from glacial deposits were found. Generally the poorly sorted gravels contained the largest flints and tended to have a granule or coarse sand matrix, whilst the smaller flint clasts occurred in a medium to fine sand matrix. Due to the possible effects of vibration during the coring process it was not possible to confirm the suspicion that graded bedding occurred in both the matrix materials and in the finer sand size materials examined. A visual comparison of the shape of the larger clasts confirmed Straw's earlier descriptions, with a high percentage of the flints being angular in shape, but with a slightly greater (but still small), percentage of sub-angular and sub-rounded forms in different beds. In the granule and sand sizes, well rounded, high sphericity quartz grains were abundant; a possible source being the Lower Cretaceous rocks beneath the Chalk, where similar highly polished quartz grains occur in the lower part of the Red Chalk and the Carstone. The abundance of very angular flint fragments in the sand sizes was again noted, but in the coarser units at least some of these may have been the result of fragmentation during coring.

The samples of fine sands and silts from the Upper division that were analysed also showed similar distributions of grain sizes to those previously studied (Alabaster & Straw, 1976) but would now be considered to represent a relatively well sorted, low energy, water-lain deposit. References to iron and manganese staining of flints and the presence of 'crumb' aggregates of manganese oxide was also confirmed by using a x20 binocular microscope to examine the medium and fine sand fractions. A more correct identification of the black manganese compound would be Pyrolusite, a manganese dioxide mineral. The number of levels and varying depths and degrees of staining by iron minerals is indicative of numerous fluctuating water-tables within the gravels since their deposition. The primary source of the iron might be from the nodules of the iron disulphide mineral Pyrite that occur in the Cretaceous Chalk, and which might also have contributed to the acidity of surface waters. The hydrous oxide of iron, Limonite, forms a major constituent of the Claxby Ironstone deposits in the Lower Cretaceous rocks of Lincolnshire, and could be contributing to the potential sources of iron. Additionally the form of Limonite known as 'bog-iron', that is currently forming by the action of microscopic organisms and vegetation in lakes in Sweden and Finland, could be a further source of iron.

The conclusion of Alabaster and Straw, that the Upper division from which the artefacts and vertebrate remains were recovered was a water-lain deposit originating in a fluvial system is supported by the study of the borehole materials. Whilst the environmental interpretation for the relatively uniform silt layer at the top of the gravels as resulting from predominantly aeolian activity is also accepted, it is now believed that the wind-blown loess settled through standing water prior to deposition. The main difference from the original publication is in the revised climatic interpretation suggested for the main part of the Upper gravels. As outlined in the description and analysis of the core materials above (section 3.5.2) there is evidence of fluvial activity with varying energy levels and duration of exposure of deposits in the middle part of the Upper gravels. A small braided river with occasional flood events causing a relatively high discharge and velocity, followed by declining discharge and velocity allowing the deposition of progressively finer sediment sizes to form the matrix between the gravel clasts would produce a sequence of sediments very similar to those recorded in the borehole cores.

The predominant brown colour of nearly all the flints at this level also suggests the presence of humic acids, and hence of vegetation on the surrounding land areas. A vegetation cover could account for the almost total absence of chalk clasts from the gravels, since a soil and vegetation cover would prevent or at least restrict the supply of such large material, in contrast to the bare slopes of frost-shattered clasts as envisaged under the cold climate conditions originally proposed (Alabaster & Straw 1976). The chalk valley sides under temperate climate with a vegetation cover would largely contribute insoluble flints, clays and acid ground-water to any stream at their foot. It should also be noted that any chalk clasts that might have been included in the original fluvial sediment load are likely to have been rapidly leached and dissolved by the humic acids generated by the vegetation cover. The single localised patch of white sand and flint shown on Section B (*ibid*), may have resulted from a relatively long period of exposure to weathering agents above the water-table, possibly on a long-lived island bar in a braided stream. The absence of any evidence of cryoturbation within these beds, and particularly in the finer laminated sands and silts, is a strong indicator that the climate was not periglacial at this stage. Similarly the absence of exotic clasts that might have been derived from fluvio-glacial rivers in advance of an ice sheet that brought such material into the area during deposition of the Welton Till, precludes this type of fluvio-glacial origin.

A modern analogue for the type of fluvial environment that is envisaged for the deposition of this Upper division of the gravels might be found at the present time in the valley of the Findhorn River in North-eastern Scotland, or in some of the restricted river valley systems in the south of Iceland.

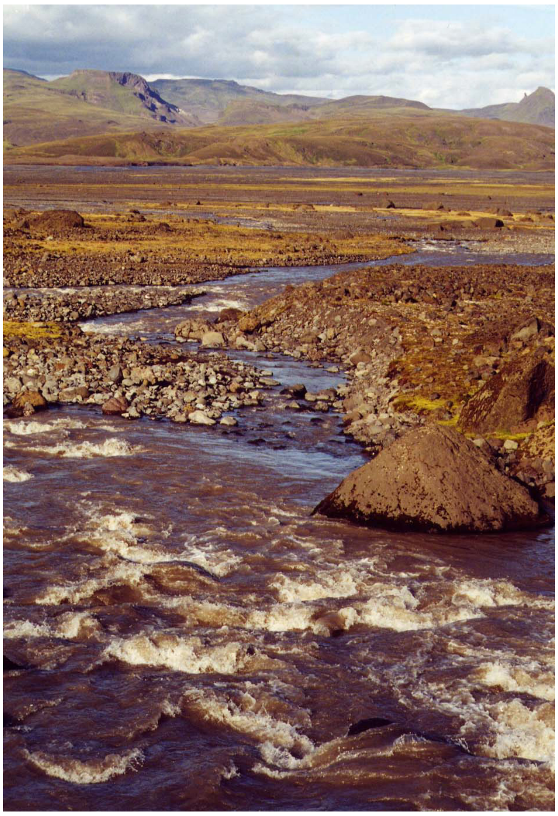

Plate 31: Braided streams in southwest Iceland

Lower Gravels

Laboratory analysis of the samples obtained from borehole cores close to the presumed boundary of the Upper Gravels with the Lower Gravels compared with the earlier findings of Alabaster and Straw (1976). The upper 2 metres of 'bedded brown sands' recorded at the top of the Lower Gravels in section B (Figure 3 this report) might have been a locally coarser unit such as that recorded in borehole 8A at this boundary, below which staining by iron and manganese compounds became very pronounced and frequent.

The iron-stained sands contained a proportion of Limonite ooliths which contributed to their dark colour. As considered in the analysis of borehole 9 these may have been derived from the Claxby Ironstone, but present a geographical problem if this is their true origin. The Claxby Ironstone occurs lower in the Lower Cretaceous sequence than the Upper Cretaceous Chalk, whilst the Welton valley is entirely cut within the Chalk. The Cretaceous strata in this area have a slight regional dip to the east, so the nearest source of Limonite ooliths must be from the west, where the Lower Cretaceous strata outcrop. This view is supported by the evidence of sedimentary structures in the gravels recorded by Alabaster and Straw (1976) that indicated a west to east flow of the current at the time of deposition. But to the west of Welton-le-Wold there is currently a valley head with the present-day Welton Beck sourced in the area around Calcethorpe, where the solid geology is still Chalk, covered partly by

Calcethorpe Till, a glacial deposit that lies above the Welton Till. Currently the south-west draining River Bain has its source in the area immediately west of Calcethorpe, thus cutting off the modern Welton Beck from a potential source of Limonite ooliths in the Claxby Ironstone. Whilst this may not impinge directly on the environmental history of the deposits under investigation it does have considerable implications for the fluvial history of the area during the Pleistocene, and particularly throughout the period of deposition of the Welton Gravels. Since Limonite ooliths are present in both divisions there must still have been a drainage pattern in operation throughout this period that extended considerably further west than at the present time, suggesting that comparable aged gravels might exist beneath tills further west than their presently known limits.

Because of the depth to which the 2003 borehole programme penetrated compared with the very limited exposure of the Lower division during the period 1969-72 it was possible to add considerably to the previous knowledge of this division. Borehole 1 reached the solid chalk floor of the valley side at a depth of 18.5m (68.2m OD.), after penetrating approximately 14.5m of back-fill and 3.5m of ‘dirty’ brown, small gravel clasts. Boreholes 7, 8, 9 and 10 all recorded 3 to 4 metres of laminated very fine sands and silts in the upper part of the Lower division (Figure 25), whilst boreholes 8 and 10 ended in a diamicton consisting of flints in a clay matrix and flints in a chalk matrix respectively. Borehole 9 finished in gravels, at a level only approximately 2 metres above the upper level of the gravels recorded in borehole 1.

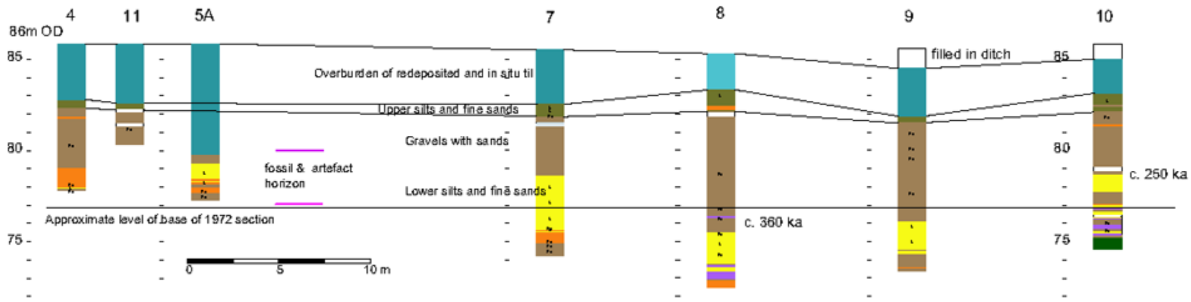

Figure 25: Composite stratigraphy in Welton gravels based on 2003 cores

As considered in section 3.5.3 above, a cold climate was postulated fro the accumulation of the thick sequence of laminated fine sands and silts encountered in the Lower division of the Welton Gravels. This view is further supported by the presence of diamictons in the lowest part of boreholes 8 and 10 as noted above. These are tentatively interpreted as being the results of solifluction processes operating down the steep sides of the valley under periglacial conditions, but would require further study to confirm this interpretation. In Straw’s Section B (Figure 3 this report) an ice-wedge cast is illustrated in the top beds of the Lower division gravels. The formation of ice-wedges requires a very severe cold climate with little or no vegetation cover and no protective snow covering of the sediments. At the junction between the Lower and Upper divisions of the Welton Gravels, therefore, there exists the strongest, but only recorded evidence, for periglacial conditions operating in this area at that time. Under such conditions sedimentation would be very limited and a minor unconformity may occur prior to burial by deposits resulting from increasing rates of sediment production and deposition. Under a peri-glacial climate a long period of weathering might also be experienced by any flints on the surface, resulting in a high proportion of white bleached flints, although this may subsequently have been masked by secondary staining related to water-table movements. Unfortunately the lowest parts of this division were not sampled in borehole cores, so analysis was restricted to the material available from borehole 1, where the auger entered beds below the postulated floor of the quarry. The nature of the gravel reported in the description of borehole 1 suggests fluvial deposition with a lower energy than in the Upper division, an interpretation based upon the smaller maximum clast sizes and the presence of a higher proportion of silts and clay in the matrix. If this is correct, then it indicates a low energy fluvial environment prior to the diamicton and laminated sequence in the central part of the Lower division of the Welton Gravels. Modern analogues for the conditions proposed for the Lower division might now be found in northern Scandinavia or Arctic Canada.

4.2 A REVISED INTERPRETATION OF THE SEDIMENTARY CONTEXT OF THE FOSSILS AND ARTEFACTS

In view of the very limited quantity of material produced over a long period of time from a very thick sequence of sands and gravels it is relevant to question why this might be so. The report on the pollen analysis (section 3.6.1) indicates that oxidation of the sediments has resulted in the loss of this material. Similarly the absence of any shells or other small calcareous biological materials reported above (section 3.6.2) indicates the de-calcification of at least most of the gravel and sand sequence. All the bone and antler material recovered in the original study also showed signs of de-calcification, a feature particularly illustrated by the presence of the two adjacent teeth of *Palaeoloxodon antiquus* in a situation where the supporting jaw-bone was almost totally disintegrated and fragmental, whilst no other recognisable parts of the skull were present. The only parts of the Welton Gravels investigated that had a small calcareous content occurred either very close to the top, immediately below the silt that divided them from the Welton Till; or in relatively thin units sandwiched between very fine sand or silt beds. In both these cases it is possible that the overlying less permeable deposits restricted the downward percolation of acidic ground-water and thus limited the de-calcification in the beds immediately below them.

A re-consideration of the distribution of the mammal finds illustrated in Section A and B (Figure 3 this report and Alabaster & Straw 1976) indicates that they were nearly all recovered from a similar level and frequently located beneath finer grained deposits where a similar process of partial protection from downward moving acidic waters may have operated. The finer grained sediments would not prevent any lateral movement of ground-water, which would still be related to the hydrological conductivity of the sediment involved. Secondary iron coatings and stained deposits recorded at many levels in the cores are related to varying water-table levels, themselves a restriction on the downward movement of ground-water. These results lead us to conclude that both the survival and condition of the fossil material recovered in the late 60s and early 70s was in substantial part a product of the post-depositional conditions in the gravels. The survival of the teeth, largely composed of a much more resistant material than bone, and the limited post-cranial material and the poor condition of the bovid bones and red deer antler is consistent with this interpretation. The implication for any further work would be the locating of sediment samples where de-calcification is least, and fossil preservation potential is greatest. This would suggest that coarser deposits beneath a fine-grained sediment, where there is evidence of high water-tables within the deposit should be targeted in further studies. It also implies that further fossil finds are likely to be elements of the megafauna and recovery of small vertebrate remains are most likely from the finest grained sediments where they might have been protected from decalcification.

An additional problem to be considered at this point is the original view that the fossil material was derived. The description and interpretation of the *Palaeoloxodon* teeth and tusks indicates that they are probably very nearly contemporary with the sediment in which they were found and that there has been little post-depositional movement. In view of the clast sizes of the sediments from which they were extracted they could not have been moved, even individually, by the available energy that deposited the surrounding sediment. The broad, shallow stream channels suggested by the lateral variability of the gravels would not have contained sufficient water depth to float a complete jaw bone containing the teeth, never mind an entire skull or carcase. Similarly the energy required to move material of the size of the individual teeth might also have been expected to contain flint clasts of a similar size, i.e. more than 200mm. This compares with a maximum flint clast size recorded from the gravels of less than 100mm, although flints in the overlying tills frequently exceed 200mm in size. On this evidence it is suggested that the elephant fossil material could have become incorporated in the sediment by falling in from at least the partial remains of a creature lying on the floodplain to the side of a channel that subsequently undercut its banks during lateral migration. Alternatively it could consist of the partial remains of a creature that had died on a gravel bar and was subsequently buried by aggrading sediments. The energy required to transport the larger bones and antlers in shallow fluvial environments would also need to have been high, in which case other coarse material in transport would be expected to have caused severe abrasion to their surfaces during bed-load rolling and other movements. The matrix reported on the antler of *Cervus elephas* and the *P. antiquus* tusk tip (Figure 3 this report) indicates a much lower energy environment than that required to move either of these items, but adequate to abrade them over a period of time. The bovid astragali are also of relatively small sizes and much closer to the surrounding sediment sizes; significantly they show the strongest evidence of abrasion. Originally it was suggested that they might have been derived from previously formed deposits and the abrasion related to their re-working into a secondary context. Alternatively they could be nearly contemporaneous with the sediments from which they were recovered, simply having been subjected to abrasion for a longer time, or to river flows that were not sufficient to move them, but high enough energy to move granule sized angular flints that would be highly effective agents of abrasion.

The record of the four artefacts in the report (section 2.4 this report) records the maximum dimensions as being 84, 99, 119 and 99.5mm. Again these sizes are slightly greater than any of the largest natural flint clasts recorded from cores in the gravels, but comparable with the largest flints encountered in the earlier work (Alabaster & Straw 1976). Since the naturally fractured flints in the gravels tend to form discoidal flakes and elongate irregular shapes, and not dense spherical or cuboidal forms, their masses should not be significantly different from those of flint artefacts with similar longest axes. In this case, since their axes are greater than the surrounding natural flints in the gravels, the artefacts once incorporated would only move at times of the highest energy flow. As such they are only likely to have moved as a part of the stream bed-load during peak discharge events. Any decrease in energy, possibly due to local stream-bed geometry, would lead to their re-deposition, hence transport distances are unlikely to be great. This conclusion is supported by the results of the analysis of the wear on the faces and edges of the flint tools (section 2.5 this report), that suggested they had only been moved very short distances in the fluvial environment.

4.3 A REVISED CHRONOLOGICAL FRAMEWORK

When first discovered, the sequence of Welton Gravels was attributed to the Early Wolstonian on the evidence of its inferred periglacial climate origins and the correlation of the overlying Welton Till with the Basement Till of the Holderness coast of Yorkshire; a correlation supported by Drs. Catt and Madgett in the discussion following the reading of the paper at Sheffield on 10 January 1976. Independent interpretations of the vertebrate remains and the hand axes by P. Boylan suggested they had a derived origin and suggested a Hoxnian age for the gravels; a date which supported the proposed chronological sequence. However Bristow and Cox (1973) had stated that since there were no identifiable glacial deposits of Wolstonian age in East Anglia, all glacial tills in Eastern England should be attributed to either the Anglian or Devensian glaciations. A similar conclusion was published in Perrin, Rose and Davies (1973) drawing on studies of heavy minerals in tills in the region, including a sample from Welton-le-Wold. With the subsequent testing and discrediting of the former Type Site for the Wolstonian in the English Midlands, the site at Welton-le-Wold became an anomaly as nearly all other sites formerly allocated to the Wolstonian were re-allocated to the Anglian glacial period. In the absence of further detailed work due to closure and backfilling of the former quarry shortly after the publication of the Alabaster and Straw (1976) paper, the dating of the sequence at Welton-le-Wold has remained a topic of academic debate and speculation for the following three decades (section 1.2.5 this report). Based on the available evidence, the Welton Tills could be as old as Anglian, making the Welton Gravels Cromerian or older in age. This is not impossible and would make them comparable with the Bytham Formation gravels in the south of Lincolnshire, where a large west to east valley floor has gravels sealed beneath Anglian Till. (Bateman & Rose, 1994) Alternatively they could be as young as the Aveley Inter-glacial (OIS7) or even Ipswichian (OIS5e) (although humans are believed to have been absent from Britain during this period, the time required for derivation of the artefacts might just about allow this correlation).

Unfortunately the fresh investigation of the vertebrates in this study failed to resolve the dating of the fauna since none of the species examined were diagnostic of a particular inter-glacial time period. In fact this re-evaluation and the advance of knowledge since the 1970's indicates that this fauna need not be restricted to an interglacial but could equally occur in the more temperate interstadial environments. Indeed, allowing for a variable time gap for the derivation of the more severely abraded and decomposed materials, almost any of the inter-glacial or inter-stadial time periods since the Cromerian could be represented by the Welton Gravels fauna. Similarly the reports on the artefacts, although indicating that they were probably locally derived and had not been subject to long periods of transport and abrasion, could not refine the chronology further.

Fortunately the provisional OSL dates obtained (section 3.7 this report) should help to resolve this dating issue. The oldest date of c. 360ka obtained from the Lower division of the Welton Gravels in borehole 8B and the c. 250ka date from borehole 10A , also in the Lower division, straddle the OIS 8 glacial event, which equates to the lowest part of the Saalian or Wolstonian of previous chronologies. A provisional age estimate of c. 200ka was also obtained from a sand body included within the Welton Till, equating with the earliest part of cold OIS 6, also Saalian or Late Wolstonian in previous chronologies. A sample of sands was also taken from the adjacent Lincolnshire Wildlife Trust Reserve where a sand body within the Marsh Till occurs where it lies directly over the Welton Till, with only a minor sand and silt bed between them. Currently the Marsh Till is correlated with the Hessle and Skipsea Tills that overlie the Basement Till in East Yorkshire, and have given a Devensian age on the evidence of a carbon 14 date of c. 18,240 yrs (Penny *et al.*, 1969). An initial tentative date of c. 150ka for the enclosed sands at Welton-le-Wold would date the Lower Marsh Till as late OIS 6, i.e. part of the same glacial event as the Welton and intervening Calcethorpe Tills. This date could only possibly become Devensian if the initial date becomes younger after re- calibration following a more complete investigation, including a gamma-spectrometer reading.

A revised chronology for the Welton sequence based upon the preliminary OSL date estimates might be as follows:

MIS stage	British Stages Ages in yrs. ago	Welton Le Wold deposits	Environment/Climate
2	Devensian	(?) **Marsh Till**, (only in LWT Reserve) (c.150,000yrs. provisional OSL date) (?) **Calcethorpe Till**	Full Glacial; ice sheet in LWT Reserve, but not Western area of SSSI.
3	50,000yrs.		
4	80,000yrs.		
5	Ipswichian 125,000yrs	**OR** (depending upon above OSL)	
6	150,000yrs. 'Wolstonian' (now un-named) 200,000yrs.	(?) **Calcethorpe Till** *Welton Till* c. 200,000yrs. OSL date	Full Glacial; ice-sheet covered the Wolds region.
7	'Aveley' 215,000yrs.	**Welton Gravels** (Upper Division) c .250,000yrs. OSL date	Cool Temperate; braided streams (elephant, horse, red deer, bovid; biface axes and flake)
8	250,000yrs. 300,000yrs.		
9	Hoxnian? 320,000yrs.	*Welton Gravels* (Lower Division) c. 360,000yrs. OSL date	Permafrost Cold, periglacial.
10	350,000yrs.		
11	Hoxnian/ Swanscombian 400,000yrs.		
12	Anglian 450,000yrs.	No Deposits at this site. Most extensive glaciation of Britain, ice-sheets as far south as The Thames and Severn.	Full Glacial; All Lincolnshire beneath thick ice sheet.

Table 6: Revised chronology of stratigraphic sequence at Welton-le-Wold based on preliminary age estimates of gravel and till sediments dated by OSL (Lewis 1999)

SECTION 5 PROJECT OUTREACH AND DISSEMINATION (PROJECT AREA 4)

Main Aim: To complement and enhance immediate and long-term intellectual access to the geological and archaeological resource at Welton-le-Wold.

5.1 THE BACKGROUND AND PURPOSE OF PROJECT AREA 4

The quarry at Welton-le-Wold is a newly accessible site due to its recent entry into a 10 year Countryside Stewardship Scheme. One of the main elements of the Scheme is to preserve the geological SSSI and improve access to it. This is achieved by regular scrub clearance, the creation and maintenance of safe paths and steps, and by encouraging educational access for groups and individuals. The SSSI area is managed by the landowner in partnership with the Area Of Natural Beauty (AONB) Countryside Service. Much use is made of volunteers to undertake the routine site maintenance. The AONB Countryside Service also manages the educational visits, provides a site specific risk assessment and promotes the site through a regular programme of guided walks around the quarry.

Plate 32: Creating paths for safe access to the SSSI (Photo Helen Gamble)

The outreach strategy of this project was designed from the start in partnership and with regard to the ongoing educational, access and interpretation activities being carried out by the AONB Countryside Service and the landowner. The timescale of the pilot ALSF and the initial uncertainty surrounding it's continuation meant that the key to an achievable and sustainable outreach strategy was to use this project as a catalyst to complement and strengthen ongoing efforts. Two main strands ran through our education and outreach proposals:

i. To contribute to a long-term vision of developing the quarry as a regional destination for education and research by organising and initiating events and actions that raised the profile of the site and generate interest amongst the educational and wider community.
ii. To provide up-to-date and accessible information about the geological and archaeological resource at the former quarry to feed into interpretation and education proposals either underway and/or planned by organisations already involved in the management and promotion of the site (particularly the AONB Countryside Service, the Lincolnshire Wildlife Trust and the County Council Heritage Service). Future funding proposals to develop long-

term interpretational and educational facilities will be strengthened by being well founded on detailed and up-to-date information about the significance of the geological and archaeological resource.

The outreach strategy was achieved through three main activities:

i. An educational initiative to raise awareness of the former quarry at Welton-le-Wold as an educational resource amongst schools.
ii. A high profile Welton-le-Wold Open Day to launch the newly accessible SSSI and raise awareness amongst as wide an audience as possible.
iii. An information network for all key stakeholders in the management of the quarry.

5.2 RAISING AWARENESS OF THE EDUCATIONAL POTENTIAL OF THE QUARRY AT WELTON-LE-WOLD AMONGST SCHOOLS

At the Project Design stage, a site meeting was held with a representative from the Centre for British Teachers (CfBT) School Improvement Service (who coordinate teacher training and curriculum development in Lincolnshire), and with a representative from the Education Business Partnership (EBP) (who encourage links between schools and the work place by supporting vocational training and work experience). Early on, it was decided that the most effective educational strategy for the project would be to support a ‘cluster session’ for local teachers in order to assess the opportunities offered by the quarry at Welton-le-Wold in relation to the needs of schools, and to gather feedback that would feed directly into future educational initiatives centred on the quarry. It was hoped that this would lead into a teacher training event within the project timetable. It was agreed to target secondary schools due to the nature of the resource and to health and safety considerations; and to promote the quarry in the subject areas of geography, geology and vocational courses concerned with management and the environment.

Welton-le-Wold was promoted through the CfBT website, dedicated to advertising all teacher training opportunities in Lincolnshire (www.cfbt.com/lincs/training). The advertisement was posted in April, and the date of the original cluster session was deliberately assigned to the end of June, a quiet period in the academic year.

As the initial response to the advert was poor, with only two teachers signing up, a meeting was held with the CfBT to discuss the disappointing response. It emerged that the website had been introduced in 2002 to replace the previous system of sending out training programmes to head teachers. It fell to the head teacher to distribute the information and any teacher interested in a training event would then complete a form to secure a place. The aim of the website was to enable teachers to directly access training opportunities and sign up on-line. In these early stages of the new system, however, response from teachers had been generally extremely poor, resulting in the cancellation of significant numbers of sessions.

It was decided to put the date of the cluster session back and provide a backup by writing directly to all secondary schools within a reasonable distance of Welton-le-Wold. It transpired that the teachers who did eventually attend the cluster session were not even aware of the CfBT website.

Teachers attended the cluster session which took place in October 2003. Working with the AONB Countryside Service, the session was broadened to include two other sites with important examples of glacial features that were taking part in the Countryside Stewardship Educational Access Initiative. One of these sites, only a few kilometres from Welton-le-Wold has indoor facilities for teaching, an indoor refreshment area and toilets, necessary requirements for fieldtrips.

The full day session was organised in three parts:

i. An introduction to the Wolds focusing on key geological, geographical and archaeological sites. An introduction to the special features of Welton-le-Wold and the work of the project
ii. Site visits
iii. Discussion and feedback

The outcomes of the discussion were extremely informative, and were relevant, not only to the site at Welton-le-Wold, but to the challenge of engaging schools generally. It was felt that Welton-le-Wold had great potential as a resource for school visits, but that there were problems at a national level relating to the organisation of field trips to *any* site. The main conclusions from the discussions are detailed below.

5.2.1 Feedback specifically relating to Welton-le-Wold:

- The site would work well as a 'package' with other sites, such as was experienced on the day, for secondary schools. The success of such a field trip, however, would rely on the lead teacher having a level of geological (and archaeological) knowledge that is not generally common amongst geographers. A visit to Welton-le-Wold as part of a field trip would benefit from the direct involvement of an individual who was familiar with the site and these subject areas.
- The site is very suitable and has potential for A level projects.
- The site is also suitable and has potential for gifted/master class activities.
- It is an ideal site to promote to parents as a day out with their children. Open Days and other events should be specifically advertised in local schools.

5.2.2 Feedback relating to engaging with schools generally

i. Constraints of taking children out of schools:

- A field trip often has to be organised up to one year in advance. Transport usually has to be paid for. Extra staff to accompany the group, qualified first aiders, and supply cover has to be arranged. A detailed risk assessment has to be carried out.
- Unions generally advise against fieldtrips. Two teaching unions have already signed up to the 'Agreement' which proposes to cut work loads for teachers by reducing administration to zero. This will have a big impact on taking children out of classrooms, as the teacher involved currently carries out most of the associated administration.

- Funding is very limited. Most schools have resources for only one fieldtrip a year.

ii. Constraints relating to teacher training:

- There are strictly limited numbers of training days allowed for teachers. Teachers will generally select training directly relevant to day to day issues, e.g. national performance indicators, counselling etc.

iii. General observations:

- Geology and archaeology are difficult subject areas. It is always best to produce supporting material with geographers and historians in mind.
- Individuals going into schools, even for one session, are often far more effective than teachers' packs' in terms of the lasting impact on the children.
- CD's and web sites are often not a good medium for disseminating information to teachers. Computer access in schools is poor. The majority of teachers don't have time to search for non-essential material at home.

iv. Suggestions and comments

- Produce a local resource map showing sites of geological, wildlife and archaeological interest that are accessible and where teachers can access information. All sites should be linked with the contact details of the organisations who manage them. This map should be of a standard that can be put up in the classroom.
- Produce a directory of organisations working locally that clarifies who does what and owns what. Teachers are aware of many different organisations such as English Nature, English Heritage, Heritage Lincolnshire, and the Wildlife Trusts etc. but are unclear about their remits and what they can offer to schools.
- Produce a detailed risk assessment for any site where school visits are encouraged. This will reduce the administration burden for the school.

5.3 THE WELTON-LE-WOLD OPEN DAY

The Open Day at the former quarry in Welton-le-Wold was organised in partnership with the AONB Countryside Service, the County Council Heritage Service and the Lincolnshire Wildlife Trust and took place on a very hot July weekend. The timing of major summer events is always important, and past experience in Heritage Lincolnshire has shown that events programmed for the weekend in July just before schools break up are usually well attended. This is as the weather is usually fine and families are looking for local days out before the holiday period begins.

A July event can also be well advertised at the Lincolnshire Show, which takes place in June. This approach worked well for Welton-le-Wold. A leaflet campaign was coordinated at the June Show by the AONB Countryside Service, the Wildlife Trust and Heritage Lincolnshire, who all have regular stands. Press releases were distributed widely prior to the event, and a live local radio feature was broadcast early in the morning from the site. This brought in between 400 and 500 visitors to the quarry. Many of the visitors were locals, many of whom had no idea that the quarry even existed, and there were also significant numbers of visitors from the Grimsby, Horncastle and Louth areas where local newspapers had covered the event.

Activities that took place throughout the day were:

- John Aram and Neil Pike led guided walks along the SSSI exposure to explain the history and significance of the geology, archaeology and the current management of the SSSI to protect the resource and encourage wildlife.

Plate 33: John Aram guiding a site tour at the Open Day (Photo Rachel Shaw)

- Bill Bee (a well known local amateur archaeologist responsible for most of the Palaeolithic finds recorded in the SMR from the area) and Pete Wilson demonstrated flint knapping and supervised the making of various stone tools by a great many budding flint knappers amongst the visitors.

Plate 34: Flint knapping at the Open Day (Photo Rachel Shaw)

- James Rackham and Thomas Cadbury (LCC Museum) told stories about an impressive display of Ice Age animal remains, provided by the museum stores.

Plate 35: Ice Age animal display at Welton-le-Wold

- John Aram and Sara Metcalf, manager of the Wildlife Park at Whisby gravel quarry (and a last minute participant) displayed a range of geological samples and fossils, and identified fossils brought in by members of the public. Sara also found time to set up a face painting corner.

- Joanna Hambly and Jane Cowgill identified and recorded numerous artefacts brought in by members of the public, including finds from two significant new Roman sites.

Plate 36: Finds brought in for recording at the Open Day

- Helen Gamble (AONB Officer) and Rachel Shaw (LWT) promoted and explained the work of their organisations on sites like Welton-le-Wold and their work in the Wolds generally.

As a back drop to all the activity there were displays created by all involved including:

- The ALSF project
- The special wildlife of the former quarry
- A photo story of the 'Facelift' work
- Stone tool technology
- Other geological and wildlife sites to visit in the area
- Information about the organisations participating in the Open Day

One of the objectives of the Open Day was to record memories and archives about the working quarry from any former workers who still lived locally. Two retired quarry workers did come to the Open Day and provided very useful information about the final phase of the quarry. The machinery and equipment at Welton-le-Wold were removed soon after its closure, but the gravel bench remained open and was sold as 'raised' gravel for at least a year after the official end of operations. 'Raised' gravel is that which has not been sorted or processed in any way, and would have been excavated and collected by individuals, mainly local farmers, for making/repairing farm tracks, drainage etc. The gravel bench recorded by Alabaster and Straw, and wherein the fossils and artefacts were found, was, progressively worked back in a piecemeal way until it was exhausted. The two also remembered 'occasional finds of mammoth teeth' at the quarry. The whereabouts of these are not known, but in the light of the other finds, these are more likely to have been elephant teeth. It is also interesting that only teeth were mentioned. This could be further evidence of the bias in the fossil remains due to the almost total decalcification of sediments in the quarry. A family member of another former quarry worker also came to the Open Day. She explained that in the final years of operations, ARC took over the quarry from the family run Stephen Toulson and Son Ltd. When operations ceased, ARC relocated the workforce to their other quarries. Her relative moved to a quarry in Yorkshire. The two former workers who came to the Open Day moved to a pit further east. Although for much of it's history, the quarry must have employed a very local workforce, this was not, thus, the case in the final years and this may explain why relatively few local residents have connections with the quarry at Welton-le-Wold.

5.4 AN INFORMATION NETWORK

There are a number of organisations involved in long-term interpretation strategies that include the former quarry at Welton-le-Wold. Very regular contact was maintained between the groups who manage and promote Welton-le-Wold, throughout the course of the project, and so all new information generated was immediately circulated. In addition, the on site work and the process of organising the Open Day resulted in frequent site meetings and visits from all interested groups. The results of the project will certainly feed into specific projects already planned, such as, the City and County Museum narratives, an education pack and a Reserve leaflet.

In the light of feedback from the education consultation, the value of a ‘fact sheet’ approach for education groups, schools, colleges, special interest groups or individual students, was called into question and this element was not carried out. There have been, however, several individual enquiries from members of the public and students, who became aware of Welton-le-Wold through the Open Day.

5.5 CONCLUSIONS

Since the Facelift, and throughout the project period, there has been a steady and increasing level of interest in Welton-le-Wold amongst the wider education community. It is a regular fieldtrip destination for WEA groups, and for geological societies (in 2003 the East Midlands, Hull and Hertfordshire Geological Societies visited the site). The geological potential at the quarry has also been discussed at recent geological conferences and seminars, and in 2003, quaternary geologists from the BGS, Royal Holloway and Canada have made visits. The awareness of Welton-le-Wold amongst continuing and further education groups is largely due to the activities and networks of individuals involved in managing the site. The ALSF project has certainly widened this network and heightened interest. Engagement by these groups is likely to continue and increase for as long as the quarry remains accessible, and interest is maintained through regular events and courses,

The ALSF project specifically addressed the promotion of the quarry to school age children because the AONB Countryside Service identified this educational group as the most challenging, and a priority. The challenges faced by us and revealed in the feedback were, therefore, extremely useful. It relates both specifically to the site, and to the wider issues of encouraging schools to use their localities as an educational resource. The feedback arising from the Cluster Session has been circulated to those organisations that have a remit to promote the natural and cultural environment locally, i.e. the Wildlife Trust, County Council Heritage Service, Heritage Lincolnshire and the AONB Countryside Service. This information will directly benefit future education initiatives, and Heritage Lincolnshire and the AONB Countryside Service are already exploring action relating to some of the suggestions. The education consultation carried out as part of this ALSF project has enabled us to draw conclusions and make recommendations for the future promotion of the quarry at Welton-le-Wold to schools.

The success of the Open Day exceeded our expectations. It was promoted as an opportunity to discover and learn about the Ice Age in a local context. It proved that there is a high level of interest in the subject, and feedback from visitors on the day suggested there are very few opportunities outside of museums to engage with it. The majority of visitors knew little or nothing about the Ice Age or about early human occupation in Britain, but took away with them a greatly increased understanding of the Pleistocene, its role in the creation of their local landscape, the nature of earliest human evidence and the opportunities afforded by quarried landscapes to investigate geological and archaeological periods.

The collaboration between the different organisations enabled a big event to be arranged that was diverse and interesting for visitors, without overloading any individual organisation. The Open Day also attracted a wide demographic mix, families with school age children being in the majority. The three main organisations involved each have their own ‘audiences’, though they do overlap. This benefited the Open Day as it attracted those who are commonly involved with natural heritage, but not usually with cultural heritage and vice versa.

5.6 RECOMMENDATIONS

i. Education

- Effective communication with relevant departments and teachers was found to be difficult. Direct targeting of teaching staff and departments as well as using the County based schools information networks should be employed.
- Currently neither the AONB Countryside Service, nor Heritage Lincolnshire has the resources to provide direct contact to schools on a regular basis. The demand is already there, however, and this demand will grow if sites become better known. Organisations involved in site management and outreach work will have to address this in their future educational strategic planning. The possibility of drawing from the RIGs group to provide occasional school visits/fieldtrip leaders to Welton-le-Wold (and other Wolds sites) should be explored.
- The effectiveness of any stand alone 'teachers packs' in any medium, should be very carefully considered. Supporting information for teachers should ideally be linked with a guided fieldtrip and/or school visit and should be produced in close consultation with teachers.
- The value of Welton-le-Wold as a resource for (pre-university) higher education was highlighted. The geological, biological and land management aspects of the former quarry could be specifically promoted to local sixth forms and further education colleges as a source for topics for student projects and research.

ii. Wider awareness

- It is clear that Lincolnshire's new City and County Museum (due to open in Spring 2005) will be a very important information hub for the County. The site at Welton-le-Wold will form one of the displays that will interpret the Pleistocene in Lincolnshire and the earliest evidence for human occupation in the area. The data gathered in this project should inform the museum interpretation and display.
- A poster presenting the discoveries and significance of the site, and a leaflet giving information about the location of the quarry, access and contacts, should be available at the City and County Museum, Louth Museum and other appropriate outlets. This would be an effective means of disseminating information to a wide audience, including schools, and encourage visitors to go to Welton-le-Wold.
- The Open Day should be repeated. This should form part of the outreach activities if work on the Wildlife Trust Reserve goes ahead.
- Future events and activities at the quarry should be advertised in local schools and with youth groups.
- There is already an interpretation panel at the SSSI where this project focused. The Wildlife Trust Reserve, however, has no interpretation. A well-walked public footpath passes close by to the Reserve and there are also clear views across to the major Facelift exposure. An interpretation panel should be positioned in clear view of the path so that walkers are made aware of both the significance of the quarry, and that there is access to it.

6 CONCLUSIONS

The original purpose of this project was to gain a better understanding of an important, but chronologically problematical, geological and Palaeolithic site in Lincolnshire, to raise awareness of the site's potential among the educational and wider community, and to contribute to improved intellectual access to it.

The main challenges were always those of chronology and the extent of derivation of the fossil and artefact finds. Working with the benefits of a much more detailed understanding of the Pleistocene period generally, and the detailed analysis of the finds, and of the sediments within which they occurred, has allowed the sites history to be significantly revised. What was formerly taken to be a derived i*nterglacial* mammal and artefact assemblage, re-deposited in cold phase gravels, can now be re-interpreted as a (probable) *interstadial* or cool temperate interglacial episode, mammal and artefact assemblage (no interglacial deposits were recognised within the gravel divisions, though it is possible the fauna and artefacts could have eroded from such local deposits) much of which was probably deposited in near contemporary, temperate-climate sands and gravels being laid down by a braided stream occupying a small west-east draining valley. The poor condition of some elements of the mammal fossils (horse and bovid) could indicate a different depositional history to the well-preserved elephant tusk and teeth. However, post-depositional processes, particularly that of de-calcification may explain some of the differences, and certainly provides an explanation for the lack of/poor state of bone generally, and the absence (so far) of any smaller mammal remains or palaeoenvironmental material. Overall, however, there is no reason to doubt that the artefacts and some of the fossils represent activity and/or occupation of the valley and immediate area during the Lower/Middle Palaeolithic. There is also no reason to doubt that similarly stratified archaeological contexts survive in the un quarried parts of the Welton valley, or (based on the Limonite oolith evidence explained in 4.1 above) for similar till/gravel sequences to exist further west than their present recorded extent. Wymer (in McNabb 2002) suggests that Lower/Middle Palaeolithic occupation in the East Midlands was not confined to the major river margins but extended to higher ground. The problem on higher ground has always been one of context. Archaeological material is present, but almost always as unstratified stray finds. Welton-le-Wold is the first site on high ground in the East Midlands where archaeological and fossil material can be confidently correlated with a stratigraphic sequence.

The preliminary OSL date estimates for the gravels and the tills at Welton-le-Wold, has also allowed us to take a great chronological step forward. It must be emphasised that these dates are preliminary. However, it does look as though an Anglian till can be abandoned in favour of a till deposited (probably) by an OIS stage 6 ice sheet in east Lincolnshire. The dating estimate of *c*. 360ka, further down the sequence, from the Lower Gravel Division below the fossil and artefact bearing deposits, provides a '*terminus post quem'* for the artefacts in OIS stage 10. A second OSL date for fine sands deposited at a similar level to the artefacts (Fig. 25) of *c*. 250ka provides an OIS stage 8 to stage 7 date that might be correlated with the fossil and artefact assemblages or the reworking of material from the preceeding stage 9 interglacial which might be correlated with the deposits at Purfleet (Schreve 2001). The Lower, and all of the Upper gravels and the finds within them are, therefore, very likely to have been deposited in the period between the end of OIS 10 to the beginning of OIS 6 if the preliminary OSL dating is confirmed by the results from the sample re-measurement . This is the only known stratified archaeological site of this age in the East Midlands.

In terms of our original objectives, this project, which was always intended as an assessment and evaluation exercise, has improved our understanding of the Ice Age at Welton-le-Wold, arguably well beyond our expectations. The outline of a chronological and environmental framework has been constructed. Tills correlating with a suspected, but until now, missing ice sheet in the East Midlands have been identified. Future work can concentrate on challenging, refining and adding the detail.

The level of interest in the site and all matters Ice Age amongst the general public also exceeded our expectations. There is now more to be said, and it is imperative that the SSSI's at the former sand and gravel quarry are maintained as accessible geological sections for future researchers and the inquisitive.

6.1 Recommendations for publication

As explained in the introduction of this report, the funding for this part of the project from English Heritage, was only half of the original grant applied for. English Nature was asked for the other half as it was relevant to their 'conserving geological features' criteria for the Aggregate Levy Fund. At the time of writing, this other half of the project has been taken forward by English Nature for consideration for funding in 2004-5, but it is not yet known how successful this will be. The recommendations, therefore, have been made with both options in mind, though this largely only affects the timing.

If English Nature do grant Aggregate Levy funding to extend and enhance the Wildlife Trust Geological Reserve, a continuation of the OSL dating programme should be carried out to confirm and refine the results already obtained in the 2003/4 project. After this, and if the dates are confirmed, the results of the entire project would merit publication in a national geological/archaeological journal. This could and should be done before March 2005.

If there is no further ALSF support for Welton-le-Wold, the samples already being processed (but unfortunately not ready in time for this report) must be completed and advice sought from the OSL specialist as to whether there is the necessity or the potential to take further samples from the cores already extracted. Assuming the dates are reliable, the results would merit publication in a national geological/archaeological journal. This could and should be done before March 2005.

Based on our outreach experience in this project, awareness of the site and its significance will be most effectively disseminated at the new City and County Museum, where the finds will be displayed and interpreted, and at the local museum in Louth only a few kilometres from the site. Continued liaison with the museums will ensure that information from the project will feed into the displays. A leaflet summarising the significance of the site and giving information regarding access to it should also be prepared that would be available at the museums. This could also function as the Wildlife Trust Reserve leaflet.

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